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Theory and empirical evidence on contemporary international migration

Five contributions

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Abstract

This thesis contributes to the economics of migration. This field of research analyses why people move and the consequences for origin and host societies. Our work focuses on the determinants of the international mobility of people, particularly on how globalisation forces shape international migration. Various definitions of the term *globalisation* exist. Here, it is defined as a global integration process of world markets that can be characterised by a progressive standardisation of national regulations and increasing competition among economic agents. This process results from trade and factor flow liberalisation, as well as from an improvement of communication and transport technologies (Chavagneux et al., 2007). More precisely, we study (i) how international migration interacts with other international flows, namely trade and foreign direct investment (FDI), and (ii) how migration decisions are impacted by the growing integration of economies.

It is important to note a number of key stylised facts regarding international migration. The United Nations Population Division estimates that the international stock of foreign-born individuals was about 2.89% of the world population in 1990. It was about 3.23% in 2013, which represents 231.52 million of people, a country between Brazil and Indonesia in term of population. Based on UN stock data, Lackzo and Appave (2014) estimate that in 2010, about 35% of the world stock of international migrants moved along the South-North axis, 34% along the South-South axis, 25% along the North-North axis and 6% along the North-South axis.

Movement of people across borders is growing but is still highly regulated, especially by developed countries. Wihtol de Wenden (2013) evidences that migration is far from being free. The right to emigrate is now worldly recognised, but the right to immigrate is still to be acquired by the population of the developing world. Li (2008) emphasises that high skilled individuals can move relatively freely across national borders – developed countries are competing for highly specialised human capital – while borders remain quite closed to unskilled individuals and asylum seekers.

Meanwhile, the global economic liberalisation attests that most countries now recognise the benefits of the free circulation of goods, services and capital for productive activities. Trade, FDI and migration flows have been following quite similar trends over the past decades. Let us emphasise three key facts that are common to international flows: (i) the global increase and diversification of international flows since the nineties (although migration has been limited because more regulated); (ii) the increasing regionalisation of exchanges (mainly for trade and migration) and (iii) the growing role played by developing and emerging countries in the world exchanges.

In this context, understanding to what extent international flows complement/substitute one another could ameliorate our knowledge of the aforementioned flows and our understanding of globalisation. This thesis intends to do so and thereby contributes to the emerging literature in international economics showing that international flows are interdependent.

Studying how migrants impact future migration, trade and FDI, we contribute to the literature analysing whether migration is positive or not for origin and destination countries. We show that economic migration flows, just as trade and FDI flows, are one channel of economic adjustment, and even a channel of economic growth for origin and destination countries.

Finally, our work on migration and its relationships with globalisation forces has important policy implications. We emphasise the potential gain for open economies to further collaborate on migration issues. We show that each country's migration policy may impact its and others' levels of immigration (both legal and illegal) and thereby their economies.

Résumé

Cette thèse contribue à l'économie de la migration. Ce domaine de recherche analyse les raisons pour lesquelles les individus migrent, et quelles sont les conséquences pour les sociétés d'origine et d'accueil. Dans ce travail, nous nous concentrons sur les déterminants de la mobilité internationale. Plus particulièrement, nous cherchons à savoir dans quelle mesure la mondialisation détermine la migration internationale. Plusieurs définitions du terme de *mondialisation* existent. D'après Chavagneux et al. 2007, il s'agit d'un processus d'intégration mondiale des marchés mondiaux pouvant être caractérisé par une normalisation progressive des réglementations nationales et par un accroissement de la concurrence entre agents économiques. Ce processus résulte de la libéralisation du commerce et des flux de facteurs de production, et d'une amélioration des technologies de transport et de communication. Plus précisément, nous étudions (i) la façon dont la migration internationale interagit avec les autres flux internationaux, à savoir le commerce international et les investissements directs étrangers (IDE), et (ii) la façon dont les décisions individuelles de migrer sont affectées par l'intégration croissante des économies.

Donnons quelques faits stylisés importants sur la migration internationale : la division de la population de l'Organisation des Nations Unies (ONU) estime que le stock international d'individus nés à l'étranger était d'environ 2,89% de la population mondiale en 1990. Il était d'environ 3,23% en 2013, ce qui représente 231,52 millions de personnes, un pays entre le Brésil et l'Indonésie en terme de population. À partir des données de stock de l'ONU, Lackzo and Appave (2014) estiment qu'en 2010, environ 35% du stock mondial de migrants internationaux s'était déplacé le long de l'axe Sud-Nord, 34% le long de l'axe Sud-Sud, 25% le long de l'axe Nord-Nord et 6% le long de l'axe Nord-Sud.

Bien que les mouvements de population entre pays soient croissants, ils sont fortement réglementés, notamment par les pays développés. Wihtol de Wenden (2013) met en évidence que la migration est loin d'être libre. Le droit d'émigrer est maintenant reconnu par la plupart des pays, mais le droit d'immigrer n'est pas acquis par les populations des pays en développement. Li (2008) souligne que les individus hautement qualifiés peuvent se dépla-

cer relativement librement à travers les frontières nationales – les pays développés sont en concurrence pour attirer du capital humain – tandis que les frontières restent relativement fermées aux personnes peu qualifiés et aux demandeurs d'asile.

Par ailleurs, la libéralisation économique atteste que la plupart des pays reconnaissent maintenant les avantages de la libre circulation des biens, des services et des IDE. Les flux commerciaux, d'IDE et de population ont suivi des tendances assez similaires au cours des dernières décennies. Soulignons trois éléments importants communs à ces flux internationaux : (i) l'augmentation et la diversification des flux depuis les années 1990 (bien que la migration ait été limitée puisque plus réglementée) ; (ii) la régionalisation croissante des échanges (surtout pour le commerce et la migration) et (iii) le rôle croissant joué par les pays en développement et émergents dans les échanges mondiaux.

Dans ce contexte, comprendre dans quelle mesure les flux internationaux se complémentent/se substituent, pourrait permettre d'améliorer notre connaissance des flux susmentionnés et notre compréhension de la mondialisation. Ainsi, cette thèse à pour objectif de contribuer à la littérature émergente en économie internationale mettant en évidence l'interdépendance des flux internationaux.

En étudiant dans quelle mesure les flux migratoires influencent les migrations futures, les flux commerciaux et d'investissements, nous contribuons à la littérature analysant l'effet des migrations pour les pays d'origine et d'accueil. Nous montrons que les flux migratoires pour motifs économiques, tout comme les flux commerciaux et d'investissements, forment un canal d'ajustement économique, et même un canal de croissance pour les pays d'origine et d'accueil.

Enfin, notre travail sur la migration et ses relations avec la mondialisation présente des implications importantes en termes de politiques publiques. Nous mettons en évidence que les pays ouverts ont un intérêt à collaborer davantage sur les questions de migration. Nous montrons que la politique migratoire de chaque pays peut avoir un impact non seulement sur ses propres niveaux d'immigrations légale et illégale, mais également sur celui des autres pays, et de ce fait sur leurs économies respectives.

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List of Acronyms

ABM : agent-based model
BC : budget constraint
CCE : common correlated effects
CES : constant elasticity of substitution
EU : European Union
EU15 : European Union of the fifteen
FDI : foreign direct investment
GDP : gross domestic product
GMM : generalised method of moments
IDE : investissements directs étrangers
IV : instrumental variable
LPM : linear probability model
MNE : multinational enterprise
MSE : mean squared error
NELM : New Economics of Labour Migration
OECD : Organisation for Economic Co-operation and Development
OLS : ordinary least squares
R&D : research and development
RMSE : root mean squared error
RUM : random utility maximisation
SSA : Sub-Saharan Africa
UN : United Nations
UNCTAD : United Nations Conference on Trade and Development
UNIDO : United Nations Industrial Development Organisation
UNPD : United Nations Development Programme
US : United States
USA : United States of America

1 General introduction

Migration is not a problem to be solved; it is an intrinsic element of international society and inextricably bound up with globalization itself.

— Goldin et al. (2011)

This thesis contributes to the economics of migration. This field of research analyses why people move, and what the consequences are for origin and host societies. Our work focuses on the determinants of the international mobility of people, particularly on how globalisation forces shape international migration. Various definitions of the term *globalisation* exist. Here, it is defined as a global integration process of world markets that can be characterised by a progressive standardisation of national regulations and increasing competition among economic agents. This process results from trade and factor flow liberalisation, as well as from an improvement of communication and transport technologies (Chavagneux et al., 2007).

More precisely, we study (i) how international migration influences and is influenced by other international flows, namely trade and foreign direct investment (FDI)[1], and (ii) how migration decisions are impacted by the growing integration of economies.

Although our approach pertains to the economics of migration, it is closely related to international trade, a sub-field of international economics, which analyses the exchanges of goods, services and factor flows (capital and labour) across national borders.

In this introductory chapter, we first define and contextualise contemporary international migration. Then, we present the literature related to our thesis. Doing so, we propose a number of elements to answer the following question: why is migration quantitatively important and why should it matter for policy makers? Then, we underline that the civil society could benefit from further thinking international migration in relation with globalisation forces. This leads us to draw a research agenda to which our following chapters contribute.

[1] We exclude international financial flows from our analysis. An FDI can be defined as "*[...] a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy. [...] [Relationships] arise when a direct investor directly owns equity that entitles it to 10 percent or more of the voting power in the direct investment enterprise.*" (BPM6, IMF, 2009)

1.1 Definitions and stylised facts

In this section, we provide a definition of an *international migrant*. Then, we present some brief facts on the history of international migration, after what we intend to describe and quantify contemporary international migration. Finally, we put international migration in perspective with other international flows, namely trade and FDI.

1.1.1 Definitions of an *international migrant* and measurement issues

The noun *migration* comes from the Latin noun *migratio* (1st century B.C. Cicero) which means "population displacement", and the verb *to migrate* comes from the Latin verb *migrare* (1st century B.C. Cicero) which means "to emigrate, to leave a place" (Mazzella, 2014). In this thesis, we focus our analysis on migration, yet when a national point of view is need for our analysis, we restrict our view to the concepts of *emigration* and *immigration*.

The broadest statistical definition of an *international migrant* is proposed in the Recommendations on Statistics of International Migration of the United Nations (1998): "*an international migrant is defined as any person who changes his or her country of usual residence*". The United Nations (UN) distinguish between short-term and long-term migrants. A long-term migrant is "*a person who moves to a country other than that of his or her usual residence for a period of at least a year (12 months), so that the country of destination effectively becomes his or her new country of usual residence*". A short-term migrant is a person moving to a country other than his usual residence for at least three months, but less than one year. The definition excludes travels for purposes of recreation, holiday, business, medical treatment or religious pilgrimage. Yet, countries often use various definitions to record migrants, which are often more restrictive than the recommended definition of the UN. For instance, countries have adopted different definitions regarding the origin country of the migrant (country of previous residence, country of birth, country of citizenship) and regarding the distinction between short and long-term migrants (no distinction, 3 months, 6 months, 12 months...). This variety of definitions induces a problem of comparability of international migration statistics (Lemaitre, 2005).

Some progress has been made regarding the availability and comparability of migration stock data which are based on population censuses; but some improvement is needed regarding the measurement of international migration flows. When registering flows, a country should ideally consider both citizens and foreigners, and both inflows and outflows. Yet,

current data do not provide a full picture of international migration flows. The main difficulty lies in the fact that citizens are granted the right to cross the border in either direction. Because they are unregulated, statistics on citizen's movements are of poor quality. On the other hand, developed countries highly regulate the arrival of non-citizens. Data on foreigner's inflows are usually accurate, as they are based on national statistics (population registers, residence and work permit registers), which somehow reflect the regulatory system of the country. Yet, these data are poorly comparable across countries because of the diversity of regulatory systems. Finally, few countries keep track of departures of foreigners, which does not seem to be a critical issue for migration policy design.

Instead of using incomplete and incomparable flow data, Abel and Sander (2014) propose to derive flows from stock data. In their paper, the authors argue that doing so allows one to obtain accurate flow data that are essential to understand contemporary trends in migration.

Özden et al. (2011) discuss other general difficulties one may encounter to collect accurate migration data. First, over the last century, a lot of borders have changed, some countries disappeared and new countries were created. Second, data are often presented by geographical areas of origin and are not desegregated by origin countries, mainly for the sake of anonymity. On that point, Kahanec and Zimmermann (2008) note that data are excessively anonymised and that little information is available on migrant's past experiences and their intentions of future moves. Third, data on migration often come from destination countries; only few developing countries realise rigorous data collection. Finally, Ratha and Shaw (2007) note that some international migration data, and especially South-South migration, are likely to be underestimated because official data do not (or only partially) capture irregular migrants.

Overall, it is clear that the quality of migration data is an important concern of the scientific community working on the phenomenon. The consistency and comparability of data are crucial to draw stylised facts and to generalise econometric results with an objective of policy recommendation. As expressed by Kahanec and Zimmermann (2008), poor quality data may "*lead to incorrect policy recommendations, which may lead to unpredictable consequences or even effects contrary to those intended*". In the rest of our thesis, we analyse contemporary international migration bearing in mind the concerns we just raised about macro-level migration data.

1.1.2 Stylised facts on international migration

To review the history of international migration, we can (at least) go back to the *Age of discovery* (Goldin et al., 2011). Over the 15th and 16th centuries, Europeans began the discovery of new lands, which initiated important international migration flows between continents. Part of these flows consisted in free movements such as the colonisation of North America and Australia (although the installation of European immigrants was imposed to aboriginal populations), others were forced migration such as slave trade. Until the end of the 19th century, migration was quite unregulated by governments. It is only recently, over the 20th century, that governments started to manage and regulate the movement of people across their borders with passports and border controls (Hatton and Williamson, 2005). Economic crises, wars and renewed passions for nationalism in Europe, North America and Australia, progressively pushed toward a restriction of population movements (Goldin et al., 2011). During this century, migration was only seen as a temporary tool for labour supply adjustments, nations wanted to control how many people were entering their territories, for how long, for what purpose, and what rights were given to these populations. For example, France used massive immigration from its colonies to meet temporary labour demand, and to participate to the First and the Second World War. Migration was seen as temporary, and the state put a great deal of effort (more or less successful) into sending back immigrants when they were no longer needed (Blanchard and Gelas, 2011).

Since the middle of the 20th century, international migration has been controlled but mainly unforced (excluding human trafficking)[2]. After the Second World War, millions of people who were displaced returned home or moved to other countries such as the United States, Australia, Latin American countries and Israel (Goldin et al., 2011). Following the fall of the Iron Curtain, international migration for economic purposes started growing again. The United Nations Population Division, based on national population censuses, estimates that the international stock of foreign-born individuals was about 2.89% of the world population in 1990. It was about 3.23% in 2013, which represents 231.52 million of people, a country between Brazil and Indonesia in term of population. In Figure 1.1, the evolution of the global migration stock over the past decades is presented using World Bank population data collected from national population censuses[3].

Based on UN stock data, Lackzo and Appave (2014) estimate that in 2010, about 35% of the world stock of international migrants moved along the South-North axis, 34% along the

[2]Some authors also define movements of people because of violence and persecution (refugees and asylum seekers) as forced migration. See Friebel and Guriev (2006), IOM (2003).
[3]The estimates of the World Bank are quite similar to those proposed by the UN, but are proposed every ten years from 1970, while the UN propose estimates for the years 1990, 2000, 2010 and 2013.

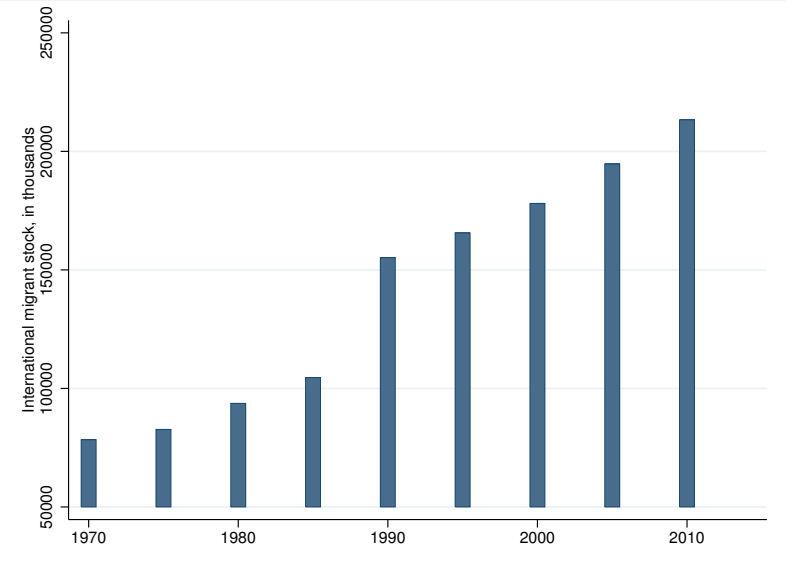

Figure 1.1.: Global stock of foreign-born individuals, 1970-2010 (World Development Indicators, World Bank, 2015)

South-South axis, 25% along the North-North axis and 6% along the North-South axis[4,5]. These four migration pathways are characterised by different gender, age and skill compositions. Women account for 48% of the total stock, but are unequally spread across the North and the South. They represent 52% of the stock of migrants in the North, while they only represent 43% in the South. Most migrants are of working age. 60% of young migrants are living in developing countries, while older migrants are mostly living in developed ones.

In terms of skill composition, a positive self-selection is at play along the South-North and the North-North axes. Docquier and Marfouk (2006) show that in 2010, the emigration rate of tertiary educated individuals (aged 25 and over) was much larger than the emigration rate of individuals with only a secondary or a primary education. South-South migration seems to be mainly unlawful but very little information is available about this population movement (Meyer, 2010), and North-South migration consists mainly of return migrants and skilled expatriates sent by multinational firms to manage subsidiaries operating in developing countries (Laczko and Brian, 2013).

Overall, in 2013, the host countries receiving the greatest number of migrants were developed countries; the main one being the United States of America (USA) with a stock of 45,785.1 thousands migrants which represents about 14.3% of the US total population (Lackzo and Appave, 2014). Abel and Sander (2014) note that migration is more diversified toward developed areas such as North America and Europe than toward developing

[4]The World Bank classifies countries (North *versus* South) according to their income level (GNI/capita).

[5]Based on the World Bank data, Lackzo and Appave (2014) estimate that in 2010, about 45% of international migration had taken place along the South-North axis, 35% along the South-South axis, 17% along the North-North axis and 3% along the North-South axis. These estimates are quite similar to those obtained with UN data.

countries, that migration is mainly intra-regional and that regions are often both sending and hosting migrants.

1.1.3 Contemporary trends in international flows

Movement of people across borders is growing but is still highly regulated, especially by developed countries. Meanwhile, the global economic liberalisation attests that most countries now recognise the benefits of the free circulation of goods, services and capital for productive activities. Figure 1.2 reports the world imports of goods and services, and FDI inflows as a percentage of GDP over the period 1970-2012[6]. Trade and FDI flows have been following similar trends than international migration stocks as illustrated in Figure 1.1 which shows a continuous increase since the middle of the 1970's with an important acceleration after the end of the Cold War.

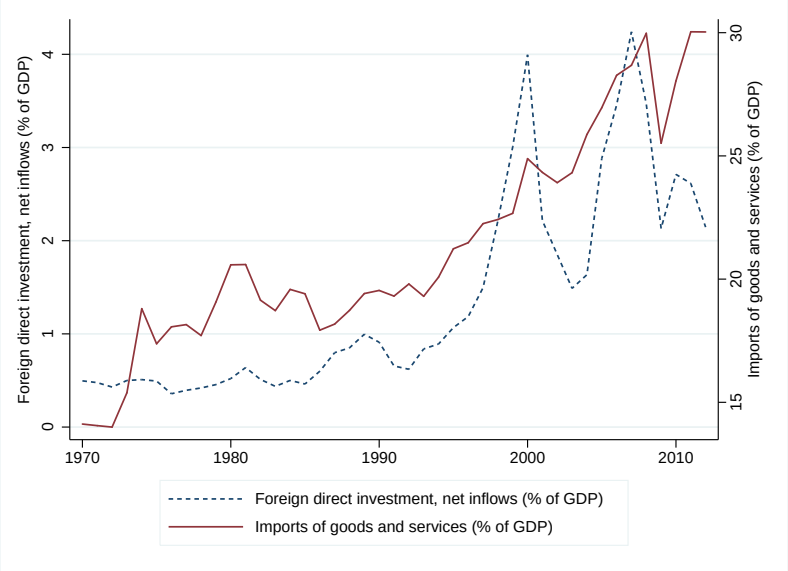

Figure 1.2.: Global trade and FDI flows, 1970-2012 (WDI, World Bank, 2015)

It is important to note a number of key stylised facts regarding international trade. First, trade is dominated by exchanges in manufactured goods. In 2010, trade consisted in 63% of manufactured products, 15% of primary goods, and 22% of services (Fouquin et al., 2012). Second, trade is highly regional as evidenced by the formation of free trade areas over the past century (Mucchielli and Mayer, 2010). Third, East and South Asia account for a growing share of the world exchanges. In 2008, the European Union (EU) accounted for 36% of world exports (goods and services), East and South Asia for 24% and the USA for 14%. The same year, the EU accounted for 40% of world imports, East and South Asia

[6]Contrarily to trade data that are quite accurate, FDI data present some consistency and comparability issues (Moosa, 2002), but we shall not develop this point here.

for 19% and the USA for 18% (Fouquin et al., 2012). In 2012, about 30.16% of trade flows were directed toward low and middle income countries (WDI, World Bank, 2015).

There are also two main points to note regarding FDI. First, in 2012, the tertiary sector accounted for 63% of the global FDI stock, while the manufacturing sector accounted for 26% and the primary sector for less than 10% (UNCTAD, 2015). Second, in 2014, FDI flows toward developing countries accounted for 55% of the global total, which was mainly due to the attractiveness of Asian economies (UNCTAD, 2015).

From these stylised facts, we can conclude that international flows have been following similar trends over the past decades. We note (i) the global increase in migration, trade and FDI since the nineties, although migration has been limited because more regulated; (ii) the increasing importance of regionalisation, and (iii) the growing role played by developing and emerging countries in the world economy. In this context, understanding to what extent international flows influence (complement/substitute) one another could ameliorate our knowledge of the aforementioned flows and our understanding of globalisation. In this thesis, we are especially interested in the trade-migration and the FDI-migration nexuses.

1.2 What determines migration?

1.2.1 Theoretical developments

No unified theory of migration has emerged so far, but rather a set of heterogeneous theories adopting various perspectives (Massey et al., 1993; De Haas, 2011). In this thesis, we only present the key migration theories.

Among them, the main theory of interest for our work is the micro neoclassical theory which considers that migration decisions, realised under perfect information, are the result of cost-benefit analyses. The pioneering model of Lewis (1954) describes migration between two sectors of an economy, for instance an agricultural and a manufacturing sector. Decisions to migrate from one sector of the economy to another depend on the wage differential existing across sectors. Individuals intend to migrate toward the sector where they can get the highest wage, as long as the wage differential is larger than the cost to do so. Incentives to migrate vanish when the differential income across sectors becomes equal to the cost.

Harris and Todaro (1970) relax the assumption of perfect information. They consider that migration decisions depend on the expected income in the destination sector, the differential income observed between the two sectors, and the likelihood to find a job in the

destination sector. In addition to explain migration from rural to urban areas, this model allows us to understand the existence of unemployment in urban areas: if the probability to find a job increases over time, an individual may decide to migrate even if his expected income is negative during the first years. The Harris and Todaro model was adapted to international migration by Borjas (1989) and Borjas (1990).

In addition to these macro-level determinants, some models incorporate the characteristics and the preferences of individuals in the modelling of migration decisions. Sjaastad (1962) associates the migration decision to an investment which depends on the socio-economic characteristics of the individual (age, level of education, gender, etc.). In this line of work, a number of recent contributions make use of the random utility maximisation (RUM) model[7] (Grogger and Hanson, 2011; Bertoli and Fernández-Huertas Moraga, 2013; Beine et al., 2015a). In this framework, an individual chooses his destination country in order to maximise his utility across all potential destinations, including his home country. His utility is made of a representative utility and an error term. The representative utility includes variables which are identical across individuals such as the expected wage and the bilateral migration cost. The error term consists in a random variable which accounts for unobserved heterogeneity among individuals, such as preferences over destination countries. The RUM framework has the advantage to reconcile the micro and the macro neoclassical analyses of migration: through the aggregation of bilateral probabilities to migrate across individuals, one can obtain a bilateral migration rate between two countries. This rate can be directly estimated by standard econometric methods.

The migrant's utility to migrate can also include amenities of the origin and destination countries, *i.e.* goods and services that are desirable but not universally available, for instance a good climate or public goods. For Tiebout (1956), differences in the supply of public goods (in terms of quantity and quality) across regions may explain why people, given their preferences, migrate toward the region offering the best set of public goods. This is also known as the Tiebout Hypothesis, which is often summarised by the statement: "*people vote with their feet*". Bodvarsson and Van den Berg (2009) note that such a consumption/equilibrium model has not been applied to international migration yet. For now, most studies using the Tiebout's model focus on location choices within developed countries. Nonetheless, the approach makes sense for international migration because amenities are unevenly distributed across countries. Democracy, freedom, health care and education systems of good quality... are indeed important drivers of international migration.

[7] RUM models find their origin in the income maximisation framework of Roy (1951), and discrete choice models in particular logit type models developed by McFadden (1974) and McFadden (1984). They have been introduced in the economics of migration by Borjas (1987) and Borjas (1999) to study the determinants of migration flows.

Finally, we can mention the meso or collective theories of migration. First, the New Economics of Labour Migration (NELM) explains that migration decisions are the result of collective decisions. This theory considers an implicit contract of mutual assistance between members of a family. By sending one of its members abroad, the household increases and diversifies its income (Stark and Bloom, 1985). This theory proposes a family-centred approach which takes into account the link existing between the left-behind family members and the the migrant. Yet, it is important to note that although presented by some researchers as an alternative approach to the main stream theory, it appears closely related to the micro neoclassical theory: an individual who intends to maximise his utility across destinations (micro neoclassical theory) can be associated, in a way, to an household intending to secure its income across different geographical places (NELM).

Second, the network theory explains why some individuals migrate while other do not, although they have the same incentives to migrate, and why migration endures over time between two countries (Goldin et al., 2011). Massey et al. (1993) define a network as a sum of relationships connecting migrants, non-migrants and former migrants between their origin and their destination countries. These individuals are linked by friendship, family and work relationships, and by solidarity with respect to their political-, ethnic- or religious community. Networks create favourable conditions for the exchange of information between distant places, which enables norm transfers and larger exchanges of population between societies. In particular, through relationships of solidarity or reciprocity, migrants decrease the migration costs of would-be migrants by facilitating their arrival, their administrative procedures, their access to employment and housing, etc. This approach is particularly interesting to study the importance of information in migration decisions.

1.2.2 Empirical evidence

Available empirical studies carried out so far clearly establish that migration flows are determined by the economic, social, political and demographic situations of the origin and the destination countries (often captured by the income differential) and by the bilateral migration cost (Hatton and Williamson, 2005; Mayda, 2010; Ruyssen et al., 2014; Beine et al., 2015a). Factors specific to the origin and the destination countries are often referred in the literature to as *push* and *pull* factors, which determine the power of repulsion of the origin country and the power of attraction of the destination country. Bilateral migration costs are usually estimated by the geographical proximity between the origin and the destination countries (the distance, the existence of a common border), by the cultural proximity (the existence of a common language or religion and past colonial ties between countries) and by migration policies.

Since the beginning of the decade, researchers have been analysing other determinants of migration decisions; we follow the survey of Beine et al. (2015a) to detail them. First, the role played by diaspora in migration decisions has increasingly been considered in the literature. For instance, Beine et al. (2011b) find that migration networks alleviates some impediments to migration (by relaxing the importance of self-selection and out-selection factors), which increases migration flows and lower their average educational levels. Beine et al. (2015a) conclude that "*a 10 per cent increase in the bilateral migration stock leads to a 4 per cent increase in the bilateral migration flow over the next ten years*". The authors also note that the role of colonial ties seems no longer significant when one take into consideration the role of migration networks. Hence the failure to consider networks can result in omitted variable biases.

The role of credit constraints, although not directly observed, is now taken into account in recent studies. This literature emphasises that potential-migrants are constrained in their migration choices by their capacity to finance their migration. If not rich enough, they are caught in a poverty trap and cannot afford to migrate even if they intend to do so. If rich enough, individuals can afford to migrate but not necessarily to all destination countries, the cost to migrate depending on dyadic variables (Hatton and Williamson, 2005). Beine et al. (2015a) note that credit constrains can be taken into account be assuming a negative correlation between the bilateral migration cost and the distribution of wages at the origin. They conclude that credit constraints do hinder migration flows.

The role of climatic factors is also receiving attention in the recent literature. A negative environmental shock in the origin country may impact migration outflows by decreasing wages at origin and increasing bilateral migration costs (because resources at origin might be destructed). Other channels are evidenced in the survey of Beine et al. (2015a): climatic shocks can reduce the attractiveness of emigration strategies due to an increased morbidity at origin. Additionally, when climatic shocks are volatile, they induce a greater volatility of wages at origin.

Finally, Beine et al. (2015a) emphasise the importance to account for *multilateral resistance to migration*: bilateral migration is determined not only by the characteristics of both related countries, but also by both countries interactions with the rest of the world. Up to now, empirical papers have been dealing with the phenomenon using a large set of fixed effects and find that *multilateral resistance to migration* does matter. However, some recent papers show that using the CCE estimator[8] of Pesaran (2006) is the most efficient way to control for multilateral resistance to migration (Bertoli and Fernández-Huertas Moraga, 2013; Bertoli et al., 2013).

[8]Common Correlated Effects mean group estimator

Overall, the majority of empirical studies analysing the determinants of (bilateral) migration flows use macro-level data and consist in the estimation of gravity-type equations. At first, studies have used standard analyses based on linear models, but papers now account for the specificities of migration data (for instance by using Poisson and NB2 models to account for the large share of zeros in the datasets). Also, omitted and unobserved variables are increasingly taken into consideration in the literature, thanks to different sets of fixed effects and to new estimators such as the CCE estimator.

1.3 The interdependence between international flows

Although international migration deserves to be studied for itself, its analysis cannot be disconnected from other international flows. First, international flows share some determinants which explains, in a way, why they are following similar trends. For instance, Buch et al. (2006) emphasise that the geographical and cultural distance and the wealth differential between origin and destination countries, determine both FDI and migration flows. Second, international flows impact one another, which induces some difficulties to identify relations of causality. Figure 1.3 illustrates this complex system, which we shall bear in mind when studying migratory phenomena in order to avoid endogeneity biases. The following sub-sections describe the trade-migration and FDI-migration nexuses.

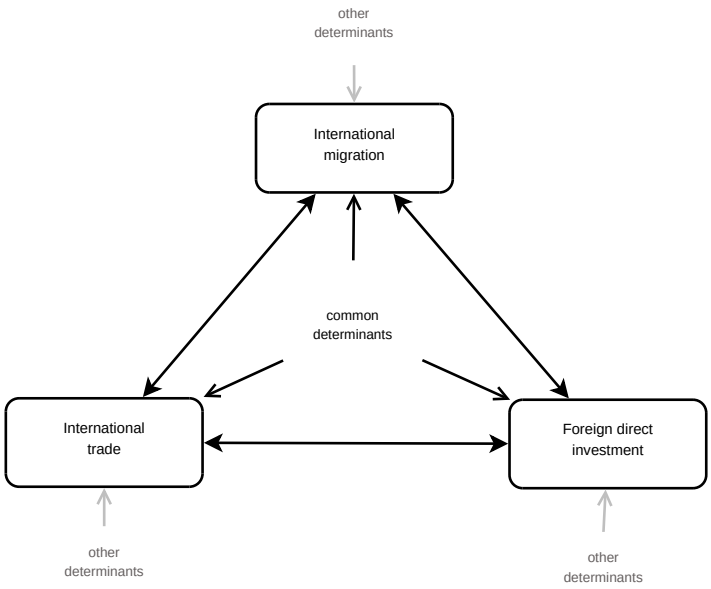

Figure 1.3.: International flows and their interactions

1.3.1 The trade-migration nexus

A rather large literature shows that migrants foster bilateral trade. Two main channels have been identified in the literature: the *preference channel* and the *trade-cost channel*. On the one hand, immigrants foster imports through their preferences for foreign goods. In addition, they participate to the dissemination of their tastes as natives may also develop preferences for these new varieties. Overall, the demand for foreign goods increases in the immigrants' host country, which fosters bilateral trade between their origin and host countries. Among others, Felbermayr and Toubal (2012) show how immigrants may foster trade with a partial equilibrium gravity equation. In their model, they make use of a utility function including a preference for foreign goods when immigrants are present in the population. Using stocks of foreign individuals born in some OECD[9] country and residing in another one for the year 2000, they show that immigrants (but not skilled immigrants) foster imports. This *preference channel* accounts for 63% of the total effect of migration on bilateral trade. The paper of Bratti et al. (2014) corroborates these findings. Using regional Italian data over the period 2002-2009, the authors demonstrate that immigrants have a significant and positive effect on bilateral imports.

On the other hand, immigrants – especially skilled immigrants involved in business related activities – foster exports through a *trade-cost channel*. Migration networks convey valuable information between origin and host countries on trade opportunities, on local commercial customs and on local preferences. These networks therefore relax the informational constraint faced by firms *i.e.* they reduce sunk and fixed export-costs, this in turn fosters bilateral trade. The paper by Felbermayr and Toubal (2012) also studies this channel. In their theoretical model, they assume that firms' export-costs toward a destination depend on the share of the foreign population born in that export destination. In the empirical validation of the paper, they find that this channel accounts for 37% of the total effect of migration on bilateral trade, this effect being higher for high skilled individuals. Among others, see Gould (1994), Rauch (2001), Peri and Requena-Silvente (2010), and Aleksynska and Peri (2014) and Aubry et al. (2012). Additionally, by conveying trustful information, immigrants reduce the risk faced by their firms when trading with countries providing low contract enforcement. Ehrhart et al. (2012) show that African migrants foster African exports by compensating for weak legal institutions and weak contract enforcement. The paper of Briant et al. (2014) corroborates the fact that immigrants compensate the quality of their origin country institutions.

[9] Organisation for Economic Co-operation and Development

The reverse causality is also to be considered. The mechanisms through which trade can impact migration are developed by Hatzigeorgiou and Lodefalk (2014). The authors note that although some papers adopt instrumental variable techniques to show that the causal relation runs from migration to trade (the pioneering author being Gould, 1994), their results may not be generalised. A number of endogeneity problems can still arise. For instance migration may depend on the conditions of the destination country's labour market, which in turn depends on the importance of trade in that country's economy (small *versus* large economy). In a small open economy, firms may favour the employment of foreign workers coming from the destinations with which they have a commercial experience. Overall, papers mainly focus on the impact of migration on trade, trying to avoid any endogeneity problems.

1.3.2 The FDI-migration nexus

A smaller and mostly empirical literature looks at the FDI-migration nexus. Some researchers study the impact of migration on FDI flows, and emphasise that migration networks spread information between their origin and their host countries which strengthens bilateral FDI flows. On the one hand, migrants may increase FDI entering their host countries. Dolman (2008) studies the influence of migration on inward FDI between 28 OECD countries and 162 partner countries, for the year 2000. He shows that migrants (especially educated migrants) spread information lowering international investment costs which fosters FDI. The papers of Docquier and Lodigiani (2010) and Foad (2012) corroborate this result.

On the other hand, migrants may increase FDI entering their origin countries. Javorcik et al. (2011) analyse US immigration and US FDI stocks into 56 partner countries, for the years 1990 and 2000. They find that immigration, in particular skilled immigration, induces outward FDI by providing their firms with better information on foreign countries and by ensuring stronger contract enforcement. Moreover, they underline that immigrants are potential entrepreneurs investing to their origin countries. Dolman (2008) and De Simone and Manchin (2012) corroborate these results. Other papers find slightly different results. El Yaman et al. (2007) study European countries over the period 1990-2000. They find that skilled migrants positively impact outward FDI stocks toward the origin country of the migrants, while skilled migrants negatively impact outward FDI stocks.

Researchers have also considered the reverse causality *i.e.* the effects of FDI on migration. Available empirical results are mixed and highlight positive and/or negative effects of inward FDI flows on emigration for developing countries. FDI flows entering a developing country generate externalities which can either lessen migration – FDI can participate to

the economic development of the migrants' origin country – or strengthen migration – by maintaining and/or creating jobs in the receiving countries and by conveying information about migration opportunities, FDI may relax the budget constraint of would-be migrants. D'Agosto et al. (2006) study the link between FDI inflows from OECD to developing countries and migration in the reverse direction, over the period 1991-2001. They find both a substitution and a complementarity effect. First, FDI positively impacts the human capital accumulation of the developing country, through knowledge transfer and by encouraging the formation of individuals. With better qualifications, workers increase their wages, which in the end decreases emigration. Second, FDI convey information which reduces risk and thereby migration costs. Thus, FDI increases emigration by relaxing the budget constraints of would-be migrants. Sanderson and Kentor (2008) corroborate the fact that FDI increases emigration, whereas Aroca and Maloney (2005) and Sauvant et al. (1993) corroborate the fact that FDI decreases emigration.

1.4 Overview of the consequences of migration for host and origin countries

1.4.1 The consequences of immigration for developed countries

Over history, the economic and cultural impact of immigrants on their host societies seems to have been rather neutral (if not positive). First, there is an important number of papers that try to identify the impact of immigration on natives' wages. Among others, Jayet et al. (2001) review the economic effects of immigration on host countries with a particular insight on France. They explain that in a closed economy, immigration may induce a downward pressure on wages (and an upward pressure on returns to capital) as it modifies the labour to capital ratio. However, this effect is largely reduced in open economy with a free circulation of capital. Reviewing empirical studies, they find no clear evidence regarding the effect of immigrants on natives' wages. Similarly, reviewing the literature, Goldin et al. (2011) note that the effect of immigrants on natives' wages seems close to zero.

Recently, with a one-sector model, Peri and Sparber (2009) highlight a positive effect of immigration on natives' wages. In their model, immigrants occupy manual tasks and push natives toward communication intensive tasks which are better paid. This approach has been extended by Ottaviano et al. (2013) to a multi-sector and open economy model. This imperfect substitution between natives and foreigners has been validated by several empir-

ical studies, such as D'Amuri and Peri (2012), De Arcangelis et al. (2014) and Mitaritonna et al. (2014).

Immigrants seem to have a neutral (if not positive) effect on the public finance of their host countries. Using the generational accounting technique, Chojnicki (2011) shows that the impact of immigrants on the social welfare system is globally positive for France. At a given time, even if immigrants are relatively favoured by the re-distributive system due to their low-skilled characteristics, their share to the working age is relatively high so that their contribution is higher than what they retire from the welfare system. In the long run, the impact of immigration on public finance is slightly positive due to the perpetual entrance of working age immigrants and consideration of their descendants. Goldin et al. (2011) note that even if some studies attest a slightly negative fiscal impact of immigrants, these costs are likely to be compensated by their overall positive contribution to the economic growth.

Goldin et al. (2011) underline that immigrants enhance economic growth, because unskilled immigrants specialise in jobs that native workers do not want to occupy (for instance the care sector), and skilled immigrants work in growing and high value added sectors that are facing a labour shortage (for instance high-technologies and education). In particular, skilled immigrants are known to be highly creative. Their entrepreneurship capacities and potential to innovate is attested by some success stories: the creators of Google, Yahoo, Intel, eBay and Paypal were all immigrants. Skilled immigrants reinforce the overall efficiency of their firm, because a higher cultural diversity stimulates innovation and problem solving which leads to more patent filings. For such a reason, developed countries intend to stimulate skilled immigration through selective migration policies that favour labour immigration for some skilled-intensive sectors.

That being said, Bodvarsson and Van den Berg (2009) show that high skilled immigrants do not always use their skills at destination, and sometimes occupy lower skilled jobs. The authors make reference to the work of Özden (2006) who referred to this phenomenon as the *brain waste*. He finds that the closer the cultural and linguistic proximity between the origin and host countries, the higher the probability for immigrants to find a job that matches their skills. He also evidences that pro-immigration policies favouring skilled immigration decrease the likelihood of brain waste (contrarily to family reunion programs), and that the quality of the education system in the origin countries of immigrants decreases the likelihood of *brain waste*.

Finally, Castles et al. (2014) note that immigration may either result in a multicultural society with different ethnic communities – when immigrants are integrated into the soci-

ety, for instance thanks to voting rights – or result in the apparition of ethnic minorities viewed as undesirable for the host society, implying discrimination and marginalisation. If well managed, immigration can create a multicultural country, an innovative and adaptive society.

1.4.2 The consequences of emigration for developing countries

Migrants are important for their origin countries. Emigration induces some negative and positive consequences for developing countries that we shall highlight here. Emigration creates a negative shock in labour supply, but the pool of unemployed persons can be important in developing countries, thus unemployed individuals may fill in positions left by emigrants (Katseli et al., 2006). This may be particularly true for unskilled workers.

However, because of a positive self-selection, emigrants are often the most educated individuals of their countries (university graduates, doctors, nurses...). These individuals have more financial means to emigrate and higher expected gains at destination. Thus, origin countries endure a loss in terms of human capital and foregone educational costs (Bhagwati and Hamada, 1974; Bhagwati and Rodriguez, 1975). This phenomenon is referred to as the *brain drain*[10]. Bodvarsson and Van den Berg (2009) review the determinants of the phenomenon. One reason for which skilled individuals emigrate is that they see little opportunities in their home country, where there is a lack of demand for skills and often an inefficient labour market. Consequently, they are not well valued nor well paid in their home countries. The lack of infrastructures (for instance for scientists and health care workers) leads to challenges regarding job satisfaction or inefficiencies in the workplace. Even when there are job opportunities for skilled workers, fiscal policies implemented in developing countries may give workers incentives to leave.

Although the emigration of skilled workers is traditionally seen as a problem for source countries, there is a non negligible number of positive externalities induced by emigration. This view participates to the *renewed optimism* about the contributions of migrants to their origin countries in term of development, counterbalancing the traditional wisdom that migration only constitutes a labour loss for sending countries (Castles et al., 2014).

Once abroad, individuals often maintain transnational social and economic relations with their origin countries. In particular, Gibson and McKenzie (2011) show that high skilled migrants are remitting about as much as their absence costs to their origin country. In

[10] Another type of migration that can be closely related to *brain drain* and *brain gain* issues, is student mobility. See the paper of Beine et al. (2014) which reviews the main determinants of student mobility.

2012, remittances represented about $490,049 million – $130,205 million toward high income countries and $359,844 million toward middle and low income countries – more than 3.5 times the amount of aid provided by developed countries to developing countries (World development Indicators, World Bank, 2015). In 2012, the net official development assistance and official aid was about $133,039 million. The evolution of global aid and remittance flows over the period 1970-2012 is presented in Figure 1.4.

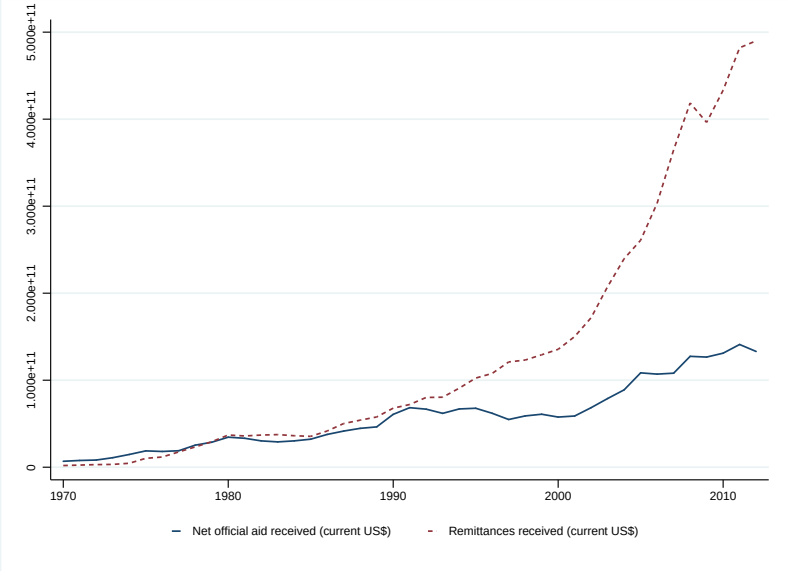

Figure 1.4.: Global aid and remittance flows, 1970-2012 (WDI, World Bank, 2015)

Goldin et al. (2011) note that remittances participate to the reduction of poverty and are used by recipient families for basic needs (nutrition, housing). As intra-household transfers alleviate financial constraints remittances also improve health and education for children (especially for girls). Remittances can also stimulate local development, allowing families to invest in small businesses that can promote access to self-employment. Overall, if remittances boost consumption and employment, they seem to have a moderate multiplier effect on local and national economies. On that matter, see also the work of Démurger (2015) on left-behind families.

Motivations lying behind international intra-household financial flows have been reviewed by Rapoport and Docquier (2006). Migrants may remit by pure altruism – they remit to improve the living conditions of their relatives stayed in the home country – or by pure egoism – they remit to maximise their revenue in the home country, for instance, in case of return. Yet reality is not that dichotomous, thus Lucas and Stark (1985) introduce the concepts of *enlightened self-interest* and *tempered altruism*. Remittances are frequently part of a family strategy. Migrants often remit to reimburse the migration cost that their family paid, and to diversify sources of revenue and insure an economic stability to their family.

The last two motivations are to be related to the theory of implicit contracts, between the family stayed home and the migrant. Naiditch and Vranceanu (2011) argue that migrants may remit to signal a social and an economic success to relatives stayed home. In a context of asymmetric information between the migrant and the family, the authors show that the amount transferred conveys information on the social status of the migrant. Remittances also depend on macro-economic variables such as the interest rate and the political instability at destination and at home, and the exchange rate between the two countries (Adams, 2009).

Furthermore, opportunities abroad create incentives for individuals to educate (Bodvarsson and Van den Berg, 2009). Individuals invest in education to increase their chances to emigrate. If not all of these educated individuals emigrate, the level of human capital of the country increases. This increase in skilled labour can, in turn, foster economic growth. Beine et al. (2001) refer to this positive spillover as the *beneficial brain drain*. In the long run, if those who emigrated return, they induce a positive shock in term of human capital and can generate knowledge spillovers (Gibson and McKenzie, 2011).

The overall impact of emigration for developing countries remains quite uncertain. Bodvarsson and Van den Berg (2009) note a lack of consensus on this issue, which of course makes difficult the formulation and implementation of policy recommendations. Regarding emigration of skilled workers, the authors conclude that "*[...] the issue for source countries is not so much whether [it] is good or bad for a poor country, but rather how to make the best of the inevitable.*"

1.4.3 Gains from migration and migration policies

Overall, it appears that migration can generate positive gains. However, even if this is the case, the costs induced by these population movements have to be absorbed in the short-run, often by some specific countries, social groups or economic sectors, while the benefits may only appear on the medium and long run. This calls, of course, for re-distributive policies. In parallel to the cost/benefit analyses that justify the opening of national borders (Clemens, 2011; Wihtol de Wenden, 2014), political science literature interrogates the legitimacy of policies restricting the individual freedom of movement[11].

Developing countries are becoming more aware that emigration may induce positive gains. Some countries are starting to elaborate policies oriented toward their diaspora, for instance, policies easing remittances and investments from emigrants (Gamlen, 2008). Nevertheless, despite no clear evidence that immigration has a positive or neutral effect on host

[11] On this particular matter, see the work of Wihtol de Wenden (2013) and Wihtol de Wenden (2014).

societies, the latter continue to see it as a threat, "*[...] as something to be managed – a cost to be minimized rather than an opportunity to be embraced*" (Goldin et al., 2011). In their book, Castles et al. (2014) make the same point: immigration is often assimilated to a threat to the state sovereignty and to the economic performance of the host country.

Consequently, migration is far from being free. The right to emigrate is now worldly recognised, but the right to immigrate is still to be acquired by the population of the developing world (Wihtol de Wenden, 2013). Li (2008) highlights that high skilled individuals can move relatively freely across national borders – developed countries are competing for highly specialised human capital – while borders remain quite closed for unskilled individuals and asylum seekers.

In view of the gap existing between the research-based policy recommendations and the implementation of migration policies, economists may need to refine their studies in order to formulate more concrete advice. They could deepen their analysis on migration policies across countries. However, at present, data on migration policies are poorly available. As stated by Gest et al. (2014), "*[...] scholars, researchers, and policy makers have not had the resources to measure, evaluate or compare migration policies and law across countries and time in a truly systematic manner.*"

In their paper, Gest et al. (2014) propose a review of existing estimates of immigration admission, naturalisation and integration policies, and conclude on the need for a new database. They present the IMPALA[12] database, which, once completed, will provide an overview of immigration laws and policies across six main areas: economic migration, family reunification, humanitarian migration, irregular migration, student migration, and the acquisition and loss of citizenship for migrant residents, across 20 OECD countries and across time. See also Beine et al. (2015b) who present some preliminary findings from this database. In the same line of research, Rayp et al. (2014) use a Bayesian state-space approach to build a composite indicator of the overall restrictiveness of migration policies across countries. This indicator allows the authors to explore policy interactions between countries.

The scientific community could improve its knowledge of migration and provide more solid policy recommendations by crossing different fields of research: economics, sociology, political sciences, geography... Some research projects are going in that direction. Among others, we can mention the Mobglob[13] 2012 ANR project, or the COMPAS[14] 2012-2017 research programme based at the University of Oxford. The Migration Summer School proposed by

[12] International Migration Policy And Law Analysis
[13] Mobilité globale et gouvernance des migrations
[14] Centre on Migration, Policy and Society

the European University Institute is also a good example of a multidisciplinary conference, gathering researchers and professionals participating to the design of migration policies. These initiatives participate to the reduction of the gap existing between researchers and policy-makers, and feed the public debate on migration which is often too ideological[15].

1.5 Research agenda and contributions

1.5.1 Research agenda

In view of this brief survey of the economics of migration, we can formulate a research agenda to which the following chapters intend to contribute.

Analysis of international migration

- **Toward a better understanding of migration decisions**
  A rather large literature analyses what one may call the *traditional* determinants of migration. However, a number of other determinants of migration decisions are less documented in the literature and could be further explored, for instance the role of the budget constraint, the role played by migration networks, or the effect of climatic factors on migration decisions (Beine et al., 2015a). Additionally, an emerging literature now considers the role of unobserved variables when estimated bilateral migration flows. The concept of multilateral resistance to migration is particularly interesting as it allows to capture, in addition to factors related to the origin and the destination countries, factors related to other alternative destination countries (Bertoli and Fernández-Huertas Moraga, 2013; Bertoli et al., 2013). Therefore, there is a need to further investigate these *new* determinants of migration.

- **A thorough exploration of the FDI-migration nexus**
  The understanding of the relation existing between international trade and international factor mobility improved greatly over the last century, in particular with the progress of the international trade theory. Since the beginning of our century, there has been a renewed interest for this research field and in particular for the analysis of international flows and their interactions. While a large (and still growing) literature evidences the pro-trade effect of migration, the literature analysing the FDI-migration nexus is still rather new. It has been initiated by the work of Aroca and Maloney

[15] The debate on migration can be ideologically oriented even by economists. See the book of Collier (2013) which opened an important debate among economists.

(2005), Kugler and Rapoport (2005), D'Agosto et al. (2006), Kugler and Rapoport (2007), Dolman (2007), and Sanderson and Kentor (2008). Existing empirical studies provide some conclusions on the relation between FDI and migration flows, but results are ambiguous. Some existing analyses present some endogeneity concerns. Only few papers try to consider the link of endogeneity existing between the two factor flows, but these papers often use lagged variables which partly solve the problem of endogeneity that may be time resistant. That being said, instrumental variables are very difficult to find, the main reason being that FDI and migration flows have common determinants (Buch et al., 2006). This new literature lacks a theoretical analysis, in particular a theoretical framework which could allow to better interpret the various results of available empirical studies.

- **Assessing the consequences of migration policies**
  Even if the benefits of international population movements are now acknowledged by the scientific community, the right to immigrate is still very restricted. Political forces fashioning migration rights seem to respond to other sources of influence than scientific analyses. Since the 2008 crisis, we have been observing a tightening of immigration policies in western countries. The consequences of such migration policies ought to be studied by economists. On the one hand, these policies could direct migration flows toward more open countries. On the other hand, they could increase the number of illegal immigrants living in the developed countries implementing them. Furthermore, knowing that migration flows are somehow related to trade and FDI flows, the following question ought to be asked: should not restrictive migration policies further be thought together with FDI and trade policies? As mentioned by Berthélemy et al. (2009): "*The opening of trade, facilitation of international investment, foreign aid, and migration controls all form a complex mix of policies that cannot be considered in isolation. They interact with each other, and to be efficient, they must be designed and implemented in a coherent manner*".

Methods and data source

- **New research perspectives with micro-level data**
  So far, most empirical studies analysing migration related issues have used macro-level data. Available papers show to what extent macro-economic and political variables impact migration flows. Nonetheless, the comprehension of individual behaviours would enrich our comprehension of migration flows. An emerging literature using micro-level data attests that such databases, although difficult to access, are often of better quality and allow to investigate a larger set of factors possibly influen-

cing migration. For instance, employer-employee data offer the possibility to improve our understanding of migration decisions for work purposes and our comprehension of firms' decisions to employ foreign workers. It seems that any opportunity to analyse such micro-level data should be seized by economists of migration, in order to provide studies which could corroborate and complement macro-level papers, but also to provide a number of concrete policy recommendations.

- **The quality of migration data**
  Finally, over the past 10 years, the quality of international migration stock data improved significantly thanks to a number of authors, particularly the work of Özden et al. (2011), Brücker et al. (2013), and Docquier et al. (2009) and Docquier et al. (2010). Yet, migration flow data, which are broadly used in the empirical literature, still present some issues of accuracy and comparability between countries. The quality of annual (or decennial) flow data restrains econometricians in their analyses of migratory phenomena, and limits them in their policy recommendations. When available, national biannual or quarterly migration data allow for better estimations. However, these data are not easily accessible because of anonymity concerns. Although this is not an objective of this thesis, more qualitative and high-frequency data seem needed to improve and refine the policy recommendations of empirical economists.

1.5.2 Contributions of this thesis

International migration and its interactions with other international flows

In this thesis, we provide number of contributions addressing the issues raised in our research agenda. **The second and third chapters** look at the link between migration and FDI flows. In **chapter 2**, we provide new theoretical evidence about the linkages existing between migration and foreign direct investment flows. We aim at filling a gap between the trade theory and available empirical evidence on the migration-FDI nexus. To do so, we develop a general equilibrium model resting upon the standard Heckscher-Ohlin (1919, 1933) framework. We consider three internationally mobile factors (capital, unskilled and skilled labour) and two transportable goods, both internationally traded. We assume a developing economy, amply endowed with unskilled labour and poorly endowed with skilled labour; and a developed economy, poorly endowed with unskilled labour and well endowed with skilled labour. We start examining what happens when the whole capital stock is invested in the North. Then, we look at the changes induced by an exogenous transfer of capital from the North to the South. Finally, we introduce imperfect international mobility of factors: investors ask for a risk premium for moving capital to the South and migrant workers must

cover a migration cost. Looking at flows generated by changes in the risk premium and the migration costs, we find a relation of substitution between capital and unskilled labour flows, and a relation of complementarity between capital and skilled labour flows.

We further develop our analysis in **chapter 3**, in which we develop some micro implications of the theoretical model presented in **chapter 2**. In the latter chapter, we show that when capital moves from northern to southern countries in search of a higher remuneration, it generates north-south skilled migration when the recipient country of the investment lacks skilled labour. Thus, capital flows and skilled migration are complements. The mechanism underlying this relation of complementarity is twofold. First, capital intensive companies implement technologies making use of capital and both unskilled and skilled labour. Therefore, when foreign enterprises establish in a country which lacks skilled labour, they strengthen the demand for skilled workers on the local labour market. Second, foreign firms, especially vertically integrated multinational enterprises, use skilled worker transfers to control and coordinate the head-quarter operations with the subsidiary operations and ensure tacit knowledge transfers. Therefore, we investigate the determinants of the employment of foreign skilled workers by firms operating in Sub-Saharan African (SSA) countries. We use cross section firm-level data on a large sample of foreign and domestic firms collected through the UNIDO[16] Africa Investor Survey 2010. We find support for complementarity between FDI and skilled migration toward SSA countries. It implies that foreign firms increase the flow of human capital toward their investment destination countries by attracting foreign skilled workers. Our results also indicate that the lack of skilled labour in the destination country induces firms to employ more foreign workers. The contribution to the literature of this chapter is twofold. Firstly, we provide evidence on the determinants of skilled migration toward less developed countries, contrarily to the bulk of existing literature which has focused on the opposite south-north direction. Secondly, we shed light on the complementarity between FDI and migration of skilled workers (which corroborates the results of chapter 3) using a firm-level analysis in an area of the world, SSA countries, on which only few contributions exist.

In the **fourth chapter**, we turn our attention to the trade-migration nexus. We analyse to what extent immigrant workers, according to their level of qualification, may favour the performance of their firm in terms of sales and participation to foreign markets. To this end, we first develop a theoretical framework resting upon the model of Mrázová and Neary (2012). We assume that (i) foreign workers allow for efficiency gains *(productivity channel)*, and that (ii) immigrants convey valuable information to their firm which decreases the variable and the fixed export-costs to their origin countries *(trade-cost channel)*. Our model predicts that immigrants should foster exports at both the extensive and the intens-

[16]United Nations Industrial Development Organisation

ive margins, that is the probability of being an exporter and the size of exports. We test this theoretical prediction using a French firm-level dataset over the period 1995-2008. In line with the trade-migration literature, we find that foreign-born workers, and especially skilled immigrants, foster exports at both margins of trade. The contribution of this chapter is twofold. First, we evidence in a model of heterogeneous firms, the different channels through which foreign employment may impact exports at both margins of trade. Doing so, we intend to fill a theoretical gap in the literature on this topic. Second, only a limited number of papers provides firm-level evidence on this phenomenon. We use firm-level export data and firm-level employment data, contrarily to most existing micro-level analyses that use firm-level export data but regional immigration stocks. Doing so allows us to improve our understanding of the mechanisms at play between foreign workers and their firms.

International migration and migration policies

Our **fifth chapter** deals with the impact of restrictive immigration policies on migration flows. Since the 2008 crisis, developed countries have been tightening their migration policies. Because national sovereignty prevails, they tend to do so unilaterally. It is now common knowledge that economies are highly interconnected, but it is not always clear into what extent a country may impact other countries through its migration policies. Improving our understanding of such a question could tell us whether countries may find a tangible interest to collaborate on migration issues. To tackle this issue, we build a RUM model in which we explicitly introduce the role of the budget constraint in the migration decision of potential migrants: individuals cannot afford migrating to a destination for which the related migration cost (which depends on the migration policy of the destination countries) is higher than their current income. We find that the migration rate between two countries depends on the characteristics of the origin and destination countries and their relative accessibility, and also on a budget constraint effect. The latter depends on other alternative countries. Thus, multilateral resistance to migration arises. We corroborate these findings with a numerical experiment based on 25 European countries on 2008. We simulate a complete relaxation of the German migration policy toward eastern European states. Our results confirm that the budget constraint matters. We show that a loosening of the German migration policy increases (or leaves unchanged) the migration rate from new member states toward Germany. We find that migration rates from new eastern European member states toward other destination countries are also impacted. The contribution of this chapter to the economic literature is twofold. To the best of our knowledge, no RUM model explicitly takes into account the role of budget constraints on migration decisions. Then, our results corroborate the importance to consider multilateral resistance to migra-

tion when analysing bilateral migration. This result calls, in a way, for more dialogue between countries implementing unilateral or bilateral migration policies, and the rest of the world.

Our **sixth chapter** deals with the impact of restrictive migration policies on illegal migration. The objective of the chapter is twofold. We want to confirm a simple intuition: illegal migration increases when developed countries implement restrictive migration policies toward the developing world. Additionally, in view of the present EU political context, we look at what happens to illegal migration when developed countries adopt different attitudes toward the developing world (collaborative or autonomous policies). To this end, we develop a spatial agent-based model in which imperfectly informed agents are internationally mobile and can migrate legally or illegally. Their migration decisions are conditioned by geographical and financial constraints. We parameterize our model in order to simulate legal and illegal migration stocks in the European Union of the fifteen in 2005. Our results show that a restrictive migration policy reduces the number of legal immigrants in the developed world, but does force some individuals into illegality. In addition, we find that policies implemented by southern EU countries impact the level of immigration faced by northern countries. This result calls, in a way, for more collaboration between EU member states as the immigration pressure faced by southern countries becomes more and more important. The contribution of this chapter to the economic literature on illegal migration is the following. Our approach provides new perspectives regarding the modelling of illegal migration. Our model rests upon the micro neoclassical theory of migration, but allows us to relax some assumptions: we assume a world under imperfect information with rational but not necessarily optimising agents. Yet, we are able to reproduce some standard results of the migration literature, while proposing new insights regarding the importance of geography and information in migration decisions.

Part I

International migration and its interactions with other international flows

2 Interacting factor flows between developed and developing countries

This chapter has been written in collaboration with Hubert JAYET.

2.1 Introduction

This chapter provides new theoretical evidence about the linkages existing between migration and FDI flows taking place between developed and developing countries. We aim at contributing to fill a gap between trade theory and available empirical evidence about the relations between migration and FDI. It is usually considered that traditional trade theory leads to the conclusion that migration and FDI flows must be substitutes: firms looking for workers available outside their home country can attract them, generating inward migration, or invest in the countries where workers are available, generating outward FDI flows. Then, migration and FDI tend to move in opposite directions.

This theoretical prediction is not confirmed by empirical evidence. Empirical analysis carried out so far has led to three main results. First, skilled migrants positively impact FDI entering their host country, suggesting a relation of complementarity between capital and skilled labour flows. More precisely, studying the influence of migration on inward FDI between 28 OECD countries and 162 partner countries for the year 2000, Dolman (2008) finds a positive impact of immigrants (in particular skilled immigrants) in OECD countries on inward FDI. Using a sample of 114 countries during the period 1990-2000, Docquier and Lodigiani (2010) find that inward FDI is positively related to skilled immigration. Foad (2012) finds similar results analysing FDI and immigration from 10 source countries to the 50 US states, between 1991 and 2004. Immigrant communities in the USA attract FDI from their origin countries, this effect being stronger for migrants with a high education level. Some papers also find that immigration fosters outward FDI. Analysing US immigration and US FDI stocks into 56 partner countries for the years 1990 and 2000, Javorcik et al. (2011) find that immigration, in particular skilled immigration, leads outward FDI by providing nat-

ive firms with better information on foreign countries, and by ensuring stronger contract enforcement. De Simone and Manchin (2012) find a positive effect between migration from eastern to western European countries and FDI in the reverse direction during the period 1995-2007.

Second, unskilled migrants negatively impact FDI entering their host country, suggesting a relation of substitution between capital and unskilled labour flows. More precisely, in their study of European countries over the period 1990-2000, El Yaman et al. (2007) find a contemporaneous substitution between unskilled immigration and FDI outflows and a dynamic complementarity between skilled immigration and FDI outflows toward the origin country of the migrants. Analysing US immigration and FDI outflows in 1990 and 2000, Kugler and Rapoport (2007) corroborate these results. They find a contemporaneous substitution between low skilled migration and FDI, and a dynamic complementarity between high skilled migration and FDI.

Third, FDI from developed toward developing countries decrease reverse migration on the long run, suggesting a relation of substitution between capital and unskilled labour flows. More precisely, studying the link between FDI inflows from OECD to developing countries and migration in the reverse direction over the period 1991-2001, D'Agosto et al. (2006) find both a substitution and a complementarity effect. First, FDI positively impacts the human capital accumulation of developing countries, and then increase wages which *in fine* decreases emigration. Second, FDI increases emigration by relaxing the budget constraint of would-be migrants. Conversely, Sanderson and Kentor (2008) find a positive relation. Working on 25 less-developed countries over the period 1985-2000, they show that FDI stocks positively impact emigration rates in the long run. Sanderson and Kentor (2008) corroborate the fact that FDI increases emigration, whereas Aroca and Maloney (2005) and Sauvant et al. (1993) corroborate the fact that FDI decreases emigration.

The usual explanations for these results come from outside the literature on international trade. The usual one focuses on the effect of migrant networks on trade and investment costs. De Simone and Manchin (2012) extend the 2x2x2 model of fragmentation and multinational production of Venables (1999) and show that, when immigrants relax the informational constraint faced by firms, foreign investment increases. Federici and Giannetti (2010) develop a continuous time dynamic model. They consider a small open developing economy which lacks capital and skilled labour. They assume that migration is temporary, and that the capital stock in the developing country is generated by capital inflows from the developed countries hosting migrants. They show that return migration increases the human capital stock in the country and acts as an information revealing network, which attracts inward FDI. Aubry et al. (2012) extend the theoretical framework of heterogen-

eous firms developed by Helpman et al. (2004) and Helpman et al. (2008), in which they consider that migrants reduce fixed costs supported by firms exporting and setting up horizontal FDI. Under the assumption that natives and foreigners are imperfect substitutes, they show that migration fosters trade and investments. In the same line, Wang (2013) extends the model of Helpman et al. (2004). He considers both low and high skilled workers. Under the assumption that natives and foreigners are imperfect substitutes, he shows that migrants allow for productivity gains as they bring foreign opportunities and thus increase the local competition.

Almost no attempt has been made to show how standard economic forces that are behind international trade may lead to complementarity of labour and capital flows. Ivlevs and De Melo (2010) use the 3x2 specific-factor framework, in which capital is mobile across sectors and labour is sector specific. In particular, they consider a non-traded good sector employing capital and unskilled labour, and an exported good sector employing capital and skilled labour. Under the assumption that capital is internationally mobile but labour is subject to national policy restrictions, they study the effects of exogenous high and low skilled migration shocks on FDI. Within this Ricardian framework, they find that skilled migration and FDI are complements. In particular, when exports are intensive in low skilled labour, emigration of high skilled labour leads to a positive capital outflow. In the same vein, Davis and Weinstein (2002) develop a Ricardian framework with a composite production factor. In this model, factor flows are motivated by the technological superiority of a country. Thus, skilled labour, unskilled labour and capital have a simultaneous incentive to enter the country with the highest technology.

To the best of our knowledge, there is no model explaining the endogenous linkages between international factor flows and making the distinction between skilled and unskilled labour. This chapter tries to fill this gap using a general equilibrium model resting upon the standard Heckscher-Ohlin (1919, 1933) framework, in which differences in factor endowments between regions are sufficient to explain factor flows. In this type of model, factor scarcities, such as capital deprivation, allow for corner solutions adequate to highlight substitution and complementarity between factor flows. We consider three internationally mobile factors (capital, unskilled and skilled labour) and two transportable goods, both internationally traded. The first good is a traditional one produced from labour only, skilled and unskilled workers being perfect substitutes; the production of the second good combines capital and labour, skilled and unskilled workers being perfect complements. We assume a Southern or developing country, amply endowed with unskilled labour and poorly endowed with skilled labour; and a Northern or developed country, poorly endowed with unskilled labour and well endowed with skilled labour.

We start examining what happens when the whole capital stock, which is owned by the North, is also invested in the North. Then, we propose some comparative statics to identify the impact of an exogenous transfer of capital from the North to the South on migration flows. Finally, we endogenise factor flows by introducing imperfect international mobility of factors: investors ask for a risk premium for moving capital to the South and migrant workers must cover a migration cost. Looking at flows generated by changes in the risk premium and the migration costs, we find a relation of substitution between capital and unskilled labour flows, and a relation of complementarity between capital and skilled labour flows.

The following section introduces the two-country model. Section 2.3 analyses the impact of exogenous capital transfers between countries. In section 2.4, we endogenise factor flows between countries and analyse the effects of factor transfers. Section 2.5 concludes, highlighting our results regarding the relation of substitution *versus* complementarity between factor flows, and suggesting some policy recommendations.

2.2 Model features

2.2.1 Single country features

Let us start considering a single country, called South. The country combines three inputs, capital, skilled and unskilled labour, to produce two transportable goods, both internationally traded. The first good is the output of a traditional sector. The traditional sector does not use capital. Skilled and unskilled labour are perfect substitutes and produce under constant returns to scale. The production task to be carried out is basic, consequently both types of workers have the capacity to perform it although skilled workers are more efficient in doing so. The production function of this sector is then $Q_1 = A(U_1 + cS_1)$, Q_1 being the output, U_1 and S_1 the respective inputs of unskilled and skilled labour, c a constant greater than unity, and A a positive constant. The intensive form of this production function is given by equation (2.1), with u_1 and s_1 being the technical coefficients *i.e.* the respective quantities of unskilled and skilled labour needed to produce one unit of output, respectively $u_1 = \frac{U_1}{Q_1}$ and $s_1 = \frac{S_1}{Q_1}$.

$$1 = A(u_1 + cs_1) \tag{2.1}$$

The second sector is a capitalist or industrial sector, as it employs capital in addition to labour. It is characterised by the following Cobb-Douglas function, $Q_2 = BK^{\beta}\left[min(U_2, S_2)\right]^{1-\beta}$, Q_2 being the output, K, U_2 and S_2 the respective inputs of capital, unskilled labour and skilled labour employed in the sector, β a constant between zero and unity, and B a posit-

ive constant. Then in the industrial sector, returns to scale are constant, capital and labour are imperfect substitutes to each other, and skilled and unskilled labour are perfect complements. Production involves two complementary tasks, a simple one and a complex one. The complex task can be carried out by skilled workers only. Both types of workers can carry out the simple tasks but, usually, wages being higher for the complex task, only unskilled workers will accept the simple one. The intensive form of the production function is given by equation (2.2), where k and l are the technical coefficients, respectively $k = \frac{K}{Q_2}$; $l = min(u_2, s_2)$, with $u_2 = \frac{U_2}{Q_2}$ and $s_2 = \frac{S_2}{Q_2}$.

$$1 = Bk^{\beta}l^{1-\beta} \tag{2.2}$$

Both outputs are perfectly mobile internationally, and then their prices are set up in international markets. We choose the traditional good as the numeraire, so that its price is unity, the price of the manufacturing good being p. We start examining what happens when all three factors are mobile between sectors of the economy but internationally immobile, so that their prices are determined locally. In perfectly competitive markets, the marginal productivity of each factor equalises its price. In the traditional sector, as long as both types of labour are employed in this sector, wages are given by equations (2.3) and (2.4), where w_u denotes the wage of unskilled labour, and w_s denotes the wage of skilled labour.

$$w_u = A \tag{2.3}$$

$$\frac{w_s}{c} = A \tag{2.4}$$

In the capitalist sector, factor prices are given by equations (2.5) and (2.6), where ρ denotes the returns to capital.

$$\rho k = \beta p \tag{2.5}$$

$$(w_u + w_s)\, l = (1-\beta)p \tag{2.6}$$

Equilibrium implies the full employment of inputs. The total endowment of each factor equalises the global demand by the two sectors of the economy:

$$U = u_1 Q_1 + lQ_2 \tag{2.7}$$

$$S = s_1 Q_1 + lQ_2 \tag{2.8}$$

$$K = kQ_2 \tag{2.9}$$

The solution to this system is developed in appendix A.1. For both types of labour to be employed in the traditional sector, the following inequality must hold:

$$K\left(Bl\right)^{1/\beta} = K\left[\frac{\left(1-\beta\right)Bp}{\left(1+c\right)A}\right]^{1/\beta} < \min\left(U,S\right) \tag{2.10}$$

What happens when this inequality does not hold depends upon the respective sizes of the skilled and unskilled labour forces. If there are less skilled workers than unskilled workers $(S < U)$, there will be no skilled worker in the traditional sector, so that the skilled wage will no longer be given by equation (2.4). If there are more skilled workers than unskilled workers $(S > U)$, there will be no unskilled worker in the traditional sector, so that the unskilled wage will no longer be given by equation (2.3). Both corner solutions are developed in appendix A.2.

2.2.2 The North/South framework

Let us now add a second country, called North. Apart their endowments in capital and both types of labour, both countries are similar to each other. Every variable x for the South will correspond to the variable x^* for the North. The world factor endowments are given by the sum of North and South endowments, such that $\bar{U} = U + U^*$; $\bar{S} = S + S^*$ and $\bar{K} = K + K^*$. We assume the South to be a developing economy, amply endowed with unskilled labour and poorly endowed with skilled labour. Conversely, the North is a developed country, poorly endowed with unskilled labour and well endowed with skilled labour. The global capital stock, $\bar{K}$, is fully owned by the North, but some part of this stock may be invested in the South.

In this two-country economy, factors are immobile and goods are perfectly mobile without any transaction cost. Thus, there is a world market for each good and the local price equals the world price in both countries. As in the previous section, we normalise the price of the traditional good to unity, p being the price of the capitalist good.

In both countries, workers are endowed with preferences represented by a Cobb-Douglas utility function v, with $v(q_1, q_2) = q_1^{\gamma} q_2^{1-\gamma}$, where q_1 denotes the worker's consumption of the traditional good, q_2 denotes his consumption of the capitalist good, and γ is a constant between zero and unity. This utility function implies that every consumer devotes a share γ of his income for buying the traditional good and a share $1-\gamma$ for buying the capitalist good.

Aggregating over all consumers and equalising the world supply and the world demand, we get:

$$Q_1 + Q_1^* = \gamma \bar{I} \tag{2.11}$$

$$p\,(Q_2 + Q_2^*) = (1-\gamma)\bar{I} \tag{2.12}$$

where $\bar{I} = I + I^* = Q_1 + Q_1^* + p\,(Q_2 + Q_2^*)$ denotes the world income, $I = w_u U + w_s S + \rho K$ is the income generated in the South, and $I^* = w_u^* U^* + w_s^* S^* + \rho^* K^*$ is the income generated in the North. The Walras equality implies that we need to check one of these conditions only. The two conditions are equivalent to:

$$(1-\gamma)\,(Q_1 + Q_1^*) = \gamma p\,(Q_2 + Q_2^*) \tag{2.13}$$

It implies that, at equilibrium, the part of the income generated by the traditional sector and devoted to buy the capitalist good must equal the part of the income generated by the capitalist sector devoted to buy the traditional good.

2.3 Impact of an exogenous capital transfer

In this section, we start examining what happens when the whole capital stock, which is owned by the North, is also invested in the North. Then, we look at the changes induced by an exogenous transfer of capital from the North to the South.

2.3.1 Initial situation: the capital stock is fully invested in the North

At the initial stage, we assume the global stock of capital to be invested locally, so that the South has no capital $(K = 0)$. As a result, in the South, the capitalist sector is inactive and all workers are hired by the traditional sector. In each sector, production equals:

$$Q_1 = A(U + cS) \tag{2.14}$$

$$Q_2 = 0 \tag{2.15}$$

The wages of both types of workers are determined by the traditional sector only. Unskilled workers are paid $w_u = A$, while skilled workers are paid $w_s = cA$. Then, the global income earned by workers in the South equals:

$$I = (U + cS)\, A \tag{2.16}$$

In the North, the capital endowment $\left(K^* = \bar{K}\right)$ is large enough and unskilled labour is scarce enough for all the unskilled workers to be employed by the capitalist sector; the traditional sector employs skilled workers only. Then, the inequality:

$$U^* < \left[\frac{(1-\beta)\, Bp}{(1+c)A}\right]^{1/\beta} \bar{K} < S^* \tag{2.17}$$

is met. In each sector, production equals:

$$Q_1^* = Ac\,(S^* - U^*) \tag{2.18}$$

$$Q_2^* = B\left(\bar{K}\right)^{\beta} (U^*)^{1-\beta} \tag{2.19}$$

Unskilled workers[1] are paid $w_u^* = (1-\beta)\, Bp\left(\frac{\bar{K}}{U^*}\right)^{\beta} - cA$, while skilled workers are paid $w_s^* = cA$, and the returns to capital are $\rho^* = \beta Bp\left(\frac{U^*}{\bar{K}}\right)^{1-\beta}$. Then, the global income earned in the North equals:

$$I^* = Bp\left(\bar{K}\right)^{\beta} (U^*)^{1-\beta} + cA\,(S^* - U^*) \tag{2.20}$$

The world income equals:

$$\bar{I} = Bp\left(\bar{K}\right)^{\beta} (U^*)^{1-\beta} + A\left[U + c\left(\bar{S} - U^*\right)\right] \tag{2.21}$$

and the equilibrium condition (2.13) gives the world price of the capitalist good:

$$p = \frac{1-\gamma}{\gamma}\frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{(1-\gamma)}{\gamma}\frac{A\left[U + c\left(\bar{S} - U^*\right)\right]}{B\left[\left(\bar{K}\right)^{\beta}(U^*)^{1-\beta}\right]} \tag{2.22}$$

so that (2.17) becomes:

$$\frac{S^*}{U^*} > \theta^{\frac{1}{\beta}} > 1 \tag{2.23}$$

[1] As noted above, for simplifying matters, we are only looking at the case $w_u^* < w_s^*$, so that skilled workers do not take unskilled jobs in the capitalist sector. This situation implies that unskilled workers are not too scarce in the North. More precisely, after a straightforward calculation, we find that the following inequality must be met: $\frac{cU^*}{U+cS} > \frac{(1-\beta)(1-\gamma)}{1+\gamma-\beta+\beta\gamma}$.

where:

$$\theta = \frac{(1+c)}{(1-\beta)} \frac{\gamma}{(1-\gamma)} \frac{U^*}{U + c\bar{S} - cU^*} \left(\frac{S^*}{U^*}\right)^{\beta} \tag{2.24}$$

At this stage, capital and unskilled labour have an incentive to move. In the North, returns to capital are $\rho^* = \beta Bp \left(\frac{U^*}{K}\right)^{1-\beta}$. If a small quantity of capital were invested in the South, the returns to capital would be $\rho = \beta p k^{-1} = \beta Bp \left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1}$. As long as the inequality $U^* < \left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{1/\beta} K < S^*$ holds, the returns to capital are higher in the South than in the North ($\rho > \rho^*$), and then there is an incentive for capital to move from the North to the South. The wage of unskilled workers in the North is higher than the wage in the South: $(1-\beta)Bp \left(\frac{K^*}{U^*}\right)^{\beta} - cA > A$, so that if they were allowed to move with low enough migration costs, unskilled workers would move from the South to the North. Then, relaxing barriers to the international mobility of factors will generates capital flows from the North to the South and unskilled labour flows from the South to the North. In the next subsection, we focus on the first type of flow, looking at the impact of a capital transfer from the North to the South. Then, in section 2.4, we endogenise the factor flows in a world where factors ask for a mobility premium: return overseas must be higher than at home so that, at equilibrium, returns are not fully equalised. Looking at the impact of a change in mobility premia, we see how factor flows interact with each other.

2.3.2 Types of capital transfers from the North to the South

Let us now look at what happens when the North transfers some part of its capital to the South, say $K > 0$, so that the capital endowment in the North is $K^* = \bar{K} - K$. The type of equilibrium the economy can reach after this transfer depends upon its impact on the constraints faced by the industrial sector in both countries. Let us remind that, in the initial situation, unskilled labour is scarce in the North while skilled labour is scarce in the South. There may be three main cases, depending upon the size of the capital transfer and the relative scarcities of skilled labour in the South and unskilled labour in the North.

The first case happens when the transfer is small enough for the capitalist sector in the South not to be able to employ all the skilled workers, so that some of them are still working in the traditional sector; and for the capitalist sector to be still large enough in the North for

employing all the unskilled workers, so that the traditional sector employs skilled workers only. Then, the following constraints are met:

$$K < \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} \min(U,S) = \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} S \tag{2.25}$$

$$\left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} \min(U^*,S^*) = \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} U^* < \bar{K} - K \tag{2.26}$$

so that:

$$K < \min\left(\left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} S, \bar{K} - \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} U^*\right) \tag{2.27}$$

or equivalently:

$$\frac{U^*}{\bar{K}-K} < \left[\frac{(1-\beta)\,Bp}{(1+c)A}\right]^{\frac{1}{\beta}} < \frac{S}{K} \tag{2.28}$$

$$\Leftrightarrow \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta} < \left[\frac{(1-\beta)\,Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1} < \left(\frac{S}{K}\right)^{1-\beta} \tag{2.29}$$

The second case occurs when the North transfers a large part of its capital to the South, while the global stock of capital is abundant. In that case, a large investment from the North to the South leaves both countries with a large capital endowment. In both countries, the capitalist sector is important enough to drain all the scarce labour – skilled labour in the South and unskilled labour in the North – from the traditional sector, which only employs the abundant labour. The following inequalities hold:

$$K > \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} \min(U,S) = \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} S \tag{2.30}$$

$$\bar{K} - K > \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} \min(U^*,S^*) = \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} U^* \tag{2.31}$$

so that:

$$\left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} S < K < \bar{K} - \left[\frac{(1+c)A}{(1-\beta)\,Bp}\right]^{\frac{1}{\beta}} U^* \tag{2.32}$$

or equivalently:

$$\min\left(\frac{Q_2}{BK}, \frac{Q_2^*}{B\left(\bar{K}-K\right)}\right) < \left[\frac{(1-\beta)\,Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1} \tag{2.33}$$

The third case happens when the North transfers a large part of its capital to the South, while the global stock of capital is relatively small. In that case, a large investment of capital from the North to the South leaves each country with a small endowment of capital. In both countries, the capitalist sector is not important enough to be able to employ all

the scarce labour, so that this labour is still employed by the traditional sector. Then, the following inequalities hold:

$$K < \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} \min(U,S) = \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} S \tag{2.34}$$

$$\bar{K} - K < \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} \min(U^*,S^*) = \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} U^* \tag{2.35}$$

or equivalently:

$$\bar{K} - \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} U^* < K < \left[\frac{(1+c)A}{(1-\beta)Bp}\right]^{\frac{1}{\beta}} S \tag{2.36}$$

2.3.3 Small exogenous investment to the South

Let us look at what happens when the North transfers a small part of its capital to the South, so that the condition (2.27) is met.

In the South, production in each sector equals:

$$Q_1 = A\left\{U + cS - (1+c)K\left[\frac{B(1-\beta)p}{(1+c)A}\right]^{\frac{1}{\beta}}\right\} \tag{2.37}$$

$$Q_2 = KB^{\frac{1}{\beta}}\left[\frac{(1-\beta)p}{(1+c)A}\right]^{\frac{1}{\beta}-1} \tag{2.38}$$

Because the traditional sector still employs both skilled and unskilled workers, both wages are determined by the traditional sector only, so that $w_u = A$ and $w_s = cA$. The returns to capital are $\rho = \beta(Bp)^{\frac{1}{\beta}}\left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1}$. Then, the global income generated in the South equals:

$$I = (U+cS)A + \beta(Bp)^{\frac{1}{\beta}}\left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1} K \tag{2.39}$$

In the North, productions equal:

$$Q_1^* = Ac(S^* - U^*) \tag{2.40}$$

$$Q_2^* = B\left(\bar{K} - K\right)^{\beta}(U^*)^{1-\beta} \tag{2.41}$$

Note that, using the expressions of Q_2 and Q_2^*, the small investment condition (2.27) may be written as:

$$\frac{Q_2^*}{\bar{K}-K} < \frac{Q_2}{K} < B\left(\frac{S}{K}\right)^{1-\beta} \tag{2.42}$$

The condition (2.42) holds as long as the average productivity of capital is higher in the South than in the North. Returns being constant, the same inequality holds for marginal productivity and returns.

Unskilled workers are paid $w_u^* = (1-\beta)Bp\left(\frac{\bar{K}-K}{U^*}\right)^{\beta} - cA$, while skilled workers are paid $w_s^* = cA$. The returns to capital are $\rho^* = \beta Bp\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}$. Then, the global income generated in the North equals:

$$I^* = cA\left(S^* - U^*\right) + Bp\left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{2.43}$$

The world income equals:

$$\bar{I} = A\left[U + c\left(\bar{S}-U^*\right)\right] + \beta\left(Bp\right)^{\frac{1}{\beta}}\left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1}K + Bp\left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{2.44}$$

Noting that $Q_1 = A\left(U+cS\right) - \left(1-\beta\right)pQ_2$, the equilibrium condition (2.13) becomes:

$$\left(1-\gamma\right)\left[A\left(U+cS\right)+Q_1^*\right] = \left(1-\beta+\beta\gamma\right)pQ_2 + \gamma pQ_2^* \tag{2.45}$$

$$\begin{aligned}\Leftrightarrow \left(1-\gamma\right)A\left[U+c\left(\bar{S}-U^*\right)\right] &= \left(1-\beta+\beta\gamma\right)\left(Bp\right)^{\frac{1}{\beta}}\left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1}K \\ &\quad + \gamma Bp\left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta}\end{aligned} \tag{2.46}$$

This equation has no explicit solution. However, as the left hand side is a positive constant and the right hand side increases from zero to infinity when p increases from zero to infinity, there is always an equilibrium price and this price is unique.

The derivatives of prices and quantities with respect to K are calculated in appendix A.3. A marginal increase in the amount of capital transferred to the South decreases the industrial production in the North ($dQ_2^*/dK < 0$) and increases it in the South ($dQ_2/dK > 0$). However, as long as the small investment condition holds (2.27), the industrial sector faces a shortage of unskilled labour in the North but not in the South. Then, the industrial production is more efficient in the South; the increase in the South is larger than the decrease in the North ($dQ_2/dK + dQ_2^*/dK > 0$), and the global production of the industrial good increases. The industrial good is relatively more abundant so that its price decreases ($dp/dK < 0$). The traditional production does not change in the North ($dQ_1^*/dK = 0$) as the allocation of the labour force does not change; while it decreases in the South ($dQ_1/dK < 0$) as the capital transferred attracts workers previously working in the traditional sector. Then, the global production of the traditional good decreases. With a lower stock of capital in the North, the industrial sector is less constrained by the scarcity of unskilled labour and then

its returns increase ($d\rho^*/dK > 0$). At the same time, the wages in the South do not change as some of the scarce labour still works in the traditional sector. The skilled wage in the North does not change, as the sectoral allocation of labour remains unchanged. As for unskilled workers in the North, their wage decreases ($dw_u^*/dK < 0$), the departure of capital lowering their ability to extract a scarcity rent.

Small exogenous transfer of unskilled workers from the South to the North

An equivalent industrial strategy is to transfer a small amount of unskilled workers from the South to the North, capital being immobile ($K = 0$). As this is equivalent to a transfer of capital, this alternative factor allocation should identically impact global outputs and prices.

If $dU^* > 0$, unskilled migrants move from the South to the North, the unskilled labour force decreases in the South from U to $U - dU = U - dU^*$; in the North, it increases from U^* to $U^* + dU^*$. A small transfer of unskilled labour implies that the following condition is met:

$$U^* + dU^* < \left[\frac{(1-\beta)\,Bp}{(1+c)A}\right]^{\frac{1}{\beta}} \bar{K} < S^* \tag{2.47}$$

so that the unskilled labour is still abundant in the South and scarce in the North. Thus in the North, unskilled labour is still scarce enough compared to capital to be fully employed by the industrial sector.

Because the whole capital is still located in the North, unskilled labour is still scarce in the North and skilled labour is still scarce in the South, the equilibrium is still given by section 2.3.1. The impact of a transfer of unskilled workers may be found differentiating prices, quantities and factor returns with respect to U^*. These derivatives are presented in appendix A.4. A marginal transfer of unskilled labour decreases the production of the traditional sector in the South ($dQ_1/dU^* = -dQ_1/dU < 0$), to the benefit of the industrial sector in the North ($dQ_2^*/dU^* > 0$), which is now able to use more labour. But in the North, using more unskilled labour implies using more skilled labour coming from the traditional sector where the output drops ($dQ_1^*/dU^* < 0$). As the production of the industrial sector increases, the world price of the manufactured good decreases ($dp/dU^* < 0$). A larger stock of unskilled labour in the North lessens the unskilled workers ability to extract a scarcity rent, so that their wage decreases ($dw_u^*/dU^* < 0$). The returns to capital decrease ($d\rho^*/dU^* < 0$) as the industrial sector is less compelled by the scarcity of unskilled labour.

Then, compared to a transfer of capital, migration of unskilled workers has the same global effects: in both cases, global production increases in the capitalist sector and decreases in

the traditional sector, leading to a lower price of the manufactured good. The difference comes from the location of production. With a North-South capital transfer, the increase in global production of the industrial sector is located in the South, while production in the North decreases. Conversely, with a South-North migration of unskilled workers, the increase in global production of the industrial sector is located in the North, this industry being still absent in the South.

2.3.4 Large exogenous investment to the South when capital is worldly abundant

We now look at what happens when the North transfers a large part of its capital to the South, while the global stock of capital is abundant, so that the condition (2.32) is met.

The outputs of each sector in the South equal:

$$Q_1 = A\left(U - S\right) \tag{2.48}$$

$$Q_2 = BK^{\beta}S^{1-\beta} \tag{2.49}$$

Skilled workers are employed by the industrial sector only. The wage of skilled workers is $w_s = (1-\beta)Bp\left(\frac{K}{S}\right)^{\beta} - A$, the wage of unskilled workers is $w_u = A$, the returns to capital are $\rho = \beta Bp\left(\frac{S}{K}\right)^{1-\beta}$. The income generated in the South equals:

$$I = A\left(U - S\right) + BpK^{\beta}S^{1-\beta} \tag{2.50}$$

In the North, sectoral outputs are given by:

$$Q_1^* = Ac\left(S^* - U^*\right) \tag{2.51}$$

$$Q_2^* = B\left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{2.52}$$

The wages are $w_s^* = cA$ and $w_u^* = (1-\beta)Bp\left(\frac{\bar{K}-K}{U^*}\right)^{\beta} - cA$, the returns to capital are $\rho^* = \beta Bp\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}$. The income generated in the North equals:

$$I^* = cA\left(S^* - U^*\right) + Bp\left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{2.53}$$

The world income equals:

$$\bar{I} = A\left(U - S\right) + BpK^{\beta}S^{1-\beta} + cA\left(S^* - U^*\right) + Bp\left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{2.54}$$

The equilibrium condition (2.13) has an explicit solution, the world price of the industrial good being:

$$p = \frac{1-\gamma}{\gamma}\frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{1-\gamma}{\gamma}\frac{A\left(U - S + cS^* - cU^*\right)}{B\left[K^{\beta}S^{1-\beta} + \left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta}\right]} \tag{2.55}$$

Introducing the expression of the price in condition (2.32), we find a condition on the capital endowments in each country:

$$\left[\phi\left(\frac{\widehat{Q}}{U^*} - 1\right)\left(\frac{U^*}{S}\right)^{1-\beta}\right]^{-1/\beta} < \frac{\bar{K}}{K} - 1 < \left[\phi\left(\frac{\widehat{Q}}{S} - 1\right)\left(\frac{S}{U^*}\right)^{1-\beta}\right]^{1/\beta} \tag{2.56}$$

where $\phi = \frac{(1-\beta)(1-\gamma)}{(1+c)\gamma}$ and $\widehat{Q} = U - S + c\left(S^* - U^*\right)$.

Derivatives with respect to K are presented in appendix A.5. When capital is worldly abundant, a marginal increase in the large amount of capital transferred from the North to the South increases the production of the industrial sector in the South ($dQ_2/dK > 0$) to the detriment of the North ($dQ_2^*/dK < 0$). For a transfer of capital from the North to the South to make sense, returns to capital must be higher in the South, $\rho > \rho*$, and then $\frac{U^*}{\bar{K}-K} < \frac{S}{K}$ so that, compared to the local capital stock, unskilled labour is more scarce in the North than skilled labour in the South. Thus, the industrial sector is less constrained by the scarce labour in the South than in the North. As a result, the industrial production is more efficient in the South and the increase in production in the South is larger than the decrease in the North. Then, the world industrial output increases ($dQ_2/dK + dQ_2^*/dK > 0$), the production of the traditional sector in both countries remaining unchanged ($dQ_1/dK = dQ_1^*/dK = 0$). The industrial good becomes more abundant and its price drops ($dp/dK < 0$). The wages of the abundant workers – unskilled workers in the South and skilled workers in the North – are not impacted by a marginal transfer of capital. The wage of skilled workers in the South rises ($dw_s/dK > 0$) as there is more demand by the capitalist sector, so that they are in a better position to extract a scarcity rent. The wage of unskilled workers in the North drops ($dw_u^*/dK < 0$) as the outflow of capital reduces their ability to extract a scarcity rent. As capital flows to the South, its returns drop there ($d\rho/dK < 0$).

2.3.5 Large exogenous investment to the South when capital is worldly scarce

We finally look at what happens when the North transfers a large part of its capital to the South, the global stock of capital being relatively small, so that the condition (2.36) is met.

In the South, outputs in each sector are given by:

$$Q_1 = A\left\{U + cS - (1+c)\,K\left[\frac{B\,(1-\beta)\,p}{A(1+c)}\right]^{\frac{1}{\beta}}\right\} \tag{2.57}$$

$$Q_2 = KB^{\frac{1}{\beta}}\left[\frac{(1-\beta)\,p}{(1+c)A}\right]^{\frac{1}{\beta}-1} \tag{2.58}$$

while in the North, they are:

$$Q_1^* = A\left\{U^* + cS^* - (1+c)\left(\bar{K}-K\right)\left[\frac{B\,(1-\beta)\,p}{A(1+c)}\right]^{\frac{1}{\beta}}\right\} \tag{2.59}$$

$$Q_2^* = \left(\bar{K}-K\right)B^{\frac{1}{\beta}}\left[\frac{(1-\beta)\,p}{(1+c)A}\right]^{\frac{1}{\beta}-1} \tag{2.60}$$

so that the world production is:

$$\begin{aligned} Q_1 + Q_1^* &= A\left\{\bar{U} + c\bar{S} - (1+c)\,\bar{K}\left[\frac{B\,(1-\beta)\,p}{A(1+c)}\right]^{\frac{1}{\beta}}\right\} \\ &= A(\bar{U} + c\bar{S}) - (1-\beta)\,p\,(Q_2 + Q_2^*) \end{aligned} \tag{2.61}$$

$$Q_2 + Q_2^* = \bar{K}B^{\frac{1}{\beta}}\left[\frac{(1-\beta)\,p}{(1+c)A}\right]^{\frac{1}{\beta}-1} \tag{2.62}$$

Then, the equilibrium condition (2.13) can be written:

$$\begin{aligned} p\,(Q_2 + Q_2^*) &= \frac{1-\gamma}{\gamma}\,(Q_1 + Q_1^*) \\ &= \frac{1-\gamma}{\gamma}\left[A\left(\bar{U} + c\bar{S}\right) - (1-\beta)\,p\,(Q_2 + Q_2^*)\right] \end{aligned} \tag{2.63}$$

so that:

$$\begin{aligned} p\,(Q_2 + Q_2^*) &= \bar{K}\,(Bp)^{\frac{1}{\beta}}\left[\frac{(1-\beta)}{(1+c)A}\right]^{\frac{1}{\beta}-1} \\ &= \left(\frac{1-\gamma}{1-\beta+\gamma\beta}\right)A(\bar{U} + c\bar{S}) \end{aligned} \tag{2.64}$$

hence the equilibrium value of the price is:

$$p = \frac{A}{B}\left(\frac{1-\beta}{1+c}\right)^{\beta-1}\left(\frac{1-\gamma}{1-\beta+\gamma\beta}\right)^{\beta}\left(\frac{\bar{U} + c\bar{S}}{\bar{K}}\right)^{\beta} \tag{2.65}$$

Introducing the equilibrium price in the condition (2.36), and after a straightforward calculation, this condition becomes:

$$\frac{\widehat{Q} + (1+c)\,S}{\bar{U} + c\bar{S}} + \frac{U^*}{\phi\left(\bar{U} + c\bar{S}\right)} < \frac{K}{\bar{K}} < \left(1 + c + \frac{1}{\phi}\right)\frac{S}{\bar{U} + c\bar{S}} \tag{2.66}$$

where, as above, $\phi = \frac{(1-\beta)(1-\gamma)}{(1+c)\gamma}$ and $\widehat{Q} = U - S + c\,(S^* - U^*)$.

In both countries, both types of workers are employed in both sectors. Then, the wages are $w_u = w_u^* = A$ and $w_s = w_s^* = cA$, and the returns to capital are $\rho = \rho^* = \beta\,(Bp)^{\frac{1}{\beta}} \left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1}$.

As long as the transfer of capital form the North to the South is large enough for Northern unskilled labour to be employed in both sectors, the price of the manufacturing good does not depend upon the allocation of capital. Therefore, a marginal change in the allocation of capital has no impact on the price ($dp/dK = 0$), the world production ($dQ_1/dK + dQ_1^*/dK = 0$ and $dQ_2/dK + dQ_2^*/dK = 0$), and factor returns. Only the international allocation of production changes: a higher amount of capital invested in the South implies a transfer of production of the manufacturing good from the North to the South ($dQ_2/dK = -dQ_2^*/dK > 0$), with the opposite effect for the traditional good ($dQ_1/dK = -dQ_1^*/dK < 0$).

2.4 International factor mobility

In this section, we look at what happens when factors are imperfectly mobile internationally. For accepting to invest in the South, capitalists must get higher returns than in the North, which may be interpreted as an exogenous risk premium, $\tau > 0$. Then:

$$K > 0 \;\Rightarrow\; \rho = \tau + \rho^* \tag{2.67}$$

Workers are internationally mobile. The initial populations of skilled and unskilled labour in the South and in the North are given by S_0, U_0, S_0^* and U_0^*. After migration, populations are given by S , U, S^* and U^*. Remember that the North is well endowed with skilled labour but not with unskilled labour, and the South is well endowed with unskilled labour but not with skilled labour. Therefore, we will be interested in movements of skilled workers from the North to the South, and of unskilled workers from the South to the North. As there are migration costs, for skilled workers to accept migrating from the North to the South, they must get a higher wage in the South, the difference needed for covering migration costs being $\mu_s > 0$. Then:

$$S > S_0 \;\Rightarrow\; w_s = \mu_s + w_s^* \tag{2.68}$$

Similarly, for unskilled workers to accept migrating from the South to the North, they must get a higher wage in the North, the difference needed for covering migration costs being $\mu_u > 0$. Then:

$$U^* > U_0^* \Rightarrow w_u^* = \mu_u + w_u \tag{2.69}$$

We study factors mobility for two equilibria. Each one results from a specific capital allocation between the two countries. The first equilibrium reflects the case in which a small share of the capital stock is invested in the South[2]. The second equilibrium corresponds to a situation in which capital is worldly abundant and invested in both countries. Note that when capital is largely invested in both countries but worldly scarce, case initially developed in section 2.3.5, factor returns being the same in both countries, factors have no incentive to move. Thus, we do not develop further this last case.

2.4.1 Small investment to the South

The equilibrium

We look at what happens when, at equilibrium, a small share of the capital stock is invested in the South. Because of the small investment condition (2.45), the North is still abundant in capital so its industrial sector is compelled by unskilled labour. In the South, the industrial sector is compelled by capital and skilled labour. Equilibrium productions and factor returns have been determined herein above, in section 2.3.3. The allocation of capital, skilled and unskilled labour is now endogenous.

Capital returns in the North and the South are respectively $\rho^* = \beta Bp\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}$ and $\rho = \beta\left(Bp\right)^{\frac{1}{\beta}}\left[\frac{1-\beta}{(1+c)A}\right]^{\frac{1}{\beta}-1}$. Let us denote $p\left(K,U^*\right)$ the price of the manufacturing good when the quantity of capital invested in the South is K and there are U^* unskilled workers employed in the North. For capital to be invested in the South, the risk premium must be low enough:

$$\tau \leq \rho - \rho^* = \beta Bp\left(0,U_0^*\right)\left\{\left[\frac{\left(1-\beta\right)Bp\left(0,U_0^*\right)}{(1+c)A}\right]^{\frac{1}{\beta}-1} - \left(\frac{U_0^*}{\bar{K}}\right)^{1-\beta}\right\} \tag{2.70}$$

where the right hand side is the difference in returns to capital when the whole capital stock stays in the North and there is no migration of workers. If this equality is not met, there is

[2]This equilibrium gives the same results than the equilibrium in which the capital stock is fully invested in the North ($K = 0$ and $K^* > 0$).

no incentive for movement of capital. If it is met, some capital flows from the North to the South. At equilibrium, the condition (2.67) is met, and may be written as:

$$\tau = \rho - \rho^* = \beta Bp\left(K, U^*\right)\left\{\left[\frac{(1-\beta)\,Bp\left(K, U^*\right)}{(1+c)A}\right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}\right\} \tag{2.71}$$

so that:

$$K = \bar{K} - U^*\left\{\left[\frac{(1+c)A}{(1-\beta)\,Bp\left(K, U^*\right)}\right]^{\frac{1}{\beta}} - \left[\frac{\beta Bp\left(K, U^*\right)}{\tau}\right]^{\frac{1}{1-\beta}}\right\} \tag{2.72}$$

The wages of skilled workers in the South and in the North are $w_s = w_s^* = cA$. They are identical in both countries and then skilled workers have no incentive to move: $S = S_0$ and $S^* = S_0^*$. The wages of unskilled workers in the South and in the North are $w_u = A$ and $w_u^* = (1-\beta)Bp\left(K, U^*\right)\left(\frac{\bar{K}-K}{U^*}\right)^{\beta} - cA$. For unskilled workers to move, the migration cost must be low enough:

$$\mu_u < w_u^* - w_u = (1-\beta)Bp\left(0, U_0^*\right)\left(\frac{\bar{K}}{U_0^*}\right)^{\beta} - (1+c)\,A \tag{2.73}$$

where the right hand side is the wage differential when the whole capital stock stays in the North and there is no migration of workers. If this equality is not met, there is no incentive for migration of unskilled workers. If it is met, some unskilled workers migrate from the South to the North, and at equilibrium the condition (2.69) is met, so that:

$$\mu_u = w_u - w_u^* = (1-\beta)Bp\left(K, U^*\right)\left(\frac{\bar{K}-K}{U^*}\right)^{\beta} - (1+c)\,A \tag{2.74}$$

which leads to:

$$U^* = \left[\frac{(1-\beta)Bp\left(K, U^*\right)}{\mu_u + (1+c)\,A}\right]^{\frac{1}{\beta}}\left(\bar{K}-K\right) \tag{2.75}$$

Impact of a marginal increase in the risk premium and the unskilled migration cost (τ, μ_u) on the factor allocation between countries

At equilibrium, we look at what happens to the factor allocation between countries when τ or μ_u varies. Calculations are presented in appendix A.6 and lead to the following results:

	$\frac{d\tau}{\tau}$	$\frac{d\mu_u}{\mu_u+(1+c)A}$
$\frac{dK}{K}$	-	+
$\frac{dU^*}{U^*}$	+	-

Table 2.1.: Impact of a variation of τ and μ_u on the factor allocation between countries (small investment case).

A marginal increase in the risk premium, τ, implies that, for accepting to invest in the South, capitalists must get a higher South-North differential in returns to capital ($\rho^* - \rho$ increases). Thus, more capital stays in the North, and the capital stock decreases in the South ($\frac{dK}{K} < 0$) to the benefit of the North. A larger stock of capital staying in the North implies a higher demand for labour by the industrial sector. Unskilled labour being scarce in the North, this higher demand increases the wages of unskilled workers in the North, attracting new unskilled workers from the South ($\frac{dU^*}{U^*} > 0$).

A marginal increase in the migration cost for unskilled workers, μ_u, implies that Southern unskilled workers have less incentives to go North. Unskilled labour is retained in the South, and the stock of unskilled labour increases in the South to the detriment of the North ($\frac{dU^*}{U^*} < 0$). In the North, the lower supply of unskilled Southern workers implies that unskilled workers must get a higher wage, depressing the returns to capital. Investing in the South becomes a more attractive option and then the capital stock increases in the South ($\frac{dK}{K} > 0$) to the detriment of the North.

Finally, when the industrial sector is large in the North and small in the South, changes in the capital and unskilled labour allocation between countries have no consequence on the allocation of skilled and unskilled labour across sectors. Thus, the wages of skilled workers remain unchanged ($w_s = w_s^* = cA$), thereby skilled workers have no incentive to migrate ($dS = dS^* = 0$).

2.4.2 Large investment to the South when capital is worldly abundant

The equilibrium

We now look at what happens when, at equilibrium, a large share of capital is invested in the South, capital being worldly abundant ($K > 0$ and $K^* > 0$). Because of the large investment condition (2.56), when capital is worldly abundant, the North is still abundant in capital so that its industrial sector is compelled by unskilled labour. In the South, the

industrial sector is compelled by skilled labour. Equilibrium productions and factor returns have been determined herein above, in section 2.3.4.

At an interior equilibrium, capital, skilled and unskilled labour have no incentive to move. Then, the equilibrium conditions (2.67), (2.68) and (2.69) are met. Using the results from section 2.3.4, these equilibrium conditions may be written as:

$$\tau = \rho - \rho^* = \beta B p \left[\left(\frac{S}{K} \right)^{1-\beta} - \left(\frac{U^*}{\bar{K} - K} \right)^{1-\beta} \right] \tag{2.76}$$

$$\mu_s = w_s - w_s^* = (1-\beta)\, B p \left(\frac{K}{S} \right)^{\beta} - (1+c)\, A \tag{2.77}$$

$$\mu_u = w_u^* - w_u = (1-\beta) B p \left(\frac{\bar{K} - K}{U^*} \right)^{\beta} - (1+c)\, A \tag{2.78}$$

where the world price of the industrial good is:

$$p = \frac{1-\gamma}{\gamma} \frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{1-\gamma}{\gamma} \frac{A \left[\bar{U} + c\bar{S} - (1+c)\,(U^* + S) \right]}{B \left[K^{\beta} S^{1-\beta} + \left(\bar{K} - K \right)^{\beta} (U^*)^{1-\beta} \right]} \tag{2.79}$$

These four equations determine the equilibrium values of K, S, U^* and p.

Impact of a marginal increase in the risk premium and the migration costs (τ, μ_s, μ_u) on the factor allocation between scountries

At equilibrium, we look at what happens to the factor allocation between countries when τ, μ_s or μ_u varies. Calculations are presented in appendix A.7 and lead to the following results:

	$\frac{d\tau}{\tau}$	$\frac{d\mu_u}{\mu_u + (1+c)A}$
$\frac{dK}{K}$	-	+
$\frac{dS}{S}$	-	+
$\frac{dU^*}{U^*}$	+	-

Table 2.2.: Impact of a variation of τ and μ_u on the factor allocation between countries (large investment case).

At equilibrium, a marginal increase in the risk premium, τ, implies that capitalists expect a higher return in the North than what they can get in the South: $\tau > \rho - \rho^*$. More capital stays in the North to the detriment of the South ($\frac{dK}{K} < 0$). The industrial sector faces a shortage of unskilled labour in the North, and a shortage of skilled labour in the South. Thus, when the capitalist sector gets larger in the North and smaller in the South, the demand for unskilled labour increases in the North, and the demand for skilled labour

decreases in the South. Both unskilled and skilled labour stocks increase in the North to the detriment of the South ($\frac{dU^*}{U^*} > 0$ and $\frac{dS}{S} < 0$).

A marginal increase in the migration cost for unskilled workers, μ_u, implies that the cost to go North becomes higher for unskilled workers: $\mu_u > w_u^* - w_u$. The stock of unskilled labour increases in the South to the detriment of the North ($\frac{dU^*}{U^*} < 0$). As the industrial sector is compelled by unskilled labour in the North, the sector gets smaller when the stock of unskilled labour decreases, and the demand for capital drops. The industrial sector gets larger in the South, but it is compelled by skilled labour. Thus, we expect the demand for skilled labour to increase in the South. Both skilled labour and capital stocks increase in the South to the detriment of the North ($\frac{dS}{S} > 0$ and $\frac{dK}{K} > 0$).

A marginal increase in the migration cost for skilled workers, μ_s, implies that the cost to go South becomes higher for skilled workers: $\mu_s > w_s - w_s^*$. Although the signs of $\frac{dK}{K}$, $\frac{dS}{S}$ and $\frac{dU^*}{U^*}$ are undetermined, we expect the following results: The stock of skilled labour should decrease in the South to the benefit of the North. In the South, the industrial sector is compelled by skilled labour, so the sector should get smaller when the stock of skilled labour decreases, and the demand for capital should drop. In the North, the industrial sector is compelled by unskilled labour, so the demand for unskilled labour should increase. As a result, we expect both capital and unskilled labour stocks to increase in the North to the detriment of the South.

2.5 Conclusion

The main aim of this work is to reconcile the standard trade theory with available empirical evidence on the link between FDI and international migration flows, particularly for flows between developed and developing countries. Our approach is quite unique in this literature as it allows us to consider the endogenous links existing between factor flows. Our main result is a relation of substitution between capital and unskilled labour flows jointly with a relation of complementarity between capital and skilled labour flows. This result corroborates studies showing that skilled immigrants positively impact inward FDI, and that unskilled immigrants negatively impact outward FDI toward their origin countries (El Yaman et al., 2007; Kugler and Rapoport, 2007). Our analysis also corroborates empirical studies showing that migrants strengthen bilateral economic relations between their home and host countries (Docquier and Lodigiani, 2010; Aubry et al., 2012). More generally, our chapter completes the theoretical analysis of the FDI-migration nexus, so far resting upon the network analysis to explain how migration fosters FDI.

With this theoretical exercise, we corroborate empirical papers showing that factor flows are highly interdependent and thereby that FDI and migration policy regimes should be thought together. In particular we sustain the following policy recommendations: (i) Developed economies protecting their industries, may want to progressively increase immigration of low skilled workers to allow their industries to remain internationally competitive. On the other hand, our results imply that developed countries could, to some extent, regulate the volume of their low skilled immigration, implementing pro-active investment/aid policies toward the migrant's origin countries. See the work of Hansen and Rand (2006) and Berthélemy et al. (2009) on the latter issue. (ii) Developing economies attracting FDI with an objective of economic development, may want to consider immigration policies supporting the arrival of high skilled workers in the short run, to meet the skilled labour demand of capitalist firms. In addition, developing countries may want to invest in education to increase their stock of human capital in the long run. On the other hand, our results imply that those countries could limit their emigration of low skilled workers by attracting multinational enterprises having a preference for native workers.

Finally, our study does not consider the case in which native and foreign workers are imperfect substitutes for firms, though it may be relevant for policy recommendations. On that issue, see the work of Peri and Sparber (2009) and Ottaviano et al. (2013).

3

FDI and migration of skilled workers toward developing countries: Firm-level evidence from Sub-Saharan Africa

This chapter has been written in collaboration with Rezart HOXHAJ and Adnan SERIC.

3.1 Introduction

Increasing global interaction between developed and developing economies has spurred a number of studies on the links between international factor flows. Most of these studies investigate the complementarity/substitutability between FDI from developed to developing countries and migration flows in the reverse direction. Yet, FDI toward southern countries also generates inflows of foreign skilled workers, a potentially crucial ingredient for future economic performance. In 2010, North-South migration represented 3% of international migration[1], thus about 7 million of people from developed countries were living in developing countries (Laczko and Brian, 2013). Although they represent a marginal part of international migration, these migrants are mainly skilled workers and play a key role in the economic and business development of their host country, by transferring knowledge and managing technological content. To the best of our knowledge, the second chapter of this thesis is the first theoretical contribution showing that FDI can flow toward developing economies along with skilled workers. Let us remind the mechanism: when capital flows from northern to southern countries in search of a higher remuneration, it generates north-south skilled migration when the recipient country of the investment lacks skilled labour. Thus, capital flows and skilled migration are complements.

The mechanism underlying this relation of complementarity is twofold. First, capital intensive companies implement technologies making use of capital and both unskilled and

[1]North-South migration represented 3% of international migration in 2010, following the definition of the North and the South given by the World Bank, which classifies countries according to their income level (GNI/capita).

skilled labour[2]. Therefore, when foreign enterprises establish in a country which lacks skilled labour, they strengthen the demand for skilled workers on the local labour market. The increase in demand may cause the return of skilled migrants from abroad or attract young professionals from developed countries in search of new opportunities (Laczko and Brian, 2013). Second, foreign firms, especially vertically integrated multinational enterprises (MNEs), use skilled worker transfers to control and coordinate their head-quarter operations with their subsidiary operations and ensure tacit knowledge transfers (Bonache et al., 2001). Thus, MNEs may generate skilled worker transfers. Usually, an expatriate is either a high skilled technician or a manager endowed with firm specific organisational skills (Tsang, 1999; Kogut and Zander, 2003). Intra-firm mobility is a growing phenomenon. In 2011, 47% of MNEs reported an increase in international assignments over the previous year; 62% of concerned workers spending between one and three years abroad (Brazier, 2012).

In this chapter, we aim to better understand the complementarity between capital flows and skilled labour flows. We are especially interested in Sub-Saharan Africa where skilled workers are likely to be a scarce resource (Ratha et al., 2011). In addition, the region has been attracting an increasing amount of skilled workers and FDI over the last decades. The share of migrants with tertiary education located in SSA countries increased from 3.24% in 1990 to 4.78% in 2000 (Artuc et al., 2015)[3]. Although no data is available after 2000, Laczko and Appave (2013) emphasise that North–South migration is increasing and that this migration is likely to be skilled. Meanwhile, the brain drain phenomenon has become increasingly relevant for the area. The database proposed by Brücker et al. (2013) indicates that the emigration of highly educated Sub-Saharan Africans increased from 10% in 1990, to 20% in 2000 and 24% in 2010[4]. On the other hand, the stock of inward FDI in Sub-Saharan Africa increased about 987% between 1990 and 2010 (36,904 million of US dollars in 1990; 108,678 million in 2000 and 401,257 million in 2010)[5].

The correlation between the share of educated migrants and the stock of inward FDI in SSA countries is about 19.93% for the year 1990 and about 34.09% for 2000. On the contrary, the correlation between the skilled emigration rate and the stock of inward FDI is about -11.91% for the year 1990, about -13.32% for 2000 and about -14.23% for 2010. These correlations suggest that further analysis of the relation existing between capital and skilled labour flows to and from SSA countries is needed.

[2]The complementarity between skilled and unskilled workers has been evidenced for South Africa by Behar (2010). The complementarity between capital and skilled labour has been evidenced by Djiofack et al. (2014) for the Cameroonian economy.
[3]Artuc et al. (2015) propose an original database of bilateral migration stocks by age of entry and educational attainment in 2000 and 1990.
[4]Proportion of migrants over the pre-migration population.
[5]Data are in US dollars at current prices and current exchange rates, and come from the database of the United Nations Conference on Trade and Development on inward foreign direct investment stocks.

In the present chapter, we investigate the determinants of the employment of foreign skilled workers by firms operating in Sub-Saharan Africa. We use firm-level data collected through the Africa Investor Survey 2010 of the United Nations Industrial Development Organization, across 19 SSA countries. This database presents a set of domestic and foreign firms. The sample includes firms operating in the three main sectors of the economy (agricultural, manufacturing and tertiary sector), with a description of their labour force composition in terms of skills (low, medium, and high skilled workers) and origin (native and foreign workers)[6].

In our study, we find support for complementarity between FDI and skilled migration toward SSA countries. It implies that foreign firms increase the flow of human capital toward their investment destination countries by attracting foreign skilled workers. Our results also indicate that the lack of skilled labour in the destination country induces firms to employ more foreign workers. We find that, over time, foreign firms tend to favour native over foreign skilled workers, in countries more abundant with skilled labour. This result suggests that a replacement of foreigners by natives takes place only when foreign firms find the appropriate skills on the local labour market.

In addition, firms aiming to serve the domestic market demand more native skilled workers. It suggests that market-oriented firms exploit the capabilities of natives in managing local environment issues, and their knowledge of the language and consumer tastes. We also find a lower usage of foreign skilled workers by foreign firms engaged in joint-venture partnerships with local firms, as compared to majority owned foreign firms. This result suggests that partner firms share the right to appoint their own key personnel in high managerial and control positions. In joint-ventures, foreign firms have less discretion to appoint their own workers in top positions. Finally, destination country characteristics can determine the easiness and the willingness of foreign workers to migrate toward SSA countries. In particular, we find that an efficient working regulation and a loosen immigration policy regime have a positive effect on foreign skilled worker employment.

The contribution to the literature of this chapter is twofold. Firstly, we provide evidence on the determinants of skilled migration toward less developed countries, contrarily to the bulk of existing literature which has focused on the opposite south-north direction. Secondly, we shed light on the complementarity between FDI and migration using a firm-level analysis in an area of the world, SSA countries, on which only few contributions exist. Our firm-level approach allows us to exploit the high degree of heterogeneity of firms in their employment decisions.

[6]For more information related to the Africa Investor Survey 2010, see the UNIDO Africa Investor Report 2011, *Towards evidence-based investment promotion strategies* s(2012).

The rest of the chapter is organised as follows. In section 3.2 we better position our work in the economic and the management literature. In section 3.3 we present the data, especially the UNIDO Africa Investor Survey 2010, and some descriptive statistics. In section 3.4 we present our econometric model and the variables of interest. In sections 3.5 and 3.6 we present our main results and some robustness checks. Section 3.7 concludes.

3.2 Foreign skilled workers and capital intensity

This work contributes to the economic literature analysing the FDI-migration nexus. At first, researchers have been studying the impact of migration on FDI. Most empirical studies emphasise that migration networks spread information between their origin and their host countries, which strengthens bilateral economic relations (Rauch, 2001; Dolman, 2008; Docquier and Lodigiani, 2010; Beine et al., 2011a; Aubry et al., 2012). In addition, skilled migration toward developing countries can contribute to improve the quality of FDI inflows toward those countries. As evidenced by Noorbakhsh et al. (2001), the level of human capital in the FDI recipient country is an important determinant of FDI. The authors find that a significant level of human capital allows to raise the volume but also the quality of inward FDI (by directing FDI toward high value-added industries). The complementarity between capital and skilled labour is evidenced, among others, by Djiofack et al. (2014) who show for the Cameroonian economy that skilled emigration has a negative impact on productivity. Thus, skilled immigration could alleviate skills constraints faced by firms operating in developing countries.

Researchers are now considering the reverse causality *i.e.* the effects of FDI on migration flows. The literature shows that FDI entering a developing country generate externalities which can either lessen south-north migration – FDI may participate to the economic development of the migrants' origin country – or strengthen south-north migration – by maintaining or/and creating jobs in the receiving countries, and by conveying information about migration opportunities, FDI may relax the budget constraint of would-be migrants. See the empirical contributions of Aroca and Maloney (2005), D'Agosto et al. (2006), and Sanderson and Kentor (2008).

Nonetheless, almost no paper deals with the impact of FDI on skilled migration toward FDI recipient countries. The second chapter of this thesis is related to this issue and the present chapter is a direct attempt to fill this gap.

The literature on skilled migration is also related to the management literature analysing expatriation within the strategy of MNEs. A large set of papers explains how MNEs use

transfers of skilled workers between their establishments to manage specific activities: the control and the coordination of their subsidiary operations, or the transfer of tacit knowledge. (Tsang, 1999; Bonache et al., 2001; Kogut and Zander, 2003; Williams, 2007). Peterson et al. (1996) using a survey realised in 1992 on 29 MNEs, find that intra-firm transfers of managers represented between 1% and 2% of the MNEs' labour force. There has been no survey conducted in the recent years giving relevant quantitative information on the use of expatriation by MNEs[7]. A recent survey ranks the most relevant reasons that motivate MNEs to use expatriates (Brookfield, 2010). Among the top ranked assignment objectives are: "to fill a managerial skills gap" (22% of the respondents), followed by "filling a technical skills gap" (21% of respondents) and "transfer knowledge" (16% of the respondents). Thus, the availability of skilled workers in the investment destination country, possibly reduces the use of skilled expatriates by MNEs.

On that matter, Tung (1982) observes that subsidiaries established in developing countries employ less local managers compared to those established in developed countries; the main reason being the lack of skilled workers in developing countries. Then, a number of papers suggests a positive relation between technological and managerial intensive activities and the expatriation of high skilled workers in countries where there is a shortage of skilled labour. In particular, several papers consider the research and development (R&D) content of the firm and the complexity of their environment, as two crucial determinants of expatriation (Boyacigiller, 1990; Delios and Bjorkman, 2000; Harzing, 2001). The R&D content of the investment, when it is employee-embedded, may explain the need of MNEs to transfer this knowledge to the subsidiary through expatriates. Delios and Bjorkman (2000) measure the technological capabilities of the firms by their R&D expenditure with respect to their total exports. They find evidence that the technological sophistication of Japanese subsidiaries positively impacts the use of expatriates when localised in China, conversely to subsidiaries localised in the United States. They argue that the skilled labour endowment in the United States could entail a larger employment of host-country nationals.

Finally, in addition to the benefits induced at the firm-level, transfers of skilled workers may also produce important knowledge spillovers for the local environment. In particular, Gong (2003) shows that foreign skilled workers may transfer technological and managerial capabilities to local workers through training activities. These positive knowledge spillovers amplify as the trained local workforce and foreign skilled workers get hired by domestic firms. Görg and Strobl (2005) find that in Ghanaian firms, workers who were previously hired by a multinational enterprise are more productive than those who were previously

[7] A survey realised in 2003 and 2004 reports that the 134 respondent firms managed 31,215 expatriates out of a total work force of 4.5 million of employees (Brookfield, 2004). Nonetheless, the survey does not report the size of the firms which makes difficult the assessment of the importance of expatriation.

employed by a domestic firm. The authors attribute this larger productivity to the industry specific knowledge gained by the employees while working for a multinational enterprise.

3.3 Data and descriptive statistics

In this chapter, we use firm-level data from the UNIDO Africa Investor Survey 2010[8], referring to the year 2009. The survey contains information on 6,484 firms in the agricultural, manufacturing and tertiary sectors[9], in 19 Sub-Saharan African countries[10]. The database we use contains 4,298 observations collected in 16 SSA countries[11]; among them 1,690 are foreign firms. Three types of foreign firm are considered: subsidiaries, joint-ventures and foreign individual investments. In this survey, a foreign firm is defined as a firm having at least 10% of foreign ownership, which is in line with the 4th Edition of the OECD Benchmark Definition of Foreign Direct Investment. Unfortunately, we have no information to differentiate vertical from horizontal investments. The survey collects information on firms' characteristics such as the value of assets, financial indicators, domestic sales, exported quantities... It also contains characteristics specific to foreign firms such as the origin country of the investor and the market entry mode. This database is suitable for our investigation as it contains detailed information on the workforce composition of the firms, disaggregated in three skill categories: (i) production, manual and sales workers, (ii) clerical and administrative staff, and (iii) managers, supervisory staff and technicians. Henceforth, we refer to these groups as low, medium and high skilled workers. For each skill category of workers, we know the number of native and foreign workers.

Regarding foreign firms, most of them come from Western European countries (641 firms), countries of East Asia (307 firms, excluding China) and SSA neighbouring countries (235 firms); see appendix B.1. In this database, investors from the north represent almost 48% of the foreign investors[12]. The most attractive countries for foreign firms are Uganda (105 northern and 242 southern firms), Kenya (156 and 112 respectively) and Ghana (64 and 79 respectively). Among the 16 SSA countries of the sample, Kenya and Ghana have the highest endowments of skilled workers, and medium to high domestic market size (approximated by their populations) and market potential (approximated by the GDP per capita and the GDP growth). Despite no clear difference between these two countries and other

[8] Among others, this database has been used by Amendolagine et al. (2013) who analyse the micro and macro factors explaining the linkages between foreign subsidiaries and local firms, and Boly et al. (2014) who look into diaspora investments and firm's export performance.
[9] We exclude firms offering financial services from our analysis.
[10] Burkina Faso, Burundi, Cameroon, Cape Verde, Ethiopia, Ghana, Kenya, Lesotho, Madagascar, Malawi, Mali, Niger, Nigeria, Mozambique, Rwanda, Senegal, Uganda, United Republic of Tanzania and Zambia.
[11] We exclude Cape Verde, Niger and Rwanda from our analysis because one macro control variable important for our analysis is not available for these countries.
[12] We define northern firms as enterprises originating from a high-income economy such as defined by the World Bank *i.e.* with a GNI per capita in 2012 equal to or higher than $12,616.

SSA countries in terms of labour market regulation or level of corruption, they are the two most attractive SSA countries for foreign investments (Table 3.1).

Table 3.2 shows that domestic firms employ on average less foreign workers (1.43% of their total workforce) as compared to foreign firms (9.09%). This is the case for low, medium and high skilled workers. Domestic and foreign firms are similar in term of age, while foreign firms are on average larger than domestic ones in term of size measured by the total full-time workforce (respectively 87 and 195 employees). As we expected, there are huge differences in capital intensity between domestic and foreign firms. The latter have, on average, an asset/employee ratio almost 15 times larger than domestic firms. Moreover, foreign firms are more export-oriented than domestic firms. Sales of foreign firms on foreign markets, on average, amount to almost 18% of overall sales, while for domestic firms this share is only 6%. Regarding the sectoral repartition, there is no big difference between domestic and foreign firms. As compared to domestic firms, foreign firms are more engaged in the primary and hard manufacturing sectors. Domestic firms are more engaged in light manufacturing and services sectors.

3.4 Model and specification

Our empirical analysis aims to shed light on the employment of foreign skilled workers by firms established in SSA countries. The complementarity between capital and foreign skilled workers has two simple firm-level implications: (i) capital intensive firms should hire more foreign skilled workers; (ii) firms should employ more foreign skilled workers when localised in a country lacking skilled workers.

We have no information on the origin country of the foreign workers in the UNIDO Africa Investor Survey 2010. Hence, we follow the intuition proposed in chapter 2: we assume that foreign skilled workers are likely coming from economies where the stock of high skilled workers is relatively more important than in SSA countries. Regarding foreign firms, especially subsidiaries and joint-ventures, part of their foreign skilled employees may be expatriates coming from the country of their headquarter. This hypothesis is in line with the literature on intra-firm transfers of high skilled workers (Peixoto, 2001). Also, skilled workers less likely come from neighbouring African countries. The literature on south-south migration shows that concerned migrants are mainly low skilled workers (Ratha et al., 2011; Shaw, 2007).

Our data imply three cross-section dimensions, the reporting firm n with $n = 1, ..., N$, the investor's origin country i with $i = 1, ..., I$, and the firm's operating country j with $j =$

	GDP per capita PPP ($ 2011)	GDP growth in 2009 (% of GDP)*	Education and Training	Population (in thousands)	Int. migrant stock (% of population)	Corruption Index	Hiring regulation	Total tax rate (% of commercial profits)*
Burkina Faso	1352	2.97	2.62	15,094	5.757	3.42	6.7	44.9
Burundi	722	3.47	2.51	8,926	1.049	2.60	10	279.7
Cameroon	2447	1.87	2.82	20,103	1.168	3.20	7.2	48.8
Ethiopia	968	8.8	2.67	84,838	0.727	4.32	6.7	30.30
Ghana	2906	3.99	3.2	23,691	7.806	4.17	8.9	32.5
Kenya	1980	2.74	3.69	39,824	2.207	2.75	7.8	49.3
Lesotho	2098	3.36	3.23	1,989	0.324	3.79	7.8	19.9
Madagascar	1419	-4.01	2.88	20,495	0.217	3.38	2.23	38.4
Malawi	838	9.04	2.78	14,573	2.157	5.21	5.6	26.3
Mali	1625	4.46	2.66	13,559	1.385	2.50	6.7	51.4
Mozambique	848	6.33	2.54	23,361	1.932	4.35	3.3	37.5
Nigeria	4906	6.93	3.03	1,55,381	0.696	3.23	10	32.2
Senegal	2152	2.42	3.41	12,586	1.953	4.35	3.9	45.5
Tanzania	1487	6.02	2.58	43,639	2.054	3.64	1.1	44.4
Uganda	1264	7.25	2.76	32,864	2.271	3.08	10	35
Zambia	2661	6.04	2.97	12,825	2.505	4.55	8.9	15

*World Development Indicators, World Bank (2014)
The other indicators are presented in appendix B.2.

Table 3.1.: Statistics on the firms' operating countries

	Domestic firms				Foreign firms			
	Obs.	Mean	[95% Conf.	Interval]	Obs.	Mean	[95% Conf.	Interval]
Total assets (millions of US$)	2,608	4.657	2.816	6.499	1,690	81.6	-36.6	200
Capital intensity (value of fixed assets in US$/empl.)	2,608	53,976	15,578	92,375	1,690	804,406	-506,127	2,114,940
Knowledge intensity (intellectual property assets in US$/empl.)	2,413	763.34	154.55	1,372.13	1,567	1194.47	421.37	1,967.58
Export intensity (exports in US$/sales in US$)	2,608	.0605	.0531	.0678	1,690	.1855	.17	.201
Age of the firm	2,608	17.276	16.7422	17.8098	1,690	17.3349	16.59	18.0798
Size (number of full time employees)	2,608	87.8213	79.0954	96.5472	1,690	195.7805	167.3021	224.2589
Foreign employees (% full time workforce)	2,595	1.43	1.19	1.67	1,685	9.09	8.51	9.68
Foreign low skilled workers	2,603	.31	.23	.39	1,684	2.24	1.93	2.54
Foreign medium skilled workers	2,605	.34	.17	.51	1,684	1.67	1.47	1.87
Foreign high skilled workers	2,608	.77	.66	.88	1,690	5.02	4.67	5.37
For. low skilled workers (% low skilled workforce)	2,439	.6	.42	.78	1,586	4.31	3.7	4.92
For. medium skilled workers (% medium skilled workforce)	2,278	2.62	1.18	4.07	1,584	13.48	12.11	14.85
For. high skilled workers (% high skilled workforce)	2,458	5.23	4.55	5.9	1,642	32.45	30.05	34.84
Primary sector (%)	2,608	3.6	2.88	4.32	1,690	7.57	6.31	8.83
Light manufacturing sector (%)	2,608	31.74	29.96	33.53	1,690	25.73	23.65	27.82
Hard manufacturing sector (%)	2,608	20.93	19.37	22.49	1,690	27.33	25.21	29.46
Construction sector (%)	2,608	7.63	6.61	8.64	1,690	7.45	6.2	8.7
Services sector (%)	2,608	36.08	34.23	37.92	1,690	31.89	29.66	34.11

Table 3.2.: Characteristics of domestic and foreign firms

$1, ..., J$. In the case of a domestic firm $i = j$. We use a negative binomial model, in particular the mean-dispersion model referred as NB2 (Greene, 2012) to estimate the determinants of the employment of foreign skilled workers. The model is specified as follows:

$$\Pr\left(Y = y_{nij}|x_{nij}\right) = \frac{\Gamma\left(\theta + y_{nij}\right)}{\Gamma\left(y_{nij}+1\right)\Gamma\left(\theta\right)}\left(\frac{\lambda_{nij}}{\theta+\lambda_{nij}}\right)^{y_{nij}}\left(1-\frac{\lambda_{nij}}{\theta+\lambda_{nij}}\right)^{\theta} \quad (3.1)$$

Our dependent variable is denoted by y_{nij} and represents the number of foreign high skilled workers. x_{nij} denotes a vector of regressors. Γ denotes the Gamma function and θ is the dispersion parameter. The unconditional mean of this model is $E\left(y_{nij}|x_{nij}\right) = \lambda_{nij}$, and the unconditional variance is $\text{Var}\left(y_{nij}|x_{nij}\right) = \lambda_{nij}\left(1+\frac{\lambda_{nij}}{\theta}\right)$[13]. Let us define the vector of regressors as:

$$x_{nij} = \left(1; \ln K_{nij}; \text{Skill}_j; \text{Firm}_{nij}^{'}; \text{MacroControls}_j^{'}\right) \quad (3.2)$$

Then, the unconditional mean which we estimate is given by:

$$\begin{aligned} E\left(y_{nij}|x_{nij}\right) = \lambda_{nij} = &\exp\left(\beta_0 + \beta_1 \ln K_{nij} + \beta_2 \text{Skill}_j\right. \\ &\left. + \gamma_1 \text{Firm}_{nij}^{'} + \gamma_2 \text{MacroControls}_j^{'}\right) \end{aligned} \quad (3.3)$$

where the main explanatory variable is $\ln K_{nij}$ and denotes the logarithm of the capital intensity of the firm, and the main control variable is Skill_j and denotes the endowment of skilled labour in the firm's operating country. We include two vectors of control variables of dimension 1xk. $\text{Firm}_{nij}^{'}$ includes the firm's characteristics and $\text{MacroControls}_j^{'}$ is a set of covariates related to the investor's origin country and the operating country of the firm. β_0 is a constant term, β_1 and β_2 are parameters to be estimated, γ_1 and γ_2 are vectors of parameters to be estimated.

Hereafter we detail the dependent and explanatory variables. The source and definition of each variable are presented in appendix B.2. Correlation matrices of covariates are presented in appendix B.3.

[13] In other words, the NB2 model is an extension of the Poisson model to which we add a stochastic term. Let us denote our conditional distribution function by $\Pr\left(Y = y_{nij}|x_{nij}, u_{nij}\right)$ and the corresponding conditional mean by $E\left(y_{nij}|x_{nij}, u_{nij}\right) = \lambda_{nij} + u_{nij}$, where $u_{nij} = \exp\left(_{nij}\right)$ and denotes the stochastic part of the function and $_{nij}$ denotes the error term. If $u_{nij} = 0$, then our model simplifies to a Poisson model. If we assume u_{nij} has a Gamma density function we obtain a NB2 model and we can write the unconditional distribution function as in equation (3.1).

3.4.1 The dependent variable

y_{nij} refers to the number of foreign high skilled workers employed by the firm n which originates from country i and operates in country j[14]. We refer to foreign high skilled workers as full-time foreign workers employed in managerial, technical or supervisory positions. This dependent variable is a discrete count variable directly measured by the questionnaire of the UNIDO Africa Investor Survey 2010.

Note that a large number of firms do not employ foreign workers. It implies a high number of zeros on the left hand side of our equation. In the sample, about 54.31% of firms do not hire foreign workers, about 61.89% do not employ foreign high skilled workers. The decision of some firms to employ no foreign skilled workers is not assumed to be qualitatively different from the decision to employ foreign workers. Thereby, using a negative binomial model allows us to include the zeros in our analysis, and to account for the over-dispersion of the dependent variable. Notice that a preliminary analysis showed that with respect to the likelihood-ratio test, the negative binomial distribution gives a better result than the Poisson distribution.

3.4.2 Explanatory and control variables

Our main explanatory variable is the capital intensity of the firm ($\ln K_{nij}$). It denotes the logarithm of the value of fixed assets per employee in the last financial year. We expect capital intensive firms to use more foreign skilled workers as compared to low capitalised firms.

Our main control variable is the endowment of skilled labour in the firm's operating country (Skill_j). It is approximated by the level of higher education and training (5th pillar) from the Global Competitiveness Report 2009-2010 (Schwab, 2009). This proxy measures both the enrolment ratio and the quality of education. It also takes into account vocational and on-the-job training which is relevant for the business community. This indicator allows us to keep 16 over the 19 SSA countries available in the UNIDO dataset. We expect firms localised in a country having a relatively low index, to employ more foreign skilled workers in order to compensate this skilled labour shortage.

The richness of the UNIDO Africa Investor Survey 2010 allows us to include a large set of micro control variables that may impact the employment of foreign skilled workers. In

[14]The question asked to the firm in the UNIDO questionnaire was the following: "How many of the total permanent full-time employees were: Production/manual/sales workers, Technical/supervisory/managerial staff, Clerical/administrative staff?" For each skill category, the firm was asked to report the total number of workers and the number of foreign workers.

particular, for foreign firms we include variables that could influence intra-firm transfers of skilled workers.

$$\text{Firm}'_{nij} = \left(\ln \text{Size}_{nij}; \ln \text{Age}_{nij}; \text{MultiPr}_{nij}; \ln \text{Exp}_{nij}; \text{Green}_{nij}; \text{Sub}_{nij}; \text{JV}_{nij}\right) \quad (3.4)$$

$\ln \text{Size}_{nij}$ denotes the size of the firm. The size is measured as the average number of full-time employees in the firm (in logarithm)[15]. $\ln \text{Age}_{nij}$ denotes the age. It is measured by the lapse of time (in logarithm) between the year of the investment or the firm's creation and the year of the survey (2009). We expect older firms to employ more local employees, as they should be more integrated into their local environment. Over time, firms are expected to gain knowledge on their institutional and business context (Wilkinson et al., 2008). MultiPr_{nij} is a dummy variable taking the value of 1 when the firm produces at least four products. $\ln \text{Exp}_{nij}$ represents the export intensity of the firm, which is measured by the value of exports with respect to total sales (in logarithm). The management literature supports the idea that multi-product firms and export oriented firms may employ more foreign expatriates to deal with the complexity of the production and distribution process (Peixoto, 2001). Thus, we expect these types of firms to employ more foreign high skilled workers. Finally, we include 18 industry dummies to control for the sector of activity of the firm. We also use country dummies controlling for the operating country of the firm. These dummies capture possible country-specific restrictions regarding the employment of foreigners.

The following variables are specific to foreign firms: Green_{nij} is a dummy variable relating the entry mode of the foreign firm, which takes the value of 1 in case of a greenfield investment, 0 in case of an acquisition of an existing firm. According to Harzing (2001) and Peixoto (2001), start-up businesses require a larger employment of managers and technicians. Thus, we expect greenfield investments to be positively related to the employment of foreign skilled workers. Sub_{nij} and JV_{nij} are dummies accounting for the type of FDI, making the distinction between subsidiary firms, joint-venture firms and foreign individual investments. Finally, we may include dummies controlling for the origin country or the origin region[16] of the foreign investor.

We also consider a set of macro variables controlling for the demographic and the economic characteristics of the firm's operating country.

$$\text{MacroControls}'_{j} = \left(\text{GDPcap}_j; \ln \text{Pop}_j; \text{Corruption}_j; \ln \text{MigStock}_j; \text{Open}_j; \text{LabReg}_j\right) \quad (3.5)$$

[15] In section 3.6.2, we control for a possible endogeneity bias between the size of the firm and our dependent variable by using an instrumental variable approach.

[16] Eastern Asia (China excluded), China, Eastern Europe and Central Asia, Western Europe, Latin America and Caribbean, North America, Middle East and North Africa, SSA countries (South Africa excluded), South Africa, and Oceania

GDPcap$_j$ denotes the GDP per capita in purchasing power parity of country j in 2009, in constant international dollars of 2011. It is a proxy for the level of wealth of the country. $\ln$ Pop$_j$ represents the population (in logarithm) of country j in 2009, and is a proxy for the market size of the country. We expect these two variables to impact positively the use of foreign workers, as they are known to be pulling factors of both FDI and migration (Buch et al., 2006). Corruption$_j$ relates the level of extra payments, bribes or favouritism actions realised by firms in the country in 2009. Regarding foreign firms, a high degree of corruption may have an ambiguous effect on the employment of foreign high skilled workers. On the one hand, a high degree of insecurity and corruption is an incentive for a foreign firm to employ reliable workers from its origin country. On the other hand, it is an incentive to rely on local employees who have a better knowledge of the local environment. $\ln$ MigStock$_j$ denotes the stock of international migrants (in logarithm) in country j in 2005. This variable controls for the possibility that some foreign workers employed by the firm were already part of the population of migrants residing in country j. It also controls for the fact that migration networks foster new migration. Open$_j$ denotes the freedom of foreigners to visit the country in 2009. We expect countries with soft regulations to attract relatively more foreign workers, who may easily receive visit or migrate with their relatives. LabReg$_j$ denotes the hiring regulations in the country in 2009. The effect of strong hiring regulations on the employment of foreign workers is ambiguous. On the one hand, a country ensuring workers protection may attract foreign workers, but on the other hand regulations may limit the employment flexibility of the firms.

3.5 Empirical results

In Table 3.3, we report the results of our baseline estimations for the sub-sample of foreign firms. Column 2 presents our baseline specification. We observe a positive and highly significant effect of the capital intensity of the firm on its employment of foreign skilled workers. In specification 2', the marginal effect shows that an increase in the capital intensity by 1% induces an increase in the use of foreign skilled workers by 0.222 unit. This result suggests a relation of complementarity between the technological content of the investment and the employment of foreign high skilled workers[17]. It also corroborates the tendency of capital intensive firms to protect their know-how using intra-firm transfers of employees (Argote and Ingram, 2000). This complementarity result is robust after controlling for the firm's sector of activity, which captures industry differences in the usage of high skilled workers.

[17] Although our study focuses on foreign hight skilled workers, we expect to find a higher degree of complementarity between the capital intensity of the firm and its use of foreign high skilled workers as compared to its use of foreign low skilled workers. We refer to foreign low skilled workers as full-time foreign workers employed in production, manual and sales activities. In line with what expected, further tests have shown that the complementarity is much stronger between the firm's capital intensity and its use of foreign high skilled workers. Results are presented in appendix B.4.

	(1)	(2)	(2')	(3)	(4)	(5)
ln K_{nij}	0.0772^a	0.0873^a	0.222^a	0.0949^a	0.0954^a	0.0939^a
	(0.0148)	(0.0147)	(0.0377)	(0.0147)	(0.0147)	(0.0148)
Skill_j	-0.369^a	-0.519^a	-1.323^a		-0.532^a	0.306
	(0.0749)	(0.0777)	(0.199)		(0.0790)	(0.240)
ln Size_{nij}	0.563^a	0.587^a	1.496^a	0.586^a	0.586^a	0.585^a
	(0.0220)	(0.0238)	(0.0656)	(0.0227)	(0.0240)	(0.0237)
ln Age_{nij}		-0.0198	-0.0506	-0.0725^c	-0.0471	0.922^a
		(0.0373)	(0.0950)	(0.0371)	(0.0375)	(0.261)
ln Exp_{nij}		0.457^a	1.165^a	0.386^a	0.472^a	0.451^a
		(0.138)	(0.353)	(0.137)	(0.138)	(0.138)
MultiPr_{nij}		0.0950	0.242	0.165^c	0.153	0.0960
		(0.0944)	(0.241)	(0.0902)	(0.0939)	(0.0940)
Sub_{nij}		-0.0129	-0.0328	0.0663	0.00394	-0.00318
		(0.0634)	(0.162)	(0.0612)	(0.0654)	(0.0632)
JV_{nij}		-0.462^a	-1.178^a	-0.459^a	-0.433^a	-0.427^a
		(0.0829)	(0.212)	(0.0813)	(0.0833)	(0.0832)
Green_{nij}		0.110	0.280	0.113	0.0810	0.136^c
		(0.0761)	(0.194)	(0.0732)	(0.0760)	(0.0761)
ln MigStock_j		0.443^a	1.128^a		0.349^a	0.426^a
		(0.0657)	(0.168)		(0.0672)	(0.0655)
ln $\text{Age}_{nij} * \text{Skill}_j$						-0.308^a
						(0.0845)
Eastern Europe & Central Asia		0.256	0.652	0.190		0.281
		(0.255)	(0.649)	(0.245)		(0.253)
Asia		0.509^a	1.298^a	0.349^a		0.519^a
		(0.0769)	(0.197)	(0.0782)		(0.0766)
China		0.682^a	1.737^a	0.514^a		0.680^a
		(0.111)	(0.286)	(0.111)		(0.111)
North America		0.412^a	1.049^a	0.248^b		0.454^a
		(0.124)	(0.317)	(0.117)		(0.124)
Latin America		0.380	0.967	0.351		0.385
		(0.410)	(1.046)	(0.381)		(0.408)
Middle East and North Africa		-0.241^b	-0.615^b	-0.225^b		-0.225^b
		(0.114)	(0.291)	(0.112)		(0.114)
SSA countries		0.188^b	0.478^b	0.0850		0.201^b
		(0.0858)	(0.219)	(0.0859)		(0.0855)
South Africa		-0.0762	-0.194	-0.179		-0.0783
		(0.120)	(0.305)	(0.121)		(0.119)
Oceania		-0.323	-0.823	-0.318		-0.336
		(0.373)	(0.951)	(0.355)		(0.372)
Observations	1,807	1,690	1,690	1,811	1,690	1,690
ln α	-0.121^b	-0.357^a		-0.453^a	-0.481^a	-0.372^a
	(0.0508)	(0.0566)		(0.0573)	(0.0587)	(0.0569)
Sector dummies	yes	yes	yes	yes	yes	yes
Origin country dummies	no	no	no	no	yes	no
Country dummies	no	no	no	yes	no	no

Standard errors in parentheses. Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.
Column 2' presents the marginal effects at the mean values of the predictors based on specification 2.

Table 3.3.: Demand for foreign skilled workers, sub-sample of foreign firms

In some specifications, we introduce destination country dummies and origin region dummies in order to control for origin and destination country factors that may influence the complementarity relation. In specification 4, we carry out a more detailed investigation by introducing in the estimation origin country dummies. In all specifications, results on the capital intensity variable do not change significantly.

Then, we find strong support that the availability of skilled workers in the firm's operating country has a negative and highly significant effect on our dependent variable. In countries relatively more endowed with skilled workers, *ceteris paribus*, firms rely more extensively on the native skilled workforce, employing less foreign skilled workers. In addition, as stressed by the expatriation literature, the availability of skilled workers in the investment destination country, reduces the use of costly expatriates by MNEs. Finally, although not reported here, the interaction effect between the capital intensity of the firm and the level of skilled labour endowment in the operating country is not significant.

We observe a positive relation between the export intensity of the firm and its use of foreign skilled workers. This result may be due to the fact that exporting firms use foreign qualified workers who have a better knowledge of international markets as compared to native workers. Richards (2001) asserts that expatriates, rather than local managers, are more appropriate to deal with international consumers since they have more international experience. On the contrary, domestic-market oriented firms extensively employ local skilled workers who have a good knowledge of the language, and the local consumers' tastes (Peixoto, 2001). Furthermore, we find that foreign investors forming a joint-venture with a local partner use less foreign skilled workers than foreign individual investors. Wang et al. (1998) note that in a joint-venture, the foreign partner has less discretion to appoint home country nationals in control and management positions. Finally, we find weak evidence that firms making greenfield investments use more foreign skilled workers as compared to those making brownfield investments[18].

Gong (2003) argues that, over time, foreign firms tend to replace their foreign technical and managerial workers with local employees. For instance, a subsidiary employs a high number of expatriates in the early phase of establishment to set-up and manage its production process. Over time, the role of expatriates tends to decline since the firm engages in local staffing development in order to build the necessary human resource capacities (Peng and Beamish, 2014). Interestingly, in most of our specifications, we find that the age of the firm has no significant effect on the use of foreign skilled workers. This result could be related to the very low skilled labour endowment in SSA countries which may prevent firms to

[18]Most FDI flowing to SSA countries are greenfield (86% of investments). Hence, the result may be conditioned by the low variability of this covariate.

fill positions with well-qualified local workers. If this intuition is correct, we expect firms operating in countries which are better endowed with skilled workers to employ, over time, more local skilled workers. To test this intuition, we use an interaction term between the age variable and the skilled labour endowment proxy (specification 5). The result shows a negative and highly significant effect of the interaction on the number of foreign skilled workers. In Figure B.1 in appendix B.5, we decompose the average effect measured by the coefficient, highlighting its significance by levels of skilled labour endowment at country level. We find that the length of operation in the operating country has: (i) a positive effect on the employment of foreign skilled workers when the skilled labour endowment in the operating country is relatively low (for about 20% of the observations); and (ii) a negative effect on the employment of foreign skilled workers when the skilled labour endowment in the operating country is relatively high (for about 22% of the observations). Thereby, over time, the substitution of foreign by native skilled workers is relevant for firms located in SSA countries which are the most abundant in skilled labour, while firms operating in countries with low endowment of skilled labour use extensively foreign skilled workers.

Finally, it is worth noting that the dummies controlling for the sectors of activity of the firms show the expected effect on the use of foreign skilled workers. Although not reported in the estimation tables, we find that, as compared to the agricultural and fishery sector, highly capital intensive sectors use a higher number of foreign skilled workers. Specifically, these sectors include mining and quarrying, machinery and equipment, construction, retail and motor vehicles sales. In addition, looking at dummies accounting for the origin region of the foreign investor, we find that as compared to Western European firms, firms coming from China, Asia and North America employ significantly more foreign high skilled workers, while firms coming from Middle East and North Africa employ significantly less foreign high skilled workers. These differences can be due to the organisational mode that can be specific to the foreign investor's culture. Looking at the marginal effects, Asian firms and especially Chinese firms seem to employ a higher number of foreign skilled workers in SSA countries as compared to other firms. In specification 2', we find that a discrete change in the predicted probability of being an Asian (a Chinese) firm increases the use of foreign skilled workers by 1.298 (1.737) unit.

In Table 3.4, we follow our analysis looking at domestic firms. Our intuition is that both foreign and domestic firms have to cope with the scarcity of skilled workers in their operating countries. For both types of firms, we find that the capital intensity impacts positively the use of foreign skilled workers. The results show that the effect is stronger for foreign firms. A marginal increase of the capital intensity by 1% entails an increase in the use of foreign skilled workers by 0.222 unit for foreign firms; while it only entails an increase

	(1)	(1')
ln K_{nij}	0.183^a	0.0433^a
	(0.0390)	(0.00926)
Skill$_j$	-0.389^b	-0.0919^b
	(0.197)	(0.0466)
ln Size$_{nij}$	0.902^a	0.213^a
	(0.0622)	(0.0171)
ln Age$_{nij}$	-0.0202	-0.00478
	(0.0921)	(0.0218)
ln Exp$_{nij}$	1.421^a	0.336^a
	(0.479)	(0.115)
MultiPr$_{nij}$	0.0498	0.0118
	(0.234)	(0.0553)
ln MigStock$_j$	0.935^a	0.221^a
	(0.171)	(0.0412)
Observations	2,608	2,608
ln α	1.771^a	
	(0.0806)	
Sector dummies	yes	yes
Country dummies	no	no

Standard errors in parentheses.
Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.
Column 1' presents the marginal effects at the mean values of the predictors based on specification 1.

Table 3.4.: Demand for foreign skilled workers, subsample of domestic firms

by 0.0433 unit for domestic firms (specification 1'). The stronger effect for foreign firms may be related to the larger access to qualified workers these firms have as compared to domestic firms. For instance, a foreign affiliate, as an alternative to recruit on the local labour market, may also receive qualified worker transfers from its foreign parent company.

In Table 3.5, we report the results of specifications including a set of host country characteristics. As we expected, the stock of international migrants in the destination country is positively associated with the employment of foreign skilled workers. On the one hand, firms may employ foreign workers already present in the country, on the other hand migration networks may foster immigration of new workers. The degree of openness of the country in terms of freedom to visit for tourists and business purposes, is positively related to the use of foreign high skilled workers. This variable is a proxy for the easiness of establishment of foreign workers and their families in the destination country. The result corroborates

	(1)	(2)	(3)	(4)	(5)
$\ln K_{nij}$	0.0874^a	0.0899^a	0.0935^a	0.0895^a	0.0940^a
	(0.0152)	(0.0149)	(0.0148)	(0.0150)	(0.0149)
Skill_j	-0.391^a	-0.342^a	-0.542^a	-0.426^a	-0.489^a
	(0.0766)	(0.0834)	(0.0794)	(0.0789)	(0.0788)
$\ln \text{Size}_{nij}$	0.574^a	0.578^a	0.585^a	0.576^a	0.577^a
	(0.0239)	(0.0239)	(0.0237)	(0.0238)	(0.0238)
$\ln \text{Age}_{nij}$	-0.0243	-0.0192	-0.0287	-0.0306	-0.0370
	(0.0379)	(0.0379)	(0.0372)	(0.0380)	(0.0378)
$\ln \text{Exp}_{nij}$	0.471^a	0.433^a	0.372^a	0.442^a	0.429^a
	(0.140)	(0.140)	(0.138)	(0.139)	(0.139)
MultiPr_{nij}	0.0795	0.0739	0.115	0.0785	0.0966
	(0.0954)	(0.0954)	(0.0940)	(0.0954)	(0.0951)
Sub_{nij}	-0.0621	-0.0664	-0.0584	-0.0701	-0.0386
	(0.0639)	(0.0638)	(0.0631)	(0.0640)	(0.0639)
JV_{nij}	-0.509^a	-0.504^a	-0.501^a	-0.507^a	-0.457^a
	(0.0839)	(0.0833)	(0.0823)	(0.0834)	(0.0834)
Green_{nij}	0.0972	0.0951	0.149^c	0.0955	0.0754
	(0.0771)	(0.0770)	(0.0764)	(0.0770)	(0.0769)
$\ln \text{Pop}_j$	0.0387				
	(0.0384)				
GDPcap_j		-5.57e-05^c			
		(3.36e-05)			
Open_j			0.102^a		
			(0.0165)		
Corruption_j				-0.0675	
				(0.0447)	
LabReg_j					0.0421^a
					(0.00985)
Observations	1,690	1,690	1,690	1,690	1,690
$\ln \alpha$	-0.313^a	-0.314^a	-0.351^a	-0.315^a	-0.331^a
	(0.0558)	(0.0558)	(0.0565)	(0.0558)	(0.0562)
Sector dummies	yes	yes	yes	yes	yes
Origin region dummies	yes	yes	yes	yes	yes
Origin country dummies	no	no	no	no	no
Country dummies	no	no	no	no	no

Standard errors in parentheses. Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 3.5.: Demand for foreign skilled workers (introducing macro covariates), sub-sample of foreign firms

the work of De Smet (2013), who shows that the easiness to employ or transfer foreign skilled workers depends on visa restrictions and bureaucratic procedures to obtain a work permit. In specification 5, we include a variable capturing the adequacy of the host-country hiring regulations. We find that a better system of protection of workers' rights impact positively the employment of foreign qualified workers. The result suggests that generating a favourable work environment is important to attract foreign skilled workers. Finally, in specification 4 we include an index measuring the corruption level in the host country. That being said, we do not find a significant effect of this variable on the employment of foreign skilled workers.

3.6 Robustness and endogeneity concerns

3.6.1 Robustness checks

We realise different robustness checks using alternative specifications and alternative empirical models. Results are presented in Table B.6, in appendix B.6. In specifications 1 and 2, we approximate the endowment of skilled labour in country j with two alternative proxies: the gross enrolment ratio in the secondary and tertiary education from the World Development Indicators of the World Bank (2014) (Skill2_j), and the Barro and Lee (2013) index that measures the completed secondary and tertiary education over the age of 25 (Skill3_j)[19]. We observe that the signs and the significance levels of the coefficients of our main variables remain stable, though we find smaller coefficients for the skilled labour endowment proxies. As compared to our initial proxy, these proxies may be more restrictive to approximate the level of human capital of a country. In developing countries, excluding on-the-job training potentially eliminates a large share of the actual skilled labour stock.

Then, we test the sensitivity of our analysis to the type of empirical model chosen. As our model presents a large number of zeros, we estimate our baseline equation using a pseudo Poisson maximum likelihood model (Santos Silva and Tenreyro, 2006) (specification 3). We include dyadic independent variables as the distance between the investor's origin country and the operating country of the firm $(\ln \text{Dist}_{ij})$ and a dummy variable taking the value of 1 if the investor origin country and the operating country of the firm share the same primary official language $\left(\text{Lang}_{ij}\right)$. In addition, we estimate our baseline specification using a corner solution Tobit model (specification 4). Although this model is more appropriate to continuous dependent variables, it can be used as a robustness test for count data models

[19] Using this index decreases the number of SSA countries considered in the analysis from 19 to 14. Missing countries are Burkina Faso, Cape Verde, Ethiopia, Madagascar and Nigeria.

(Greene, 2012). We find that the signs and the significance levels of the coefficients of the main variables are not sensitive to the empirical model chosen.

3.6.2 Endogeneity concerns

One concern related to our estimation strategy is the possible endogeneity between our dependent variable and the size of the firm measured as the total number of full-time employees. In fact, staffing decisions (number of employees and foreign skilled workers) could be simultaneously taken by the firm. Nevertheless, we need to control for the size of the establishment as it impacts directly the number of foreign high skilled workers needed in the production process. To address this issue, we adopt a two-step instrumental variable (IV) technique estimated by an exponential generalised method of moments (GMM) in order to instrument the size of the firm. Results are presented in Table B.7, in appendix B.7.

We first use as instruments the number of full-time low skilled workers employed by the firm, and the operational costs faced by the firm in the last financial year (specification 1). The number of low skilled employees is sufficiently correlated with the overall size of the firm (correlation around 86%), and does not include the number of foreign high skilled workers. Functionally, the number of low skilled employees should not depend on the nationality of the firm's skilled workers. Hence, we assume this instrument is not correlated with the dependent variable. Although the total number of high skilled workers used by the firm could be to some extent functionally correlated with the number of low skilled workers (complementarity or substitution in the production process), we claim that this degree of correlation is less serious if we consider only the foreign skilled workers (it is a sub-sample of the whole skilled workers sample). In this respect, endogeneity could be more relevant in extreme cases when the whole skilled workforce of the firm is composed by foreign skilled workers. However, although not reported in the table, results do not change if we drop these firms from the estimation. Using the second instrument, we assume that the operational costs such as rent, telecommunication and establishment maintenance are correlated with the size of the firm (correlation is around 19%), but not with the number of foreign skilled workers. We perform a Hansen J test to test the exogeneity of the instruments. It is not significant $(p = 0.1685)$, confirming the orthogonality of at least one instrument.

Additionally, in specification 2 we test a second set of instruments: the number of mid-skilled workers and the previously used operational costs. The total number of mid-skilled workers (desk clerks and administrative staff) is correlated with the size of the firm but less seriously correlated with our dependent variable. Contrarily to low skilled workers, in most of the firms mid-skilled workers are not part of the production process since they cover

administrative functions within the firm. Again, the Hansen J test confirms that at least one instrument is exogenous ($p = 0.2697$). In all IV estimations, the results on the variables of interest remain robust.

3.7 Conclusion

The attraction of foreign human capital and containment of the "brain drain" phenomenon is of crucial importance for poor countries. FDI promoting skilled worker employment increases the human capital base of destination countries, creating preconditions for future economic development. In this chapter, we investigate the determinants of the employment of foreign high skilled workers by domestic and foreign firms operating in less developed countries poorly endowed with skilled labour such as Sub-Saharan African countries. In particular, we look at the complementarity between the capital intensity of the firm and its use of foreign qualified workers. We use a cross section dataset built from the Africa Investor Survey 2010, including 16 SSA countries. We exploit both firm and country characteristics to analyse the choice of the firm to hire either a foreign or a native high skilled worker.

We derive four main results from our analysis. First, at the firm-level, after controlling for the availability of skilled labour in the firm's operating country, we find that the capital intensity of the firm positively impacts its use of foreign skilled workers. We find similar results for both foreign and domestic firms, although the relation of complementarity between the capital intensity and the employment of foreign skilled workers is stronger for foreign firms than for domestic ones. Foreign firms are typically more capital abundant, hence more likely to develop job opportunities for skilled workers than domestic firms.

Second, we find that the availability of skilled workers in the firm's operating country has a negative and highly significant effect on its use of foreign skilled workers. In countries relatively more endowed with skilled workers, over time, firms rely more extensively on the native workforce, employing less foreign skilled workers. In other words, we find that firms tend to substitute foreign by native workers when they get more integrated into their local environment.

Third, our results suggest that firm partnerships and especially joint-ventures employ more native skilled workers as compared to other types of firms. The same result is found for domestic-market oriented firms which get more locally embedded than exporting firms, and therefore foster domestic employment.

Fourth, our study sheds light on the degree of substitution between natives and foreigners. The fact that both foreign and domestic capital intensive firms hire foreign skilled workers suggests that foreign and native workers are not perfect substitutes. Firms aiming to access to specific skills are obliged to recruit foreign skilled workers. This is very likely to happen in SSA countries.

Thereby, our study recommends some policy interventions aimed at increasing the human capital base in SSA countries. Our analysis suggests that governments implementing policies to attract FDI, may adopt appropriate measures to satisfy the increase in demand for skilled workers boosted by foreign capital inflows. In the short run, governments may want to facilitate the immigration of skilled workers in order to reduce the skilled labour shortage. For instance, governments could adopt simpler procedures for the free movement of foreign employees, and implement reliable and suitable working regulations. In addition, governments could invest in education and training in order to increase the stock of human capital in their countries. Over time, this strategy would, to some extent, stimulate the substitution of foreign by native skilled workers.

Then, SSA governments which want to enhance job creation for native skilled workers may want to favour joint-ventures over other types of FDI, domestic oriented firms over export oriented firms, and capital intensive sectors over other sectors of the economy. Nonetheless, our analysis does not consider a number of potentially important spillovers of immigration. Thus, governments should consider, in parallel to policies favouring domestic employment, that immigrants stimulate the economic activity of their host country, by creating trade and investment opportunities between their host and origin countries.

Furthermore, policies attracting FDI in SSA countries could prevent the emigration of qualified workers, or favour the return of those who migrated toward northern economies. Thus, the establishment of foreign firms could reduce the brain drain faced by SSA countries, especially if foreign firms have a preference for native workers. FDI inflows could even induce a brain gain effect if they attract young qualified workers from northern economies.

Finally, we find that Asian and especially Chinese firms tend to use more foreign skilled workers than other foreign firms. In light of the current increasing inflows of Chinese and Indian FDI in Africa and the ongoing debate on the poor degree of local integration of these firms – see Morrissey and Zgovu (2011) on that matter – our results suggest some concrete recommendations. SSA governments may ease transfers of foreign skilled workers (but not necessarily transfers of foreign unskilled workers) by Asian and Chinese firms in order to allow them to settle more easily and to alleviate a potential skilled labour shortage in the short run. However, governments could use regulations to encourage these firms to

substitute foreign by native skilled workers as they become more integrated into their local environment. In that context, it seems that the immigration of skilled Asian workers would be beneficial for the development of Sub-Saharan Africa.

4

Merchandise exports and firms' heterogeneity: Does foreign employment matter? Firm-level evidence from France

This chapter has been written in collaboration with Clément NEDONCELLE.

4.1 Introduction

In this chapter, we turn our attention to the trade-migration nexus. We analyse to what extent immigrant workers, according to their level of qualification, may favour the export performance of their firm. Analysing whether immigrants impact the export activity of French firms is a crucial issue, not only because France hosts a substantial stock of immigrants, but also with respect to the increasing international migration flows. Between 1995 and 2010, the stock of immigrants in France increased about 26.54%; from 6.24% of the French population in 1995 to 7.24% in 2010 (Brücker et al., 2013).

In parallel, trade represents an important part of the French GDP. It amounted to 43% of the GDP in 1995, and to 54% in 2010. More especially, merchandise trade represented about 37% of the GDP in 1995, and about 43% in 2010[1]. Over that period, the value of French merchandise exports increased about 42.35%, from 301,933 million of US dollars in 1995 to 523,767 million in 2010[2,3].

Therefore, if immigrants impact French exports, policy makers ought to consider it when designing both migration and trade policies. For instance, since the 2008 crisis, France (just as other developed countries) has been tightening its migration policy with the twofold objective of reducing the volume and increasing the skill content of its immigration stock

[1] Data come from the World Development Indicators of the World Bank

[2] Data are in million of US dollars at current prices and current exchange rates, and come from the database of the UNCTAD (United Nations Conference on Trade and Development) on merchandise exports and imports.

[3] The share of French merchandise exports with respect to total world exports has slightly decreased over this period, from 5.833% in 1995 to 3.423% in 2010.

(Castles et al., 2014). In that context, one may wonder to what extent such a policy could impact the export performance of French enterprises.

It is now common knowledge that immigrants foster trade between their origin and their host countries. The main mechanism evidenced so far is that immigrants convey valuable information between their origin and host countries, which decreases costs faced by exporters. Through this *trade-cost channel*, immigrants foster exports at the extensive and intensive margins (Hatzigeorgiou and Lodefalk, 2011). Additionally, immigrants may positively impact the productivity of their firm, thus decreasing the marginal production cost of their firm (Peri and Sparber, 2009; Ottaviano and Peri, 2012; Mitaritonna et al., 2014). Through such a *productivity channel*, immigrants foster exports at the intensive margin only. In their survey of the trade-migration nexus, Hatzigeorgiou and Lodefalk (2014) emphasise that this pro-trade effect is magnified when immigrants are educated, when countries are dissimilar and have weak legal institutions, and for differentiated goods. Furthermore, the authors highlight that little evidence has been provided at the firm-level. Nonetheless, such studies could improve our understanding of the mechanisms at play within firms and allow us to derive concrete policy recommendations.

The understanding of heterogeneity in trade performances improved greatly over the last decade, in particular thanks to the recent development of the *new* new trade theory following up the paper of Melitz (2003). On the empirical side, the recent availability of firm-level data has led to a large set of papers analysing, in addition to the traditional macro-economic determinants of trade (relative proximity between the trading partners, market potential at destination, exchange rates volatility...), firm-level factors explaining heterogeneous export behaviours. Studies carried out so far clearly establish that a firm's performance is determined by its size, product structure, capital intensity and productivity (Bernard et al., 2012).

In this chapter, we propose a firm-level analysis on foreign workers and merchandise exports. In line with recent firm-level studies, we emphasise that heterogeneity in employment also explains heterogeneous export behaviours. The main mechanism evidenced so far by macro-level studies is that immigrants, and especially skilled immigrants, convey information between their origin and host countries, which decreases variable and fixed costs faced by exporters. This, in turn, fosters exports at the intensive and extensive margins. To the best of our knowledge, only five studies provide micro-level evidence of this phenomenon. First, using French firm-level data on exports toward 61 foreign markets over 1986-1992, Koenig (2009) shows that a firm's probability of exporting manufactured goods toward immigrants' origin countries increases by 1.2% when the lagged stock of immigrants in the region increases by 10%. The effect is stronger when immigrants are

older and more educated. Second, using firm-level data on four central European countries and different export destinations for the year 2009, Pennerstorfer (2011) finds that firms' exports are positively impacted by the stocks of immigrants living in their regions. The author concludes that immigrants foster exports at both margins of trade toward their origin countries, the effect being more significant and stronger for the extensive margin of trade. Third, using employer-employee Swedish data over the period 1998-2007, Hatzigeorgiou and Lodefalk (2011) show that immigrants foster trade at both the intensive and extensive product margins. Among other explanations, they conclude that this effect derives from the superior knowledge of foreign-markets detained by immigrant workers, who can reduce both fixed and variable export-costs. Fourth, using data on Danish manufacturing firms over the period 1995-2005, Hiller (2013) shows that regional immigration impacts the quantities exported but also the composition of exports at the firm-level. Finally, with the same Danish data over 1995-2007, Parrotta et al. (2014b) show that ethnic diversity positively impacts exports, and especially outcomes related to the extensive margin of trade, namely the probability of exporting and the number of export destinations.

In the present chapter, we intend to disentangle the different channels through which foreign workers may impact the export performance of their firm. In other words, we aim at analysing under which conditions and in which proportions both margins of trade may be impacted by foreign employment.

To this end, we first develop a theoretical framework with heterogeneous firms in monopolistic competition resting upon the model of Mrázová and Neary (2012). It allows us to understand to what extent the labour force composition of a firm may impact its export performance. We assume that (i) foreign workers allow for efficiency gains (thus impacting marginal costs), and that (ii) immigrants decrease the variable and the fixed costs to export toward their origin countries. Our model predicts that immigrants should foster exports at both margins of trade, through either one of (or both) the *productivity* and the *trade-cost channels*.

We test these predictions using a dataset on French manufacturing firms over the period 1995-2008. We use exports of goods at the firm-destination level from the French custom administration, which we combine with balance-sheet data from the French tax authority, and employee data from the firms' annual employee declarations. This dataset contains information on the region of birth of the employees (we can distinguish between French, European and non-European workers) and on their socio-professional category, from which we derive their level of qualification in order to distinguish skilled from unskilled workers.

As an empirical strategy, we investigate whether the export performance of the firm is determined or not by its employment of foreign-born workers. We find that hiring immigrant workers has a positive effect on exports at both the intensive and extensive margins. However, we cannot exclude that exporting firms may attract foreign workers because of their export status. Thus, in order to confirm that our results are not biased, we estimate the effect of employing immigrant workers on exports using a propensity score matching method. We find that both margins of trade positively react to an increase in foreign employment at the firm-level. In line with the literature, we provide evidence that a substantial part of the effect comes from skilled workers. Our results also suggest that both the productivity and the trade costs channels are at play. Overall, our results corroborate studies conducted at both the aggregate and micro levels on the topic.

The contribution to the literature of this chapter is twofold. First, only few papers provide a theoretical framework to justify that immigrant workers foster trade at the extensive margin or/and at the intensive margin (Aubry et al., 2012; Felbermayr and Toubal, 2012). The originality of this chapter is to evidence, in a model of heterogeneous firms, the different channels through which foreign employment may impact exports at both margins of trade. Second, only a limited number of papers provides firm-level evidence on this phenomenon. We use firm-level export data and firm-level employment data, contrarily to most existing micro-level analyses that use firm-level export data but regional immigration stocks; the only paper using firm-level employment data being Hatzigeorgiou and Lodefalk (2011). Doing so allows us to improve our understanding of the mechanisms at play within firms, and thereby to derive a number of policy recommendations.

The rest of the chapter is organised as follows. In the next section we present the related literature on the trade-migration nexus. In section 4.3 we present our French firm-level data and a set of stylised facts. In section 4.4 we develop a theoretical framework in order to better understand the mechanisms at play between foreign workers and the export behaviour of their firm. We detail our empirical specification and present our results in section 4.5. In section 4.6 we intend to disentangle the productivity from the trade-cost channel. In section 4.7 we propose an alternative empirical strategy that enables us to deal with some endogeneity concerns. Section 4.8 concludes and suggests a number of policy recommendations.

4.2 The trade-migration nexus

Although this chapter is related to the literature dealing with immigration and exports, it is worth to survey the impact of immigration on both imports and exports[4]. First, the mechanisms through which immigrants foster imports and exports can be similar, thus presenting a full picture can reinforce our understanding of the phenomenon. Second, one is that feedback effects may be at play, in particular between imports of intermediate goods and exports of final goods.

A rather large empirical literature explains how immigrants foster bilateral trade between their origin and host countries. Migrants can impact both imports and exports of goods through different channels that we intend to describe hereafter. The magnitude of the effect depends on immigrants' characteristics (mainly their skills, age and age of arrival), the studied goods (homogeneous or differentiated goods) and the characteristics of the trading partners (proximity between the two trading partners, quality of institutions in both countries...) (Koenig, 2009).

Demand effects

Because they have preferences for foreign goods and because they disseminate their tastes among natives, immigrants increase the demand for foreign varieties, which in turn fosters imports of final goods from their origin countries[5].

In their paper, Felbermayr and Toubal (2012) show how immigrants foster trade with a partial equilibrium gravity equation. In their theoretical model, they make use of a utility function including a preference for foreign goods when immigrants are present in the population. Using stocks of foreign-born individuals by place of birth from OECD countries for the year 2000, they show that immigrants (but not particularly skilled immigrants) foster imports. They find that this *preference channel* effect accounts for 63% of the total effect of immigration on bilateral trade. The paper of Bratti et al. (2014) corroborates these findings. With regional Italian data over the period 2002-2009, the authors show that immigrants have a significant and positive impact on imports. See also the pioneering work of Gould (1994) and Head and Ries (1998).

[4] Only few papers adopt the opposite view, looking at how emigration may impact trade. See Bastos and Silva (2012), Ehrhart et al. (2012) and Briant et al. (2014) on that issue.

[5] Mundra (2005) underlines that when immigrants adapt to their host societies and assimilate the local customs, their demand for foreign goods may fall, in favour of local goods.

In addition, foreign workers increase imports by providing valuable and trustful information on their origin countries. Some papers show that migrants reduce the risk associated to business activities in their origin countries, when the latter provides low contract enforcement. For instance, Ehrhart et al. (2012) find that African migrants reinforce African exports by compensating for weak legal institutions and therefore weak contracts' enforcement. Briant et al. (2014) corroborate the fact that immigrants compensate the quality of their home country institutions.

Finally, few papers analyse how immigrants may foster imports of intermediate goods. Among them, Mundra (2005) uses data on imports and exports for 47 US trading partners over the period 1973-1980, and finds that immigration to the US positively impacts exports of final goods and imports of both final and intermediate goods. Furthermore, when immigrants provide their firm with a better access to intermediate goods (at a lower prices or with a better quality), this may increase its performance in terms of domestic sales and exports. That being said, to the best of our knowledge, there is no theoretical nor empirical evidence on this feedback effect.

Trade costs

Immigrants, and especially skilled immigrants, foster exports toward their origin countries by lowering variable and fixed export-costs. Migrants convey valuable information between their origin and host countries on trade opportunities, on local commercial customs and on local preferences. Their knowledge of international markets allows them either to engage in retail activities, or to advise their firms on their foreign business. Moreover, immigrants reduce cultural and linguistic barriers, promote trust and reduce risk. This, in turn, reduces transaction costs and allows for better contracts' enforcement.

Felbermayr and Toubal (2012) also study this *trade-cost channel*. In their theoretical model, they assume that trade costs depend on the share of foreign individuals born in the export destination country. In the empirical validation of the paper, they find that this channel effect accounts for 37% of the total effect of immigration on bilateral trade. This effect tends to be higher for high skilled individuals. In the same line, Hatzigeorgiou and Lodefalk (2011) evidence that immigrants may reduce both variable and fixed export-costs by relaxing informational barriers thanks to their superior knowledge of foreign-markets. Then, the paper of Aubry et al. (2012) extends the model of heterogeneous firms developed by Helpman et al. (2004) and Helpman et al. (2008) and shows that immigrants reduce fixed export-costs and horizontal FDI costs. They validate their theoretical predictions using

macro bilateral data on migration, FDI and trade[6]. Overall, a large set of papers corroborates these findings; see the pioneering work of Gould (1994), Head and Ries (1998) and Rauch (2001) and the work of Peri and Requena-Silvente (2010), Aleksynska and Peri (2014).

Productivity

Immigrant workers may also foster exports by increasing the productivity of their firms, which in turn reduces the production costs. Two strand of the literature can be related to this *productivity channel*.

First, in the continuation of Peri and Sparber (2009) and Ottaviano and Peri (2012), Mitaritonna et al. (2014) show that natives and immigrants are imperfect substitutes, and that immigrants push toward a task specialisation (foreign workers specialise in manual tasks while natives specialise in complex tasks) which allows for productivity gains. With French firm-level data over the period 1995-2005, they find that an exogenous increase in the local supply of immigrants fosters the firm's productivity.

Second, immigrants may (either positively or negatively) impact the production performance of their employers by increasing the cultural diversity among workers. On the one hand, skilled immigrants reinforce the overall efficiency of their firm, because a higher cultural diversity stimulates innovation and problem solving which leads, for instance, to more patent filings. Their entrepreneurship capacities and potential to innovate is attested by some success stories: the creators of Google, Yahoo, Intel, eBay, Paypal were all immigrants (Goldin et al., 2011). In addition, immigrants increase the global ability of their firms to compete in global markets. They have an export know-how that can be adapted to any foreign market. Parrotta et al. (2014b) use the concept of *meta-competence* to name this know-how. On the other hand, ethnic diversity can create linguistic and cultural frictions which may lead to communication problems, and weaken trust and social ties between workers. Parrotta et al. (2014a) present evidence that cultural diversity impacts negatively the firm's productivity. Some papers in the management literature also present mixed evidence regarding the advantages of multiculturalism. See Loth (2009) who discusses how cultural diversity may positively or negatively impact production processes, and Goodall and Roberts (2003) who discuss the potential gains for culturally diverse multinational firms which efficiently manage their multicultural teams.

[6] Our work differs from the work of Aubry et al. (2012) in two aspects. First, we propose a theoretical justification for immigrants to foster trade at both margins of trade, while the theoretical model of Aubry et al. (2012) focuses on the extensive margin of trade. Second, we use a firm-level dataset to investigate firms' behaviours, contrarily to Aubry et al. (2012) who use macro-level data.

4.3 Data and stylised facts

4.3.1 Data

We merge three datasets providing us information on French firms over the period 1995-2008, by means of the French firm identifier (SIREN number).

First, we use the firms' annual employee declarations (Déclarations Annuelles des Données Sociales, DADS) containing almost exhaustive information on the employment of firms settled on the French metropolitan territory from 1995 to 2008. This employer-employee dataset allows us to know whether an employee was born in France, born in the EU or born outside the EU. Unfortunately, the dataset does not contain information about the exact country of birth of the foreign workers. In this dataset, a foreigner is a person who was born abroad. Thus, naturalised individuals are considered as foreigners in our study.

We also have information on the socio-professional category of each worker, from which we deduct its level of qualification[7]. To do so, we associate to each socio-professional category the corresponding cognitive, communication and manual indexes proposed by Mitaritonna et al. (2014). The authors derive this indexes from the O*NET database (Bureau of Labor Statistics) and the ISCO88 definition of occupations. We consider a worker as skilled when his *cognitive*/manual ratio is higher than (or equal to) the 75th percentile of the distribution of ratios across workers. For robustness tests, we use an alternative definition: a worker is considered as skilled when his *communication*/manual ratio is higher than (or equal to) the 75th percentile of the distribution of ratios across workers[8]. This definition of skills is occupational, contrarily to most existing studies that define the skill level of a worker using his educational background. We aggregate these employee-level data at the firm-level and obtain, for each firm, the number of native, EU-born and extra-EU-born workers employed, and for each category the share of skilled and unskilled workers.

Then, we use firm-level trade data from the French customs over the period 1995-2009. This database reports the volume (in tons) and the value (in euros) of exports for each CN8 product (European Union Combined Nomenclature at 8 digits) and destination, for each firm located on the French metropolitan territory. Some shipments are excluded from this data collection. Inside the EU, firms are required to report their shipments by product and destination country only if their annual trade value exceeds the threshold of 150,000

[7] The socio-professional category is only available over the period 1997-2008

[8] For further robustness tests, we also consider a stricter definition: a worker is skilled when his cognitive/manual or his communication/manual ratio is higher than (or equal to) the 95th percentile of the distribution of ratios across workers.

euros. For exports outside the EU, all flows are recorded unless their value is smaller than 1,000 euros or one ton. Yet, those thresholds only eliminate a very small proportion of total exports. From this dataset, we only keep merchandise shipments.

Finally, we use balance-sheet data (Bénéfices Réels Normaux, BRN) over the period 1995-2009 constructed from reports of French firms to the tax administration. It provides us with information on the value added, total sales, the capital stock and other variables at the firm-level. Unfortunately, this dataset does not contain information on the share of foreign-owned capital. The BRN dataset contains between 650,000 and 750,000 firms per year (around 60% of the total number of French firms). Importantly, this dataset is composed of both small and large firms, since no threshold applies on the number of employees for reporting to the tax administration. Depending on the year, these firms represent between 90% and 95% of French exports contained in the customs data.

Once these data combined, we obtain a firm-level dataset of 3.5 million observations over the period 1995-2008. Note that these data could have allowed us to construct an employer-employee panel dataset. Yet, because of computational constraints, we build a firm-level panel data by aggregating information on employees at the firm-level. In addition, our final dataset contains French firms exporting manufactured goods during at least one year over the studied period. About 64.57% of observations present nil export values. French firms which only produce for the domestic market over the studied period are excluded from the dataset.

Some descriptive statistics on exporting firms (1.24 million of observations) are presented in Table 4.1. From this table, we infer that firms export on average 2.67 thousands of euros (average per year over the studied period). Although not reported in the table, 76.29% of firms do not employ any foreign worker. Looking at firms' employment per region of birth, we observe that exporters employ about 95.5% of natives over their total workforce. They employ much less EU foreign workers (about 0.3% of their total workforce) than non-EU foreign workers (about 4.1% of their total workforce). Then, looking at firms' employment per region of birth and skill level, we see that most immigrant workers are low-skilled workers.

Finally, because we can identify three groups of workers according to their region of birth, we are able to measure a level of cultural diversity within each firm. More precisely, we calculate the Herfindahl and Theil indexes of cultural concentration, which we detail in appendix C.1. In their papers, Ottaviano and Peri (2006), Parrotta et al. (2014b) and Parrotta et al. (2014a) use a Herfindahl measure of concentration to capture the inverse cultural diversity within a group. Using this index allows us to evaluate both the cultural richness

of a firm (the number of groups represented within a firm) and the balanced distribution of individuals across groups. In other words, this index measures the probability that two individuals were born in the same region. We also use the Theil index, which is derived from the Shannon-Weaver entropy index. It is used by Parrotta et al. (2014a) to measure the probability that a firm's workforce is perfectly homogeneous. Looking at Table 4.1, we see that the inverse cultural diversity within firms is rather high, yet it is on average lower among skilled workers than among the total workforce[9].

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
ECONOMIC CHARACTERISTICS					
Profit (in thousands of €)	1,240,989	.85	49.55	-24,374.95	11,610.52
Revenue (in thousands of €)	1,240,989	32.11	1,579.82	0	839,872.8
Total assets (in thousands of €)	1,240,989	59.07	3,168.91	0	1,266,499
Size (total employment)	1,141,835	25.70	214.39	1	63,836
Capital intensity (fixed assets/employee)	1,073,040	2,840.86	44,108.58	0	1.41e+07
Total exports (in thousands of €)	1,240,984	2.67	56.32	1e-06	12,284.63
Age	919,266	19.04	13.79	1	80
Nr. of products exported	1,198,991	34.04	134.12	1	10,194
EMPLOYMENT PER REGION OF BIRTH					
Share of French workers	1,141,835	.955	.143	0	1
Share of European foreign workers	1,141,835	.003	.036	0	1
Share of non-European foreign workers	1,141,835	.041	.138	0	1
Normalised Herfindahl index	1,141,835	.912	.210	0	1
Normalised Theil index	1,141,835	.931	.152	0	1
EMPLOYMENT PER REGION OF BIRTH AND SKILL LEVEL					
cognitive skills (25% threshold)					
Share of French skilled workers (over total workforce)	502,389	.373	.394	0	1
Share of European foreign skilled workers	502,389	.002	.036	0	1
Share of non-European foreign skilled workers	502,389	.015	.099	0	1
Share of French unskilled workers	502,389	.565	.395	0	1
Share of European foreign unskilled workers	502,389	.005	.040	0	1
Share of non-European foreign unskilled workers	502,389	.038	.136	0	1
Normalised Herfindahl index (overall workforce)	502,389	.908	.212	0	1
Normalised Herfindahl index (among skilled workers)	380,994	.955	.164	0	1
Normalised Theil index (overall workforce)	502,389	.925	.159	0	1
Normalised Theil index (among skilled workers)	380,994	.966	.117	0	1
communication skills (25% threshold)					
Share of French skilled workers	502,389	.234	.342	0	1
Share of European foreign skilled workers	502,389	.002	.032	0	1
Share of non-European foreign skilled workers	502,389	.010	.081	0	1
Share of French unskilled workers	502,389	.704	.362	0	1
Share of European foreign unskilled workers	502,389	.005	.043	0	1
Share of non-European foreign unskilled workers	502,389	.042	.149	0	1
Normalised Herfindahl index (overall workforce)	502,389	.908	.212	0	1
Normalised Herfindahl index (among skilled workers)	312,971	.956	.167	0	1
Normalised Theil index (overall workforce)	502,389	.925	.159	0	1
Normalised Theil index (among skilled workers)	312,971	.967	.117	0	1

Table 4.1.: Summary statistics

4.3.2 Stylised facts

A large literature in trade emphasises the multiplicity of dimensions along which firms are heteregeneous (size, productivity, financial constraints...), that shape heteregenous export outcomes across firms (Bernard et al., 2012). The picture however seems to be more com-

[9]The higher the Herfindahl and the Theil indexes, the lower the cultural diversity among workers.

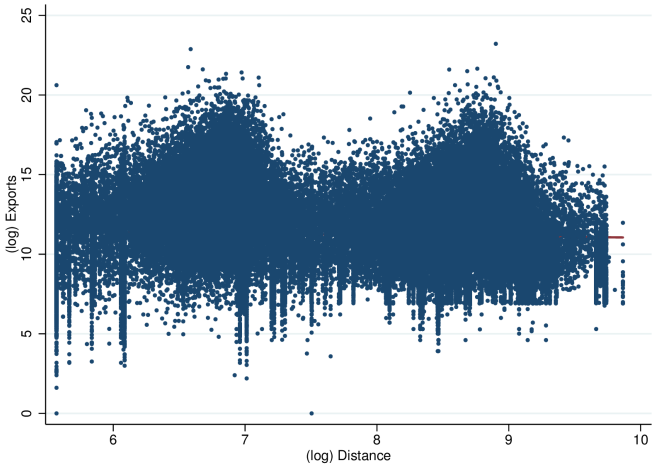

Figure 4.1.: Exported quantities per destination and bilateral distance (2008)

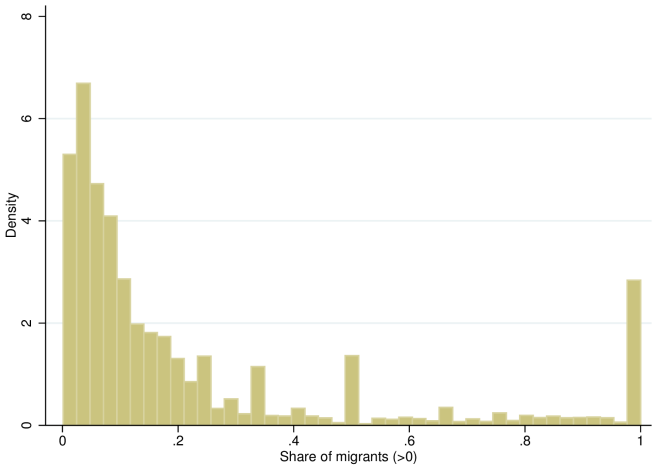

Figure 4.2.: Distribution of the shares of foreign workers

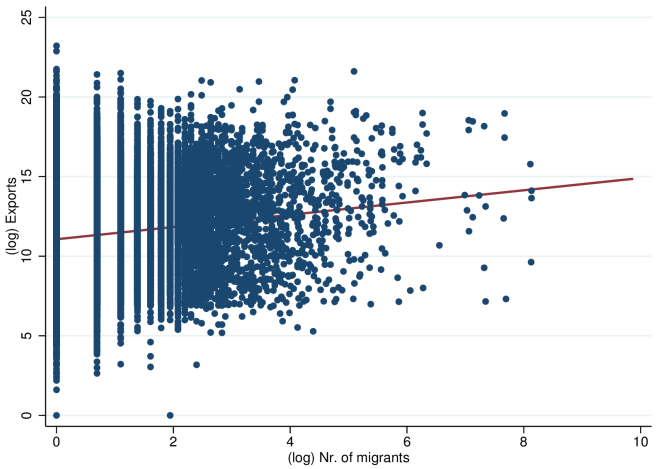

Figure 4.3.: Exported quantities and employment of foreign workers (2008)

plex than this heterogeneity across firms. Eaton et al. (2011), using French firm-level trade data, provide some empirical evidence supporting the existence of an additional heterogeneity source. Empirical evidence they present shows that homogeneous firms with respect to standard trade determinants, may exhibit heterogeneous export outcomes.

Heterogeneity in foreign employment may explain heteregeneity across destinations at the firm-level, alongside to the well-documented hetereogeneity across firms. In particular, if immigrant workers provide information to their firm on their origin countries, then their firm is likely to have different export behaviours across destinations. On top of this, firms are heterogenous in their employment of immigrants, so that heterogeneity across firms may come alongside to the heterogeneity across destinations.

We provide here some stylised facts about French trade flows that highlight the heterogeneity of exports across destinations and across firms.

Fact A: Only some firms are able to reach distant markets, suggesting heterogeneity of across firms, but also across destinations.

Figure 4.1 presents the firm-level exported quantities by destination country in 2008 and the geographical distance between France and the export destination country[10]. The trade-deterring effect of distance is present. We can identify two groups of firms, firms exporting toward close destinations and firms exporting toward distant ones. We infer from this graph that there is a substantial number of firms able to export to distant markets. Firms are not only highly heterogeneous in their total exported quantities, which has been largely documented in the trade literature, but also in their export destinations.

Fact B: Firms are heterogeneous in their employment of foreign-born workers, resulting in heterogeneous export outcomes across firms and across destinations.

Figure 4.2 presents the distribution of the shares of foreign-born workers per firm in 2008. Firms which do not employ any foreign worker are not plotted on the graph. Firms are highly heterogeneous in their employment of foreign workers, most of them hire a very small share of immigrants. The distribution is even more skewed to the left when we look at the share of foreign skilled workers, plotted in Figures C.1 and C.2, in appendix C.2.

This is confirmed by Figure 4.3 which presents the exports of French firms and their employment of foreign workers in 2008. This figure shows a positive and significant correlation between the exported quantities and the employment of foreign workers, which is also true

[10] We obtain similar figures for other years of the sample, thus we only present facts for 2008. This is the case for all coming figures.

for foreign skilled workers (appendix C.2, Figures C.3 and C.4). This result is consistent with previous empirical studies showing the pro-trade effect of immigrants.

We argue that employing immigrant workers may explain why export outcomes are heterogeneous across firms and across destinations. On the one hand, foreign employment differs across firms and intrinsically generates heterogeneity across firms. On the other hand foreign workers provide different information to their firms, depending on their origin countries, which generates heterogeneity across destinations. The rest of the chapter will focus on this argument. We start by presenting the theoretical framework rationalising the effect of immigrant workers on export behaviours, before presenting some empirical results supporting our argument.

4.4 Theoretical framework

In this section, we rest upon the model of Mrázová and Neary (2012) to analyse what the authors call first-order selection effects in a model of monopolistic competition *à la* Melitz (2003). More precisely, we look at the choice of a firm to supply or not a market. We want to analyse whether employing foreign skilled workers (i) determines the choice of the firm to supply a market (its domestic market and any foreign market), and whether (ii) it allows that firm to produce larger quantities for each market it supplies. In other words, we want to know if employing foreign workers fosters trade at the firm-level, at both the extensive and intensive margins.

4.4.1 Model set-up

Let us consider a world with $n+1$ symmetric countries open to trade: a domestic country denoted d and n foreign countries indexed by x.

The domestic country is endowed with a stock of composite labour denoted L. Following Ottaviano and Peri (2012), we assume this composite labour is a constant elasticity of substitution (CES) aggregate made of two types of workers with different levels of qualification, who are assumed to be imperfect substitutes. The subscript e denotes the skill level of a worker such that $e = \{s, u\}$ where s is akin for *skilled* and u is akin for *unskilled* worker. Thereby:

$$L = \left[\sum_{e} \theta^{e} \left(L^{e} \right)^{\frac{\delta - 1}{\delta}} \right]^{\frac{\delta}{\delta - 1}} \; ; \; \forall e = \{s, u\} \tag{4.1}$$

where θ^e denotes the skill-specific productivity level and $\delta\,(>0)$ denotes the elasticity of substitution between the two types of workers. Let us assume that skilled workers are more productive than unskilled workers ($\theta^s > \theta^u$).

Each worker, regardless of his qualification level, is either native from the domestic country or foreign-born. The origin of a worker is denoted by the subscript $o = \{d, m\}$ where d is akin for *domestic* and m is akin for *foreign* worker. In each skill group, native and foreign workers are assumed to be imperfect substitutes, such that:

$$L^e = \left[\sum_o \theta^{eo} \left(L^{eo}\right)^{\frac{\gamma_e - 1}{\gamma_e}}\right]^{\frac{\gamma_e}{\gamma_e - 1}} \;;\; \forall e = \{s, u\} \;;\; \forall o = \{d, m\} \tag{4.2}$$

where θ^{eo} denotes the origin-specific productivity level of workers with qualification e, and $\gamma_e\,(>0)$ denotes the elasticity of substitution between native and foreign-born workers. We allow this elasticity to differ across skill groups.

Ottaviano and Peri (2012) highlight, indeed, that native and foreign workers have different abilities in terms of communication and relational skills, therefore they make different occupational choices. In particular, the authors estimate the elasticity of substitution between US-born and foreign-born workers over the period 1990-2004. After controlling for education and experience, they find robust evidence that these two types of worker are not perfect substitutes.

In our model, foreign workers may come from different countries. That being said, when they have the same level of qualification, we assume they are perfect substitutes and make no distinction between them, such that:

$$L^{em} = \sum_{x=1}^{n} L^{ex} \;;\; \forall e \tag{4.3}$$

where L^{ex} denotes the stock of foreign workers with qualification e who were born in a foreign country x.

We further assume that $\delta < \gamma_e \,\forall e$ so that the substitution pattern is higher between native and foreign-born workers than between skilled and unskilled workers.

Workers are paid at their marginal productivities, and the wage of one unit of labour composite factor equals unity which ensures the factor price equalisation among countries.

In each country, there is a continuum of firms under monopolistic competition indexed by i producing with the labour composite factor. Thus, the number of firms also equals the number of varieties available in the country.

4.4.2 Demand

The preferences of a representative consumer are given by a CES utility function:

$$U = \left[\int_{i\in\Omega} (q_i)^{\frac{\sigma-1}{\sigma}} \mathrm{d}i\right]^{\frac{\sigma}{\sigma-1}} \tag{4.4}$$

where Ω denotes the set of available varieties, q_i is the demand for variety i and σ denotes the elasticity of substitution between any two goods. Note that preferences are identical across countries.

The consumer maximises his utility function subject to the following budget constraint:

$$\int_{i\in\Omega} q_i p_i \mathrm{d}i \leq R \tag{4.5}$$

where p_i is the price of variety i and R denotes the aggregate revenue spent in the country.

Following Dixit and Stiglitz (1977), the aggregate set of varieties consumed as an aggregate good ($Q \equiv U$) and the associated aggregate price are given by:

$$Q = \left[\int_{i\in\Omega} (q_i)^{\frac{\sigma-1}{\sigma}} \mathrm{d}i\right]^{\frac{\sigma}{\sigma-1}} \tag{4.6}$$

$$P = \left[\int_{i\in\Omega} (p_i)^{1-\sigma} \mathrm{d}i\right]^{\frac{1}{1-\sigma}} \tag{4.7}$$

Notice that because of symmetry, aggregate demands and other aggregate variables are equal across countries.

Solving the consumer program by the Lagrangian gives the demand for variety i in the country:

$$q_i = Q\left(\frac{p_i}{P}\right)^{-\sigma} \tag{4.8}$$

and the expenditure on variety i or equivalently the revenue of firm i:

$$r_i = p_i q_i = R\left(\frac{p_i}{P}\right)^{1-\sigma} \tag{4.9}$$

where $R = PQ$.

4.4.3 Supply

Firm's characteristics

Any firm i is characterised by an *exogenous* productivity level denoted ϕ_i, drawn from a random distribution, and by an *endogenous* productivity level denoted α_i. Together, ϕ_i and α_i determine the *global* productivity of the firm, given by $g_i = \phi_i \alpha_i$, so that the function g_i is increasing in both arguments ϕ_i and α_i.

Our first important addition with respect to Melitz (2003), is the endogenous component of the firm's productivity. This component depends on the workforce composition of the firm in term of foreign employment such that:

$$\alpha_i = \alpha(\lambda_i^1, ..., \lambda_i^n) \tag{4.10}$$

where λ_i^x denotes the share of workers born in the foreign country x $(\forall x = 1...n)$ and employed by firm i[11]. The function α is defined over $[0,1]^n$ and concave in its arguments, such that there exists an optimum of the workforce composition that maximises the endogenous productivity of the firm. The function α is symmetric in its arguments.

The positive impact of the composition of the firm's workforce on its endogenous productivity can take place through different channels. First, immigrant workers, disregarding their country of birth, may induce a task specialisation between native and immigrant workers, which enables their firm to be more productive. Second, foreign (skilled) workers, according to their country of birth, may impact the productivity of their firm because multiculturalism is good for creativity, problem solving and innovation. However, the effect of diversity on the firm's productivity may become negative when the share of immigrants becomes large, for instance because communication problems arise. Let us denote the channel through which immigrant workers impact their firm's productivity the *productivity channel*.

In this chapter, we assume that firm i selects the composition of its workforce in order to maximise its global productivity. However, its recruitment, that is its choice of λ_i^x $\forall x$, is constrained by the scarcity of foreign workers on the French labour market. Consequently, its employment of foreign workers is always sub-optimal and:

$$\frac{\partial \alpha_i}{\partial \lambda_i^x} \geq 0 \, \forall \, x = 1...n \tag{4.11}$$

[11] Note that: $\lambda_i^d + \sum_{x=1}^{n} \lambda_i^x = 1$, where λ_i^d denotes the share of workers born in the domestic country and employed by firm i.

so that firm i's endogenous productivity increases or remains unchanged when its share of workers born in country x increases. Different firms may be constrained differently in their choices of foreign employment.

This assumption makes sense because if foreign workers had a negative impact on the productivity of their firm, we would observe no firm employing foreign workers. In this last case, there would be no equilibrium to the model.

In addition, this assumption is reasonable since the share of immigrants in France is not very large over the studied period. According to Brücker et al. (2013), the share of immigrants increased from 6.24% of the French population in 1995 to 7.24% in 2010. Over the total stock of immigrants, skilled foreign workers represented only 11.94% in 1995, and 22.62% in 2010. Thus, foreign labour (and especially foreign skilled labour) can be considered as a scarce resource in France.

Furthermore, firms in our dataset employ on average 0.044% of foreign workers over their total workforce, and between 0.012% and 0.017% of foreign skilled workers. Because of this small proportions, the endogenous productivity of French firms is likely to increase with the number of foreign workers they employ. It is reasonable to assume that a French firm hires a foreign worker to the detriment of a native worker than to the detriment of another foreign worker: the correlation between the normalised Theil index and the share of foreign workers is about -0.57%[12].

Finally, the firm has no intrinsic preference regarding the origin of the foreign workers it hires. The set of foreign workers the firm hires depends on a stochastic process, therefore firms are heterogeneous in their employment of foreign workers born in a country x.

Domestic production

The technology of firm i to produce q_i^d units of goods for the domestic market is given by:

$$c_i^d = w\frac{1}{g_i}q_i^d + f^d \tag{4.12}$$

where w denotes the remuneration of one unit of labour composite factor in the country. Hereafter, the wage is normalised to unity. Each unit of good requires $\frac{1}{g_i}$ unit of the labour composite factor to be produced; thus $\frac{1}{g_i}$ also represents the marginal cost of the firm. f^d is a positive constant greater than unity denoting a domestic market entry cost[13]. Due to this fixed cost, the firm produces under increasing returns to scale.

[12] We find a correlation of -0.59% using the normalised Herfindahl index.
[13] Because we consider a one time-period model, we make no distinction between fixed and sunk costs.

The ex-ante profit of a firm serving the domestic market is denoted by:

$$\pi_i^d = p_i^d q_i^d - c_i^d \tag{4.13}$$
$$= r_i^d - \frac{1}{g_i} q_i^d - f^d \tag{4.14}$$
$$= R\left(\frac{p_i^d}{P}\right)^{1-\sigma} - \frac{1}{g_i} q_i^d - f^d \tag{4.15}$$

After maximisation, we obtain the price of variety i when sold on the domestic market:

$$p_i^d = \left(\frac{\sigma}{\sigma - 1}\right) \frac{1}{g_i} \tag{4.16}$$

Here, because the firm is in monopolistic competition, it charges a fixed mark-up over its marginal cost.

Using equation (4.16), we can re-write the quantity produced by firm i for the domestic market (equation 4.8) as follows:

$$q_i^d = Q\left[P\left(\frac{\sigma - 1}{\sigma}\right) g_i\right]^{\sigma} \tag{4.17}$$

Similarly, the revenue of the firm, given by equation (4.9), can be re-written:

$$r_i^d = R\left[P\left(\frac{\sigma - 1}{\sigma}\right) g_i\right]^{\sigma-1} \tag{4.18}$$

Note that the ratio of any two firms' revenues now depends on the ratio of their productivity levels: $\frac{r_i^d}{r_{i'}^d} = \left(\frac{g_i}{g_{i'}}\right)^{1-\sigma}$. It implies that a high endogenous productivity may compensate a low exogenous productivity, and conversely.

Inserting equations (4.16) and (4.17) in equation (4.15), we find the ex-post profit of firm i realised on the domestic market:

$$\pi_i^d = \frac{R}{\sigma}\left[P\left(\frac{\sigma - 1}{\sigma}\right) g_i\right]^{\sigma-1} - f^d \tag{4.19}$$

Export

The technology of firm i to produce q_i^x units of goods for a foreign market x is given by:

$$c_i^x = \frac{\tau_i^x}{g_i} q_i^x + f_i^x \; ; \; \forall x \tag{4.20}$$

τ_i^x denotes a variable cost to export the merchandise from the domestic country toward a destination country x. This cost is firm-specific and greater than unity such that:

$$\tau_i^x = T^x + \tau\left(\lambda_i^x\right) \mapsto \mathbb{R}^{+*} \tag{4.21}$$

where T^x is a constant greater than unity and where τ represents the firm-specific component of the cost. We assume that immigrant workers decrease the variable export-cost of their firm toward their origin countries, thus:

$$\frac{\partial \tau\left(\lambda_i^x\right)}{\partial \lambda_i^x} \leq 0 \tag{4.22}$$

Then, f_i^x denotes a positive foreign market-entry cost. The latter fixed cost is firm-specific and depends on the firm's employment of foreign workers born in the export destination country. This cost is given by:

$$f_i^x = F^x + f\left(\lambda_i^x\right) \mapsto \mathbb{R}^{+*} \tag{4.23}$$

where F^x denotes a positive cost to enter the foreign market x and where the function f represents the firm-specific component of the cost such that:

$$\frac{\partial f\left(\lambda_i^x\right)}{\partial \lambda_i^x} \leq 0 \tag{4.24}$$

Because these variable and fixed costs are different across export destinations, a firm may not export to all foreign countries. With our dataset on French exporters, we have shown in sub-section 4.3.2, that firms do not export to all possible destinations. They face important costs to conquer a foreign market due to tacit business practices, official regulations and consumers' tastes that differ across countries.

Allowing these costs to differ across countries and to decrease with the employment of immigrants coming from the export destination, is the second important addition we do with respect to Melitz (2003). It allows us to account for the fact that foreign workers provide their employers with valuable information on their origin countries, which reduces both the variable and fixed costs faced by their firms to export toward their origin countries. Let us name the channel through which foreign workers impact the export-costs of their firms the *trade-cost channel*.

We further assume it is more costly to produce for a foreign market than to produce for the domestic market, so that: $f^d \leq f_i^x \ ; \ \forall i \, \forall x \neq d$.

The ex-ante profit of firm i realised on market x is given by:

$$\pi_i^x = p_i^x q_i^x - c_i^x \tag{4.25}$$

$$= r_i^x - c_i^x \tag{4.26}$$

$$= R\left(\frac{p_i^x}{P}\right)^{1-\sigma} - \frac{\tau_i^x}{g_i} q_i^x - f_i^x \tag{4.27}$$

Maximising the profit, we find the price charged by the firm on market x:

$$p_i^x = \left(\frac{\sigma}{\sigma - 1}\right)\frac{\tau_i^x}{g_i} \tag{4.28}$$

Firm i faces the same elasticity of demand on the domestic market than on any foreign market. Thus, the export price is a constant multiple of the domestic price: $\tau_i^x p_i^d$.

Inserting equation (4.28) in equation (4.8), we can re-write the quantity sold on market x:

$$q_i^x = Q\left[P\left(\frac{\sigma - 1}{\sigma}\right)\frac{g_i}{\tau_i^x}\right]^{\sigma} \tag{4.29}$$

Similarly, inserting equation (4.28) in equation (4.9), the revenue of the firm can be re-written:

$$r_i^x = R\left[P\left(\frac{\sigma - 1}{\sigma}\right)\frac{g_i}{\tau_i^x}\right]^{\sigma-1} \tag{4.30}$$

Inserting equations (4.28) and (4.29) in equation (4.27), we find the ex-post profit of firm i realised on market x:

$$\pi_i^x = \frac{R}{\sigma}\left[P\left(\frac{\sigma - 1}{\sigma}\right)\frac{g_i}{\tau_i^x}\right]^{\sigma-1} - f_i^x \tag{4.31}$$

Finally, because $\pi_i^d \geq \pi_i^x \; \forall x \neq d$, if firm i is able to supply market x, it is also able to supply its domestic market. Thus, there is no export-only firm.

4.4.4 First-order selection effects

Our theoretical model allows us to derive some predictions regarding the effect of foreign workers on exports at both margins of trade.

Following Mrázová and Neary (2012), we assume that a general equilibrium exists (providing us with the number of firms and the value of aggregate variables at equilibrium). Our

objective is not to analyse this equilibrium, but rather to focus on firms' export decisions. Thus, we do not solve it in this chapter. As reported by Mrázová and Neary (2012), a number of papers has shown that an equilibrium exists in any general model of monopolistic competition (Negishi, 1961; Arrow and Hahn, 1971). This is likely to be the case for our model. The first assumption we add with respect to Melitz (2003) is the existence of an endogenous productivity component (α_i). The second one is that the variable export-cost decreases with the share of foreign employees coming from the export destination (τ_i^x). These two minor assumptions should not put into question the existence of an equilibrium as the structure of our model remains identical to the initial model of Melitz (2003). The third one is that the fixed cost to enter a foreign market depends on the share of foreign employees coming from that export destination (f_i^x). The same assumption is done by Aubry et al. (2012) and does not put into question the existence of an equilibrium in their paper.

According to Mrázová and Neary (2012), noting that the firm's profit is continuous and decreasing in the marginal cost is sufficient to study the emergence of first-order selection effects. As this is the case for our model, we follow our analysis studying whether the employment of foreign workers impacts a firm's first-order decisions. To do so, we simply compare different firms within the same equilibrium, assuming that firms are small, so that their actions have no impact on the general equilibrium. In other words, we realise a cross-section comparison to understand whether differences in foreign employment induce differences in export behaviours.

Selection into the domestic market

Proposition 1. *The domestic profit of any firm i is an increasing function of its global productivity (g_i) and is given by: $\pi_i^d(g_i)$. Due to the existence of a positive fixed cost to enter the domestic market, $\pi_i^d(0) = -f^d < 0 \ \forall i$. Thus, there exists a unique productivity threshold to enter the domestic market, g^*, such that $\pi^d(g^*) = 0$.*

Corollary 1. Proposition 1 implies that the lowest productivity of producing firms is given by g^*. Firms having a productivity below this minimum would earn a negative profit, thus they do not enter the domestic market.

Proposition 2. *The higher the share of foreign workers coming from any country* $x\,(\forall x = 1...n)$ *employed by firm* i*, the higher its probability to match the entry threshold.*

Proof 2. The domestic profit of firm i can also be written: $\pi_i^d\left(\phi_i, \lambda_i^1, ..., \lambda_i^n\right)$. Its probability to enter the domestic market is given by:

$$\Pr\left(\pi_i^d \geq 0\right) \Leftrightarrow \Pr\left(g_i \geq g^*\right) \tag{4.32}$$

Thus, to serve its domestic market, firm i should meet the following condition:

$$g_i \quad \geq \quad g^* \tag{4.33}$$

which can be re-written:

$$\phi_i \quad \geq \quad \frac{g^*}{\alpha_i} \tag{4.34}$$

$$\Leftrightarrow \phi_i \quad \geq \quad \frac{g^*}{\alpha\left(\lambda_i^1, ..., \lambda_i^n\right)} \tag{4.35}$$

As expected, we find that the level of exogenous productivity (ϕ_i) needed by firm i decreases when its employment of foreign workers from country x increases at the margin:

$$\frac{\partial \phi_i}{\partial \lambda_i^x} \quad = \quad \frac{-\phi_i}{\alpha\left(\lambda_i^1, ..., \lambda_i^n\right)} \frac{\partial \alpha\left(\lambda_i^1, ..., \lambda_i^n\right)}{\partial \lambda_i^x} < 0\,\forall x \tag{4.36}$$

Thus, condition (4.33) is easier to meet for firm i, when its employment of foreign workers increases.

Equivalently, for a given exogenous productivity (ϕ_i), a marginal increase in the share of foreign workers coming from any country x induces an increase in the firm's global productivity:

$$\frac{\partial g_i}{\partial \lambda_i^x} \quad = \quad \phi_i \frac{\partial \alpha\left(\lambda_i^1, ..., \lambda_i^n\right)}{\partial \lambda_i^x} \geq 0\,\forall x \tag{4.37}$$

Thereby, its probability to match the entry threshold increases with its employment of foreign workers:

$$\frac{\mathrm{d}\Pr\left(g_i \geq g^*\right)}{\mathrm{d}\lambda_i^x} \quad \geq \quad 0\,\forall x \tag{4.38}$$

Corollary 2. Proposition 2 implies that for any two firms i and i' only differing in their employment of foreign workers such that: $\lambda_i^x < \lambda_{i'}^x\,\forall x$, then: $\Pr\left(g_i \geq g^*\right) < \Pr\left(g_{i'} \geq g^*\right)$.

This effect takes place through the *productivity channel*.

Proposition 3. *The higher the share of foreign workers coming from any country* $x\,(\forall x = 1...n)$ *employed by firm* i*, the higher the quantity it produces for the domestic market.*

Proof 3. The quantity produced for the domestic market by firm i is given by: $q_i^d\left(\phi_i, \lambda_i^1, ..., \lambda_i^n\right)$. From equations (4.17) and (4.37) we find:

$$\frac{\partial q_i^d}{\partial \lambda_i^x} = \sigma Q\left[P\left(\frac{\sigma-1}{\sigma}\right)\right]^{\sigma} \frac{\partial g_i}{\partial \lambda_i^x}\left(g_i\right)^{\sigma-1} \geq 0\,\forall x \tag{4.39}$$

Thus, a marginal increase in the share of foreign workers coming from any country x increases the firm's productivity, and thereby the quantity it supplies.

Corollary 3. Proposition 3 implies that for any two firms i and i' only differing in their employment of foreign workers such that $\lambda_i^x < \lambda_{i'}^x\,\forall x$, then $q_i^d < q_{i'}^d$. This effect takes place through the *productivity channel*.

Export performance

Proposition 4. *The profit of any firm* i *realised on any foreign market* x *is given by* $\pi_i^x\left(\phi_i, \lambda_i^1, ..., \lambda_i^n\right)$*. Due to the existence of a positive entry cost on market* x*,* $\pi_i^x = 0$ *implicitly defines a threshold function for market* x*:* $\psi_i^x\left(\phi_i, \lambda_i^1, ..., \lambda_i^n\right)$ *with* $\frac{\partial \psi_i^x}{\partial \phi_i} < 0$*.*

Corollary 4. Proposition 4 implies that the lowest ability firm i should have to supply the foreign market x is given by: ψ_i^x. In other words, to enter and serve the foreign market x, firm i should get a positive profit.

Proposition 5. *The higher the share of foreign workers coming from any foreign country* $x\,(\forall x = 1...n)$ *employed by firm* i*, the higher its probability to match market* x*'s entry threshold. This implies that* $\frac{\partial \psi_i^x}{\partial \lambda_i^x} < 0\,\forall x$*.*

Proof 5. Firm i's probability to serve a foreign market x is given by:

$$\Pr\left(\pi_i^x \geq 0\right) \tag{4.40}$$

Let us look at what happens to the profit realised on the foreign market x, when firm i increases its employment of foreign workers coming from country x. From equations (4.31) and (4.37) we find:

$$\begin{aligned}\frac{\partial \pi_i^x}{\partial \lambda_i^x} =& \frac{\sigma-1}{\sigma} R \left[P\left(\frac{\sigma-1}{\sigma}\right)\right]^{\sigma-1} \left(\frac{g_i}{\tau_i^x}\right)^{\sigma-2} \left(\frac{\partial g_i}{\partial \lambda_i^x}\tau_i^x - g_i \frac{\partial \tau_i^x}{\partial \lambda_i^x}\right) \frac{1}{\left(\tau_i^x\right)^2} \\ & - \frac{\partial f_i^x}{\partial \lambda_i^x} > 0\end{aligned} \tag{4.41}$$

We observe three effects due to the increase in foreign employment from country x: an increase in the firm's productivity and a decrease in both the variable and the fixed export-costs for the foreign market x. Thus, firm i's probability to serve market x increases with its employment of foreign workers coming from that export destination:

$$\frac{\mathrm{d}\Pr\left(\pi_i^x \geq 0\right)}{\mathrm{d}\lambda_i^x} \quad \geq \quad 0 \tag{4.42}$$

In addition, let us look at what happens when firm i increases its employment of foreign workers coming from a third country denoted x'. From equations (4.31) and (4.37) we find:

$$\frac{\partial \pi_i^x}{\partial \lambda_i^{x'}} \quad = \quad \frac{\sigma-1}{\sigma} R \left[P\left(\frac{\sigma-1}{\sigma}\right)\frac{1}{\tau_i^x}\right]^{\sigma-1} \left(g_i\right)^{\sigma-2} \frac{\partial g_i}{\partial \lambda_i^{x'}} > 0 \, \forall x' \neq x \tag{4.43}$$

Here, the positive impact of foreign workers on their firm's profit only takes place through the *productivity channel*. Thus, firm i's probability to serve market x increases with its employment of foreign workers coming from country x'.

$$\frac{\mathrm{d}\Pr\left(\pi_i^x \geq 0\right)}{\mathrm{d}\lambda_i^{x'}} \quad \geq \quad 0 \, \forall x' \neq x \tag{4.44}$$

Corollary 5. Proposition 5 implies that for any two firms i and i' only differing in their employment of foreign workers born in country x such that: $\lambda_i^x < \lambda_{i'}^x$, then: $\Pr\left(\pi_i^x \geq 0\right) < \Pr\left(\pi_{i'}^x \geq 0\right)$. Finally, it implies that for any two firms i and i' only differing in their employment of foreign workers born in another foreign country x' such that: $\lambda_i^{x'} < \lambda_{i'}^{x'}$, then: $\Pr\left(\pi_i^x \geq 0\right) < \Pr\left(\pi_{i'}^x \geq 0\right)$.

Empirically, we should observe that the probability to enter a foreign market x positively depends on the firm's employment of foreign workers born in country x. We expect a higher effect for foreign skilled workers. Such an observation would confirm that immigrant workers foster exports toward their origin countries at the extensive margin. Yet, this positive effect could corroborate the existence of both (or either one of) the studied channels: the *productivity channel* and the *trade-costs channel*. Foreign workers from destination x could increase the productivity of their firms, but they could also decrease the variable cost and/or the fixed cost of their firms to export toward their origin countries.

In addition, we should observe that the probability of entry positively depends on the firm's employment of foreign workers born in another country than the export destination. Such an observation would confirm that immigrants impact foreign activities by increasing their firm's productivities, and corroborate the existence of a *productivity channel*.

Proposition 6. *The higher the share of foreign workers coming from any country* $x\,(\forall x = 1...n)$ *employed by firm* i*, the higher the quantity it exports toward a foreign country* x*.*

Proof 6. The quantity exported to any foreign market x by firm i is given by: $q_i^x\left(\phi_i, \lambda_i^1, ..., \lambda_i^n\right)$. Let us look at what happens to the exports of firm i toward market x, when it increases its employment of foreign workers coming from country x. From equation (4.29) we get:

$$\frac{\partial q_i^x}{\partial \lambda_i^x} = \sigma Q\left[P\left(\frac{\sigma-1}{\sigma}\right)\right]^{\sigma}\left(\frac{g_i}{\tau_i^x}\right)^{\sigma-1}\left(\frac{\partial g_i}{\partial \lambda_i^x}\tau_i^x - g_i\frac{\partial \tau_i^x}{\partial \lambda_i^x}\right)\frac{1}{\left(\tau_i^x\right)^2} > 0 \qquad (4.45)$$

Thus, a marginal increase in the share of foreign workers coming from country x induces both an increase in the firm's productivity and a reduction of its variable export-cost, and thereby an increase in the quantity exported toward market x.

Let us look at what happens when firm i increases its employment of foreign workers coming from another foreign country, x'. From equation (4.29) we get:

$$\frac{\partial q_i^x}{\partial \lambda_i^{x'}} = \sigma Q\left[P\left(\frac{\sigma-1}{\sigma}\right)\frac{1}{\tau_i^x}\right]^{\sigma}\left(g_i\right)^{\sigma-1}\frac{\partial g_i}{\partial \lambda_i^{x'}} > 0\,\forall x' \neq x \qquad (4.46)$$

We can conclude that a marginal increase in the share of foreign workers coming from country x' induces an increase in the firm's productivity, and thereby an increase in the quantity exported toward market x.

Corollary 6. Proposition 6 implies that for any two firms i and i' only differing in their employment of foreign workers from country x such that $\lambda_i^x < \lambda_{i'}^x$ then $q_i^x < q_{i'}^x$. In addition, for any two firms i and i' only differing in their employment of foreign workers from country x' such that $\lambda_i^{x'} < \lambda_{i'}^{x'}$ $\forall x' \neq x$ then $q_i^x < q_{i'}^x$.

Empirically, we should observe that foreign workers born in the export destination foster exports at the intensive margin. Yet, this could corroborate the existence of both(or either one of) the *productivity channel* and the *(variable) trade-cost channel*. In addition, we should observe that employing foreign workers from other countries than the export destination fosters exports at the intensive margin. This would corroborate the existence of a *productivity channel* and allows us to conclude on the effect of foreign employment on the intensive margin of trade.

To conclude, Table 4.2 summaries the different effects of foreign workers on the export performance of their firms at both the extensive and intensive margins.

	productivity (g_i)	**variable export-cost** (τ_i^x)	**fixed export-cost** (f_i^x)
$\mathrm{d}\Pr(\pi_i^x \geq 0)/\mathrm{d}\lambda_i^x$	+	+	+
$\mathrm{d}\Pr(\pi_i^x \geq 0)/\mathrm{d}\lambda_i^{x'}$	+	0	0
$\partial q_i^x/\partial \lambda_i^x$	+	+	0
$\partial q_i^x/\partial \lambda_i^{x'}$	+	0	0

Table 4.2.: Effects of foreign workers on their firm's export performance

4.5 Empirical strategy and results

In this section, we detail our empirical strategy to test our theoretical predications. One theoretical result we get is that firms can be ranked, for a given year and a given destination, according to their export performance. Thus, we investigate the effect of foreign workers on their firm's exports by comparing firms at the year-destination level.

Our dataset contains one domestic country, France, and two export zones indexed by x, the European Community (France excluded) denoted EU, and the rest of the world denoted $nonEU$, such that $x = \{EU, nonEU\}$.

We estimate the following equation:

$$\begin{aligned}\text{Perf}^x_{i,t} =& \beta_0 + \beta_1 \text{Mig}_{i,t-1} + \beta_2 \ln \text{CapInt}_{i,t-1} + \beta_3 \ln \text{Employ}_{i,t-1} \\ &+ \beta_4 \ln \text{Age}_{i,t} + \theta^x_t + \rho_s + \varepsilon^x_{i,t}\end{aligned} \tag{4.47}$$

$\text{Perf}^x_{i,t}$ is the dependent variable and denotes the export performance of firm i at time t on a foreign market x. We analyse exports at both the extensive and intensive margins of trade. When studying the extensive margin, we explore the entry and the participation probabilities, as well as the number of export destinations per zone (in logarithm), that is the number of foreign countries in zone x toward which the firm exports, and the number of CN8 products exported per zone (in logarithm). When studying the intensive margin, our dependent variable is the logarithm of the value exported toward zone x, $\text{Perf}^x_{i,t} = \ln\left(q^x_{i,t}\right)$. We consider the total value exported, and do not distinguish by products.

In line with our theoretical model, we include year-destination fixed-effects, θ^x_t, to investigate variations within this dimension, that is across firms at a given time and a given destination[14].

Our main variable of interest is denoted $\text{Mig}_{i,t-1}$ and represents the share of foreign workers (disregarding their region of birth) employed by firm i at time $t-1$. We expect foreign employment to be positively related to the firm's export performance.

We include firm-level controls that may impact firm's performance, and thus the export hierarchy, across firms at a given time and for a given zone. $\text{CapInt}_{i,t-1}$ denotes the firm's capital intensity and is measured by the gross fixed assets per employee, $\text{Employ}_{i,t-1}$ denotes the size of the firm approximated by the number of employees, and $\text{Age}_{i,t}$ is the age of the firm since its creation. We expect the capital intensity and the size of the firm to impact positively its export performance.

We also include sectoral time-invariant dummies, ρ_s, to control for unobserved heterogeneity across sectors. We attribute to each firm the 2-digit sector of its main NC8 exported product. Finally, β_0 is a constant term, β_1, β_2, β_3 and β_4 are parameters to be estimated, and $\varepsilon^x_{i,t}$ is the standard error term. Standard errors are clustered at the sector-year level. We use the White correction for heteroscedasticity.

[14] Since our dataset is zone-specific and not country-specific, it is not straightforward to use macro-level control variables here, such as the bilateral distance or the GDP of the export destination. Thus, we include a set of year-destination fixed-effects in order to control as much as possible for destination-specific unobserved heterogeneity.

In the next sub-sections, we investigate the impact of foreign employment on exports at the extensive and at the intensive margins of trade. We then investigate foreign skilled employment.

4.5.1 Extensive margin of trade

We start by investigating the impact of foreign employment on exports at the extensive margin of trade. Several measures of the extensive margin can be used. First, we investigate the impact of foreign employment on the entry probability. We define the entry dummy variable as such: a firm enters a foreign market x at time t if it did not serve this market at time $t-1$, and serves it at time t. The value of this entry dummy is unconditional to the number of years the firm is serving the market. Due to the size of the sample, we estimate equation (4.47) using a linear probability model (LPM)[15].

Results with respect to the entry probability are presented in the first three columns of Table 4.3. In column 1, we regress the entry dummy variable on the share of foreign workers using the whole sample of firms (EU and non-EU exporters). Surprisingly, the estimate of the effect of immigrant workers on the entry behaviour is not significant, which is not consistent with our theoretical predictions nor with the literature. We replicate this estimation restricting our sample to firms exporting toward non-EU countries in column 2, and to firms exporting toward EU countries in column 3. We find that the nil effect of immigrant workers holds for both sub-samples. However, this result should be considered with caution. The entry dummy variable allows us to capture firms that start exporting only, and excludes information related to the export status of the firms. In other words, we do not take into account firms that are exporters at time $t-1$ and at time t, nor firms that export at time $t-1$ but do not at time t.

We widen the picture by investigating the participation of firms to foreign markets. Using a LPM, we regress a participation dummy variable taking the value of 1 if the firm exports toward a foreign market x at time t, 0 otherwise. Doing so, we only look at the export status of the firm with respect to market x.

Results are presented in the last three columns of Table 4.3. We find that the share of foreign workers has a significantly positive impact on the probability of exporting. The effect is at play when looking at the whole sample of exporting firms (column 4), and when looking at firms exporting either toward non-EU or toward EU countries (columns 5 and 6). The results are now as we expected, but the magnitude of the coefficients is rather low.

[15] To check that the LPM estimates are not misleading, we performed some preliminary estimations using a standard conditional logit model and find results pretty close to those obtained with a LPM. We simply favour LPM estimates to logit estimates because of computational constraints.

Such mixed results regarding the effect of migrants on the extensive margin of trade may be explained by the structure of the data. Since we are working at the zone level, and not at the country level, within-zone variance of entry and participation probabilities across firms is very low. A large set of firms are exporting to both EU and non-EU zones every year, which makes difficult the identification of the effect of foreign employment on exports at the extensive margin.

Dep. variable:	Entry dummy			Participation dummy		
Sample (x)	whole	nonEU	EU	whole	nonEU	EU
	(1)	(2)	(3)	(4)	(5)	(6)
$Mig_{i,t-1}$	-0.002	-0.002	-0.001	0.059^a	0.074^a	0.043^a
	(0.010)	(0.012)	(0.013)	(0.009)	(0.017)	(0.009)
$CapInt_{i,t-1}$	-0.002^a	0.004^a	-0.017^a	0.008^c	0.029^a	-0.012^a
	(0.002)	(0.001)	(0.002)	(0.004)	(0.001)	(0.001)
$Employ_{i,t-1}$	0.018^a	0.017^a	0.022^a	0.047^a	0.077^a	0.017^a
	(0.001)	(0.002)	(0.002)	(0.006)	(0.001)	(0.001)
$Age_{i,t}$	-0.012^a	-0.011^a	-0.015^a	-0.001	-0.000	-0.001
	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)
Observations	254,071	187,059	67,012	1,315,948	657,974	657,974
R^2	0.004	0.005	0.006	0.026	0.058	0.005
Zone-year fixed-effects	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.3.: Extensive margin: entry and participation

We follow our analysis by studying the effect of immigrant workers on an alternative dependent variable. We use the number (in logarithm) of foreign countries toward which a firm exports within a given zone. Here, we only look at exporting firms, thus the dependent variable is non-negative. Using this measure allows us to gain some variance across firms. In addition, this approach is justified by the fact that exporting firms are heterogeneous in many dimensions, including the number of destinations served (Bernard et al., 2012).

Results obtained with a standard OLS procedure are reported in the first three columns of Table 4.4. We find that immigrant workers have a positive and significant impact on the number of destinations served by their firm. A 10% increase in the share of foreign workers employed by a firm, generates a 2.8% increase in the number of foreign destinations served by that firm. This result is stronger when looking at firms exporting toward EU countries (column 3). Thus, the estimate obtained with the whole sample is driven by firms exporting toward the EU, that is to destinations relatively close from France.

Then, we use the number of exported products per zone as an alternative dependent variable. This measure of the extensive margin of trade is used by Hiller (2013) and is in the spirit of the work of Mayer et al. (2014). With respect to our theoretical model, this last dependent variable is the closest definition of the extensive margin of trade we may found. In our theoretical model, each firm produces a single good under monopolistic competition. Thus, it makes sense to include the product dimension in our empirical analysis. Crucially, using this variable allows us to take into account that a large number of firms are multi-product firms.

Results are reported in the last three columns of Table 4.4. Here again, we find that foreign-born workers impact positively and significantly the number of products exported by their firms, the effect being slightly stronger for firms exporting toward the EU zone.

Dep. variable:	ln(nr. of destinations)			ln(nr. of products)		
Sample (x)	whole	nonEU	EU	whole	nonEU	EU
	(1)	(2)	(3)	(4)	(5)	(6)
$Mig_{i,t-1}$	0.286^a	0.274^a	0.294^a	0.374^a	0.355^a	0.385^a
	(0.022)	(0.025)	(0.033)	(0.031)	(0.040)	(0.043)
$CapInt_{i,t-1}$	0.044^a	0.039^a	0.048^a	0.068^a	0.042^a	0.084^a
	(0.002)	(0.004)	(0.002)	(0.005)	(0.003)	(0.004)
$Employ_{i,t-1}$	0.300^a	0.304^a	0.299^a	0.434^a	0.447^a	0.424^a
	(0.004)	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)
$Age_{i,t}$	-0.004	-0.004	-0.004	-0.006	0.001	-0.009
	(0.004)	(0.006)	(0.006)	(0.005)	(0.007)	(0.007)
Observations	879,727	326,586	553,141	895,390	335,894	559,496
R^2	0.177	0.184	0.179	0.256	0.284	0.248
Zone-year fixed-effects	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.4.: Extensive margin: nr. of destinations and nr. of products

Overall, this set of results on the effect of immigrant workers on exports at the extensive margin points toward the following conclusion. Foreign workers seem to provide a *trade premium* to their employing firm. If the entry probability does not seem to be favoured, immigrant workers increase the participation of their employers to foreign markets, the number of destinations served and the number of exported products. We interpret these results as favourable evidence of the positive impact of immigrants on exports at the extensive margin of trade. These results corroborate, among other studies, the paper of Koenig (2009) which provides evidence of the positive impact of regional immigration on the probability of local firms to start exporting.

Finally, in our survey of the literature, we underlined previous evidence showing that foreign workers may positively impact their firm's productivity. This effect may be at play through the increase in diversity among workers, and especially among skilled workers, that enables creativity and innovation within the firm. To test this hypothesis, we replace our measure of foreign employment by an index of place of birth concentration at the firm-level. Results are presented in appendix C.3, Table C.1. We find that all measures of concentration with respect to the region of birth of the employees are inversely and significantly related to the firm's export performance at the extensive margin. In other words, we find that, after controlling for standard firm-level characteristics, culturally diverse firms export to a larger number of destinations and a larger number of products.

4.5.2 Intensive margin of trade

We now investigate if variations in the employment of foreign-born workers impact exported quantities. We estimate equation (4.47) with a standard OLS procedure, using the log-value of the exports as a dependent variable. Results are presented in Table 4.5. We report our baseline estimation for the whole sample of firms in column 1. As we expected, the coefficient associated to the share of foreign workers is positive and highly significant. A 10% increase in the firm's share of immigrant workers increases the quantity exported by around 7%. This result is in line with previous macro and micro-level studies showing a positive and significant impact of immigrants on exports (Hatzigeorgiou and Lodefalk, 2014). Additionally, our estimate is larger than existing studies which find an average elasticity between 1% and 2%; see the meta-analysis of Genc et al. (2012).

Columns 2 and 3 present results of the estimations performed on the two sub-samples respectively restricted to non-EU and to EU exporters. With both sub-samples, we find that employing foreign-born workers has a positive effect on exports at the intensive margin. The estimated coefficients associated to foreign employment appear significantly positive, yet slightly lower for the sample of firms exporting toward the EU. EU exports react relatively less to a change in foreign employment than non-EU exports. If foreign workers provide information about the origin country's market to their firm, this information advantage could be less valuable if immigrants are EU citizens than if they come from a more distant country. In other words, destination-specific information may be more valuable for trading activities with non-EU countries than with EU countries. This would be consistent with the fact that EU countries are close to France in many dimensions such that firms would not require much information to export toward the EU[16].

[16] In section 4.6 we further investigate whether or not the region of birth of the immigrant workers matters.

Dep. variable: $\ln\left(q^{x}_{i,\,t}\right)$			
Sample (x)	whole	nonEU	EU
	(1)	(2)	(3)
$\text{Mig}_{i,\,t-1}$	0.727^{a}	0.802^{a}	0.672^{a}
	(0.062)	(0.057)	(0.082)
$\text{CapInt}_{i,\,t-1}$	0.232^{a}	0.310^{a}	0.184^{a}
	(0.014)	(0.013)	(0.008)
$\text{Employ}_{i,\,t-1}$	0.714^{a}	0.820^{a}	0.650^{a}
	(0.020)	(0.009)	(0.015)
$\text{Age}_{i,\,t}$	-0.193^{a}	-0.284^{a}	-0.133^{a}
	(0.018)	(0.015)	(0.012)
Observations	895,386	335,893	559,493
R^2	0.227	0.267	0.215
Zone-year fixed-effects	yes	yes	yes
Sector dummies	yes	yes	yes
Cluster - sector level	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.5.: Intensive margin

We then test whether our results are driven by our measure of immigration at the firm-level. As suggested by Hatzigeorgiou and Lodefalk (2014), we use the total number of immigrant workers as an independent variable, instead of using the share of immigrant workers. To illustrate the difference, let us take an example with two identical firms only differing in their foreign employment. The first one employs one foreign worker over ten workers, the second one employs ten foreign workers over one hundred workers. Looking at the share of foreign workers, these two firms are perfectly similar and should retrieve the same benefits from employing foreign workers. Nonetheless, doing so, we neglect the fact that each foreign worker may bring some additional benefits to his employing firm, in terms of both productivity and information on foreign markets. Using the number of foreign workers allows us to capture this effect. Results are presented in Table C.2, in appendix C.3. We find similar results as those obtained in Table 4.5, which confirms the positive effect of foreign-born workers on exports at the intensive margin. As expected, the magnitude of the estimate is lower when we use the number instead of the share of foreign workers.

Finally, we replace our measure of foreign employment by an index of place of birth concentration at the firm-level. Results are presented in appendix C.3, Table C.3. Similarly to the results presented for the extensive margin of trade, we find that, after controlling for standard firm-level characteristics, culturally diverse firms export larger quantities.

4.5.3 Foreign skilled workers and exports

We now investigate the effect of foreign skilled workers on export behaviours. Following the literature, these workers are supposed to have more abilities than low-skilled foreign workers to transform their knowledge on foreign markets into real trade opportunities for their firm (Hatzigeorgiou and Lodefalk, 2011). Up to now, we have provided evidence of the pro-trade effect of immigrant workers, unconditionally to their skill level. We expect the effect of foreign skilled workers on their firm's exports to be larger than the effect of foreign workers as a whole (disregarding their qualifications).

We now use as an independent variable the share of foreign skilled workers in the firm's skilled workforce, denoted $\text{SkilledMig}_{i,t-1}$, instead of using the share of foreign workers within the firm. This variable is derived from an index presented in section 4.3, which allows us to rank all workers employed by French firms according to their skill intensity (cognitive or communication skills), and to designate as *skilled* workers the 25% of workers composing the right tail of the distribution.

Extensive margin of trade

First, let us analyse the extensive margin of trade by using the number of export destinations per zone as our dependent variable. In the first five columns of Table 4.6, we report the results when we use the cognitive intensity definition of skilled workers.

In column 1, we replicate the baseline specification presented in Table 4.4 column 1, but we restrict our sample to firms on which we have information on the skill composition of their workforce, in order to get a benchmark coefficient. We find a significantly positive impact of foreign employment on the number of destinations served by the firm.

In column 2, we analyse the share of foreign skilled workers. As we expected, we find that foreign skilled workers have a significantly positive impact on exports at the extensive margin. The elasticity obtained is much larger than the benchmark elasticity obtained in column 1. A 10% increase in the share of foreign skilled workers generates a 2.2% increase in the number of destinations served, while a 10% increase in the total foreign workers generates a 1.3% increase.

In column 3, we add the share of skilled workers – independently of their birth country – within the firm in our specification ($\text{Skilled}_{i,t-1}$). We find that the effect of foreign skilled workers on exports is resistant to the introduction of this variable. Both coefficients associated to foreign skilled workers and skilled workers are significantly positive. In addition,

the coefficient associated to foreign skilled workers is still larger that the benchmark coefficient (column 1). This results is in line with the literature showing that skilled foreign workers have some influence on the strategic decisions of their firms.

In columns 4 and 5, we replicate the same estimations as in columns 2 and 3, but using a more restrictive measure of skilled workers. We now define as skilled workers the 5% of workers composing the right tail of the distribution of skills across workers. These workers are likely to be executives and top-managers, that is to occupy decisional positions within their firm. We nevertheless find no effect of high skilled immigrants on exports at the extensive margin. We believe that this measure may be too restrictive since it reduces drastically the number of firms employing foreign skilled workers. For instance, EU-born and non-EU-born workers both represent on average less than 0.001% of the total skilled workforce.

Then, we look at the number of products exported per zone. Results are presented in the last five columns of Table 4.6. Here again, we find a significantly positive effect of foreign skilled workers on the number of products exported by their firm. A 10% increase in the share of foreign skilled workers generates a 2.9% increase in the number of products exported by the firm (column 7), while a 10% increase in the total foreign employment generates a 1.7% increase (column 6). The introduction of the share of skilled workers in the specification (column 8) does not alter the sign nor the significance level of the coefficient associated to the employment of skilled immigrants. Looking at columns 9 and 10, we still find no effect of foreign top-skilled workers on exports at the extensive margin.

Overall, this set of results provides evidence of the pro-trade effect of skilled foreign workers. As a robustness check, we test whether this effect depends upon the type of skill analysed. We now use jobs' communication intensity to designate workers as *skilled* workers. Results are presented in appendix C.3, Table C.4 and corroborate our previous findings.

Intensive margin of trade

We follow our analysis by looking at exports at the intensive margin. In Table 4.7, we report the results when we use the cognitive intensity definition of skilled workers.

In column 1, we replicate the baseline specification presented in Table 4.5 column 1, but here again we restrict our sample to firms on which we have information on the skill composition of their workforce. We find a significantly positive impact of foreign employment on the number of destination served by the firm.

Dep. variable:	ln(nr. of destinations)					ln(nr. of products)				
Sample (x)	whole	whole	whole	whole	whole	whole	whole	whole	whole	whole
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$Mig_{i,t-1}$	0.132^a					0.174^a				
	(0.017)					(0.025)				
$SkilledMig_{i,t-1}$ (25%)		0.222^a	0.197^a				0.294^a	0.258^a		
		(0.025)	(0.024)				(0.031)	(0.029)		
$SkilledMig_{i,t-1}$ (5%)				0.011	0.042				0.247	0.204
				(0.271)	(0.272)				(0.508)	(0.512)
$Skilled_{i,t-1}$ (25%)			0.182^a					0.274^a		
			(0.018)					(0.035)		
$Skilled_{i,t-1}$ (5%)					-0.215					-0.443^a
					(0.146)					(0.131)
$CapInt_{i,\,t-1}$	0.059^a	0.056^a	0.055^a	0.057^a	0.057^a	0.087^a	0.082^a	0.081^a	0.083^a	0.083^a
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.009)	(0.009)	(0.009)	(0.009)
$Employ_{i,\,t-1}$	0.309^a	0.304^a	0.317^a	0.305^a	0.305^a	0.452^a	0.449^a	0.467^a	0.449^a	0.449^a
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)
$Age_{i,\,t}$	0.010	0.004	0.006	0.002	0.002	0.013	0.008	0.011	0.006	0.006
	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Observations	237,029	237,029	237,029	237,029	237,029	244,989	244,989	244,989	244,989	244,989
R^2	0.180	0.178	0.180	0.178	0.178	0.269	0.274	0.276	0.273	0.273
Zone-year fixed-effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.6.: Extensive margin and cognitive skills

In column 2, we use as an independent variable the share of foreign skilled workers. We find a positive and significant coefficient associated to this variable. As we expected, this elasticity is higher than the elasticity obtained when looking at the share of foreign workers disregarding their skill level (column 1). A 10% increase in the share of foreign skilled workers generates a 5.2% increase in the quantities exported by the firm, while a 10% increase in the total foreign workforce generates a 4.7% increase. Thus, if immigrant workers have a positive effect on the quantities exported, a large part of this effect comes from skilled immigrants. In column 3, we find that the effect of foreign skilled workers on exports is resistant to the introduction of the share of skilled workers in the specification.

In columns 4 and 5, we replicate the same estimations but using a more restrictive measure of skilled workers (5% threshold). Similarly to the results found for the extensive margin of trade, we find no effect of high skilled immigrants on exports at the intensive margin.

As a robustness check, we use jobs' communication intensity to designate skilled workers. Results are presented in appendix C.3, Table C.5, and corroborate our previous findings.

At this stage, our main results are the following: The pro-trade effect of immigrants is clearly at play at both trade margins. The number of destinations served, the number of exported products and the exported value, all positively react to foreign-born employment. We have also presented evidence supporting a larger pro-trade effect of skilled workers. The next section aims at better identifying the channels through which immigrants favour trade at the firm-level.

4.6 Disentangling the *productivity* from the *trade-cost* channel

We follow our analysis by identifying the two effects of immigrant workers emphasised in our theoretical model, namely the *productivity channel* and the *trade-cost channel*. More precisely, we intend to disentangle the effect of foreign workers on the productivity of their firm, from their effect on the variable and fixed export-costs.

To this end, we distinguish foreign workers by region of birth. It allows us to estimate separately the effect of foreign workers born in zone x on the exports of their firm toward zone x, and the effect of foreign workers born in another zone x' on the exports of their firm toward zone x. We expect workers born in the export zone to impact both the productivity of their firm *and* to provide valuable information on their home countries that reduces export-costs. On the contrary, we expect foreign workers who were not born in the

Dep. variable: $\ln\left(q_{i,t}^{x}\right)$					
Sample (x)	whole	whole	whole	whole	whole
	(1)	(2)	(3)	(4)	(5)
$\text{Mig}_{i,t-1}$	0.473^{a}				
	(0.051)				
$\text{SkilledMig}_{i,t-1}$ (25%)		0.519^{a}	0.468^{a}		
		(0.070)	(0.068)		
$\text{SkilledMig}_{i,t-1}$ (5%)				-0.349	-0.346
				(0.612)	(0.617)
$\text{Skilled}_{i,t-1}$ (25%)			0.393^{a}		
			(0.029)		
$\text{Skilled}_{i,t-1}$ (5%)					-0.025
					(0.357)
$\text{CapInt}_{i,t-1}$	0.287^{a}	0.314^{a}	0.313^{a}	0.316^{a}	0.316^{a}
	(0.017)	(0.016)	(0.016)	(0.016)	(0.016)
$\text{Employ}_{i,t-1}$	0.743^{a}	0.743^{a}	0.769^{a}	0.743^{a}	0.743^{a}
	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)
$\text{Age}_{i,t}$	-0.180^{a}	-0.202^{a}	-0.198^{a}	-0.205^{a}	-0.205^{a}
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Observations	244,989	244,989	244,989	244,989	244,989
R^2	0.268	0.269	0.270	0.268	0.268
Zone-year fixed-effects	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.7.: Intensive margin and cognitive skills

export destination to impact only the productivity of their firm and have no information effect. In our specification (equation 4.47), we replace the main variable of interest by the two following variables: $\text{Mig}^{EU}_{i,\,t-1}$ which denotes the share of foreign workers born in the European Union employed by firm i at time $t-1$, and $\text{Mig}^{nonEU}_{i,\,t-1}$ which denotes the share of foreign workers born outside the EU employed by firm i at time $t-1$.

Following the literature, foreign workers may however help their firms to export toward other countries than their origin country, because they have a *general* knowledge about foreign markets. As we look at export zones, and not at countries, this effect of knowledge transferability, that is likely to be higher for foreign markets close to the worker's origin country, is partially taken into account in our estimations.

We first estimate the impact of immigrant workers by region of birth on the extensive margin of trade. We report the results in Table 4.8. In columns 1 and 2, we regress the number of export destinations per zone on different firm-level controls and on the zone-dependent measures of foreign employment. We estimate the effect of both types of immigrants on two sub-samples respectively composed of EU and non-EU exporters. We find that the number of destinations served by the firm outside of the EU are relatively more impacted by immigrants born outside the EU than by immigrants born in the EU (column 1). Similarly, immigrants born in the EU have a larger impact on the number of destinations served by their firm within the EU zone, than immigrants born outside the EU (column 2).

Another way to look at the picture is to focus on the comparison of coefficients across columns. We can infer, comparing columns 1 and 2, that EU-born workers impact more the number of export destinations within the EU zone than the non-EU zone. The converse effect is found for non-EU-born workers. This result suggests that the informational channel of foreign-born workers is at play at the extensive margin.

Then, in columns 3 and 4, we look at the number of products exported per zone. We find similar evidence as when we focus on the number of export destinations per zone. However, comparing coefficients across columns, we see that the informational effect of immigrant workers on the number of products seems to be at play only for non-EU workers.

Finally, we estimate the impact of immigrant workers by region of birth on the exports value per zone. We report the results in Table 4.9. As expected, we find that immigrant workers increase more the exported quantities toward countries of their origin zone than toward other countries. We nevertheless find that the elasticity of EU export flows to the employment of EU-born workers is much larger compared to other elasticities of export flows to foreign employment.

This set of results is in line with our theoretical prediction. On the one hand, we underline that immigrants, disregarding their origin country, have a positive impact the their firm's exports. This could be a first indication that immigrants impact the *productivity* of their firm, and corroborate papers studying the migration-productivity nexus. On the other hand, we show that immigrants convey market-specific information that is likely to reduce variable and fixed export-costs. This evidences the existence of a *trade-cost channel* largely documented in the literature.

Dep. variable:	ln(nr. of destinations)		ln(nr. of products)	
Sample (x)	non-EU	EU	non-EU	EU
	(1)	(2)	(3)	(4)
$\text{Mig}^{EU}_{i,\,t-1}$	0.175^a	0.193^a	0.266^a	0.255^a
	(0.046)	(0.058)	(0.052)	(0.059)
$\text{Mig}^{nonEU}_{i,\,t-1}$	0.218^a	0.186^a	0.286^a	0.237^a
	(0.026)	(0.024)	(0.036)	(0.026)
$\text{CapInt}_{i,\,t-1}$	0.048^a	0.039^a	0.084^a	0.042^a
	(0.002)	(0.004)	(0.004)	(0.003)
$\text{Employ}_{i,\,t-1}$	0.299^a	0.304^a	0.424^a	0.447^a
	(0.006)	(0.005)	(0.006)	(0.005)
$\text{Age}_{i,\,t}$	-0.004	-0.004	-0.009	0.001
	(0.006)	(0.006)	(0.007)	(0.007)
Observations	553,141	326,586	559,496	335,894
R^2	0.179	0.184	0.248	0.341
Zone-year fixed-effects	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes

Standard errors in parentheses. Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.8.: Extensive margin and foreign employment by zone of birth

4.7 Endogeneity concerns and alternative empirical strategy

An important endogeneity concern when estimating the impact of immigration on trade is the existence of the reverse causality. As documented in the paper of Hatzigeorgiou and Lodefalk (2014), existing studies adopting instrumental variable techniques show that the causal relation runs from migration to trade. However, the authors underline that this result may not be generalised. It may well be the case that migration depends on the conditions of the host country's labour market, which in turn depend on the importance of trade in that country's economy.

Dep. variable: $\ln\left(q_{i,t}^{x}\right)$		
Sample (x)	nonEU	EU
	(1)	(2)
$\text{Mig}_{i,t-1}^{EU}$	0.458^{a}	1.008^{a}
	(0.017)	(0.060)
$\text{Mig}_{i,t-1}^{nonEU}$	0.497^{a}	0.505^{a}
	(0.077)	(0.073)
$\text{CapInt}_{i,t-1}$	0.185^{a}	0.310^{a}
	(0.008)	(0.013)
$\text{Employ}_{i,t-1}$	0.650^{a}	0.819^{a}
	(0.015)	(0.009)
$\text{Age}_{i,t}$	-0.133^{a}	-0.284^{a}
	(0.012)	(0.015)
Observations	559,493	335,893
R^2	0.216	0.267
Zone-year fixed-effects	yes	yes
Sector dummies	yes	yes
Cluster - sector level	yes	yes

Standard errors in parentheses.
Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table 4.9.: Intensive margin and foreign employment by zone of birth

At the micro-level, firms may favour the employment of foreign workers coming from the destinations with which they already have a commercial experience, or where they intend to export. In other words, firms' export performance may determine their decisions to employ immigrant workers. To the best of our knowledge, only one paper evidences this reverse causality at the firm-level. Molina and Muendler (2013) show that firms planning to export prepare their workforce by hiring workers from other exporters, in order to get a better access to the foreign market targeted.

The estimations presented previously might thus present an endogeneity bias. Ideally, we would need an instrumental variable at the firm-level that impacts the firm's foreign employment but not its exports. We could use an instrument at the regional-level, for instance lagged regional immigration stocks as done by Koenig (2009) or the average number of immigrants employed in other firms in the same industry as done by Hiller (2013). However, using a regional-level instrument does not allow us to keep the firm-level dimension of our analysis.

We therefore propose an alternative empirical strategy that allows us to keep information on foreign employment at the firm-level. We estimate the average treatment effect of employing immigrant workers on export behaviours. To do so, we use the propensity score matching (PSM) method which is now widely used in the estimation of treatment effects (Rosenbaum and Rubin, 1983). This method allows us to overcome the problem that firms employing immigrant workers may be different from firms employing none[17].

We consider the effect of an increase in foreign employment between time $t-2$ and time $t-1$ on export behaviours. Let T_i denotes the treatment dummy variable for firm i taking the value of 1 if $\text{Mig}_{i,\,t-1} > \text{Mig}_{i,\,t-2}$, and 0 otherwise. We are able to identify two groups of firms, the treated group formed by all firms with $T_i = 1\,\forall i$, and the non-treated group formed by all firms with $T_i = 0\,\forall i$.

The first step of this estimation technique is to check that the economic characteristics (except the export performance) of the two groups of firms are not statistically different, to ensure that our estimation will not be biased by a selection effect among the two groups. In Table C.6 (appendix C.3), we present some descriptive statistics for the two groups of firms. We also present the T-statistics showing whether or not the mean of each variable is equal among the two groups. The null hypothesis cannot be rejected for all variables, suggesting that treated firms are not different, on average, from firms that are not treated.

[17] Of course, we bear in mind that a PSM approach allows us to deal with endogeneity issues only because we assume that we can observe most of the factors driving the potential bias, that is all important variables that impact a firm's treatment. The richness of our dataset allows us to believe that selection on unobservables is negligible, and that the PSM approach allows for causal inference.

Then, using a standard logit model, we regress the treatment dummy variable (T_i) on various firm-level observables[18]. We consider here variables that are well-know to be compatible with gravity firm-level equations. Estimation results are presented in Appendix, section C.3, Table C.7.

We are able to assign to each firm an estimated probability – a score – to be treated using the predicted values derived from the logit estimation. This score allows us to match a treated firm i ($T_i = 1$) with one non-treated firm i' ($T_{i'} = 0$) that exhibits a score close to the score of firm i. We can then investigate differences in export outcomes between treated and non-treated firms, that is between firms having very close probabilities to employ immigrant workers, but which are actually different in their foreign employment.

For both margins, the estimated average treatment effect on treated firms is presented in Table 4.10, column 1. The three coefficients are positive and highly significant, which confirm our previous findings obtained using a standard regression analysis. Being treated leads, *ceteris paribus*, to an increase in export outcomes, that is in the number of export destinations, the number of products exported and the exported quantities. Thus, both margins of trade react positively to foreign employment.

In the next columns of the table, we study different treatment effects[19]. In column 2, we look at an increase in the number of foreign workers between time $t-2$ and time $t-1$, instead of looking at an increase in the share. We still find a significantly positive impact of foreign employment on export behaviours. As we expected, the magnitude of this effect is lower when we look at the increase in the number than when we look at an increase in the share.

We then study the effect of an increase in the employment of foreign-born workers between time $t-5$ and time $t-4$ in order to control for remaining endogeneity concerns. Estimated results presented in column 3 are significantly positive confirming previous results on both margins of trade. In addition, the coefficients are higher as compared to those obtained in column 1, suggesting that immigrants need time to integrate within their firm and thus to impact the productivity and the export decisions of their firm.

To check the robustness of these results, we reproduce the same estimations using an alternative matching algorithm. We use a 5-neighbour instead of a one-to-one matching algorithm which allows us to check whether our results depend upon the matching strategy we use or not. Instead of comparing a treated firm with the closest non-treated firm, we now com-

[18] We have also used a probit model, and results are qualitatively similar to the ones presented in the current version of this work. Those results are available upon request to the authors.

[19] Although not reported here, we perform a first-stage analysis for each treatment variable and find no selection bias between the two groups of firms studied.

pare a firm with the five closest non-treated firms. Results are presented in Table 4.11. We find that our results do not seem to be driven by the matching algorithm, and confirm the positive effect of foreign workers on exports at both margins. Not surprisingly, the magnitude of the effects is lower when we use a 5-neighbour rather than a one-to-one matching algorithm, simply because the matching operation is less precise.

Then, we investigate whether our results on foreign skilled workers are robust to the estimation technique used. The treatment now consists to increase the share of foreign skilled workers. We first use the cognitive dimension to define skilled workers. Results obtained with the one-to-one matching algorithm are presented in Table 4.12 and confirm the pro-trade effect of skilled foreign workers. We find that skilled foreign workers have a positive impact on both trade margins. This result is robust to the use of 4-year lags. It is also robust to the use of the measurement of skills (appendix C.3, Table C.8). The treatment effects obtained are, in most cases, higher than the effects obtained when looking at an increase in the total foreign employment of the firm (Table 4.10, column 1).

We check the robustness of our results using a 5-neighbour matching algorithm. Results are presented in appendix C.3, Tables C.9 and C.10, and are consistent with previous evidence despite the lower precision of the matching procedure.

We finally investigate whether our results on foreign workers by zone of birth hold when we use a PSM method. The regression analysis allow us to control for both variations in the employment of the EU-born and non-EU-born workers simultaneously, but doing so using the PSM technique is less straightforward. We instead consider the following treatment: a firm i is treated if its share of EU-born workers increases relatively more than its share of non-EU-born workers between time $t-2$ and time $t-1$. Estimates for both trade margins are presented in Table 4.13. In column 1, we restrict the sample of firms to non-EU exporters, and in column 2 we restrict the sample to EU exporters. We find that all estimates are positive and significant. We also find that an increase in the share of non-EU workers relatively to the share of EU-workers favour more exports toward non-EU countries than toward EU countries. This result suggests that immigrants favour trade through both a *productivity* and a *trade-cost channel*. For each dependent variable, we can interpret the difference between the two coefficients as an indirect measure of the trade-cost channel. Additionally, the largest discrepancy between the estimates of the two sub-samples is observed for the number of exported products. This suggests that exporting products to distant markets requires information about local consumer's tastes and preferences.

We check the robustness of our results using 4-year lagged variables to build our treatment variable. Results are reported in Table 4.14. We also reproduce our analysis using a 5-

neighbour matching algorithm. These results are reported in appendix C.3, Tables C.11 and C.12. All those tests confirm our previous findings and thus the robust positive effect of immigrant workers on exports at both margin of trade.

Sample (x): whole			
	(1)	(2)	(3)
Treatment	$Mig_{t-1} > Mig_{t-2}$	$Mig^{nb}_{t-1} > Mig^{nb}_{t-2}$	$Mig_{t-4} > Mig_{t-5}$
ln(nr. of destinations)	0.208^a	0.165^a	0.310^a
	(0.006)	(0.006)	(0.007)
ln(nr. of products)	0.336^a	0.289^a	0.445^a
	(0.007)	(0.007)	(0.008)
$\ln\left(q^x_{i,t}\right)$	0.316^a	0.217^a	0.534^a
	(0.012)	(0.013)	(0.015)

Standard errors in parentheses. Intercept not reported.

^{a} denotes significance at the 1% level.

Table 4.10.: Exports and foreign workers – PSM (one-to-one matching algorithm)

Sample (x): whole			
	(1)	(2)	(3)
Treatment	$Mig_{t-1} > Mig_{t-2}$	$Mig^{nb}_{t-1} > Mig^{nb}_{t-2}$	$Mig_{t-4} > Mig_{t-5}$
ln(nr. of destinations)	0.072^a	0.036^a	0.186^a
	(0.004)	(0.004)	(0.005)
ln(nr. of products)	0.120^a	0.078^a	0.248^a
	(0.004)	(0.005)	(0.006)
$\ln\left(q^x_{i,t}\right)$	0.136^a	0.060^a	0.374^a
	(0.009)	(0.009)	(0.010)

Standard errors in parentheses. Intercept not reported.

^{a} denotes significance at the 1% level.

Table 4.11.: Exports and foreign workers – PSM (5-neighbour matching algorithm)

4.8 Conclusion

This chapter investigates the pro-trade effect of immigrants at the firm-level. Theoretically, we rationalise the effect of immigrant workers on their firm's exports at both margins of trade. We show that immigrant workers convey valuable information about their home countries which reduces the variable and the fixed export-costs of their firm. In addition, we evidence that immigrants increase their firm's productivity, which, in turn, increases exports. We underline that the intensive margin is determined by both the productivity and variable export-costs of the firm, while the extensive margin is also determined by fixed export-costs. Our theoretical framework predicts that the probability to export and the quantities exported should positively react to the employment of foreign workers.

Sample (x): whole		
	(1)	(2)
Treatment	$\text{SkilledMig}_{t-1} > \text{SkilledMig}_{t-2}$	$\text{SkilledMig}_{t-4} > \text{SkilledMig}_{t-5}$
ln(nr. of destinations)	0.233[a]	0.344[a]
	(0.010)	(0.013)
ln(nr. of products)	0.354[a]	0.474[a]
	(0.011)	(0.015)
$\ln\left(q_{i,t}^{x}\right)$	0.311[a]	0.562[a]
	(0.020)	(0.26)

Standard errors in parentheses. Intercept not reported.

[a] denotes significance at the 1% level.

Table 4.12.: Exports and cognitive skills – PSM (one-to-one matching algorithm)

Sample (x)	nonEU	EU
	(1)	(2)
Treatment	$\left(\text{Mig}_{t-1}^{EU} - \text{Mig}_{t-2}^{EU}\right) < \left(\text{Mig}_{t-1}^{nonEU} - \text{Mig}_{t-2}^{nonEU}\right)$	$\left(\text{Mig}_{t-1}^{EU} - \text{Mig}_{t-2}^{EU}\right) < \left(\text{Mig}_{t-1}^{nonEU} - \text{Mig}_{t-2}^{nonEU}\right)$
ln(nr. of destinations)	0.496[a]	0.319[a]
	(0.009)	(0.011)
ln(nr. of products)	0.606[a]	0.324[a]
	(0.011)	(0.012)
$\ln\left(q_{i,t}^{x}\right)$	0.839[a]	0.623[a]
	(0.017)	(0.021)

Standard errors in parentheses. Intercept not reported.

[a] denotes significance at the 1% level.

Table 4.13.: Exports and foreign employment by zone of birth (I) – PSM (one-to-one matching algorithm)

Sample (x)	nonEU	EU
	(1)	(2)
Treatment	$\left(\text{Mig}_{t-4}^{EU} - \text{Mig}_{t-5}^{EU}\right) < \left(\text{Mig}_{t-4}^{nonEU} - \text{Mig}_{t-5}^{nonEU}\right)$	$\left(\text{Mig}_{t-4}^{EU} - \text{Mig}_{t-5}^{EU}\right) < \left(\text{Mig}_{t-4}^{nonEU} - \text{Mig}_{t-5}^{nonEU}\right)$
ln(nr. of destinations)	0.482[a]	0.388[a]
	(0.012)	(0.014)
ln(nr. of products)	0.665[a]	0.363[a]
	(0.014)	(0.015)
$\ln\left(q_{i,t}^{x}\right)$	0.846[a]	0.756[a]
	(0.022)	(0.027)

Standard errors in parentheses. Intercept not reported.

[a] denotes significance at the 1% level.

Table 4.14.: Exports and foreign employment by zone of birth (II) – PSM (one-to-one matching algorithm)

Using a French firm-level dataset over the period 1995-2008, we find a positive effect of foreign-born workers on the number of destinations served, the number of exported products and the quantities exported by their firm. Our results are robust to the use of the propensity score matching method to evaluate the effect of foreign employment on export outcomes. In line with the literature, we find that the pro-trade effect of foreign workers is driven by skilled foreign workers.

In order to disentangle the two channels emphasised in our theoretical model, we distinguish workers by regions of birth. We find that immigrant workers from the EU favour relatively more exports at both margins toward EU countries than immigrants born outside the EU. In addition, we find that immigrants from the EU favour relatively more exports at both margins toward EU countries than toward non-EU countries. These results suggest that both *productivity* and *trade-cost channels* are at play.

Our results suggest some policy recommendations to favour French exports. Pro-active immigration policies, particularly selective immigration policies aiming at increasing the skill content of immigration, could create a favourable environment for exporting activities. In that respect, a simplification of labour regulations for skilled immigrants could create employment incentives for French firms. This would, in turn, create favourable conditions within the employing firm to start exporting or to expand their export activities.

Finally, policy makers should bear in mind that any change in the French migration policy could impact French exports. For instance, a change in the selection of immigrants by region of birth, could lead to trade creation and/or trade diversion effects. This is due to the fact that immigrants not only impact their firm's productive performance, but also their firm's export-costs toward their origin regions.

Part II

International migration and migration policies

5 How do migration policies impact migration flows? A RUM model with budget constraint

This chapter has been written in collaboration with Claire NAIDITCH.

5.1 Introduction

Since the 2008 crisis, developed countries have been tightening their migration policies (Castles et al., 2014). Because national sovereignty prevails in terms of immigration (Goldin et al., 2011), they tend to do so unilaterally, without collaborating with neighbouring developed countries nor with migrant sending countries. Although it is now common knowledge that economies are highly interconnected, it is not clear if and how the migration policies of one country impact migration flows to that country and to the rest of the world. Improving our understanding of these interactions would enable us to know whether countries may find a tangible interest to further collaborate on migration issues.

In this chapter, we address the following question: how does the migration policy of one potential destination country impact migration flows to that country and to other destination countries? Theoretically, a change in the migration policy of a potential destination implies a change in the migration cost to that country. This, in turn, implies at the same time a change in the net utility of migrating to that destination and either a contraction or a relaxation of the budget constraint of would-be migrants; thus it affects important determinants of individual migration decisions. For instance, if a potential destination tightens its migration policy regime, the cost of emigrating toward that country increases. This in turn implies a decrease in the net utility of migrating to that destination. If this decrease is important, then the destination country becomes less attractive and fewer individuals intend to emigrate there. But even if this destination remains attractive, the migration cost may become too high for some individuals who then either remain in their home country or migrate to another country.

Empirical papers have shown that the budget constraint weighs heavily on migration decisions. There is an important discrepancy between migration intentions and migration decisions. Lacking resources, some individuals are caught in a poverty trap and cannot afford to migrate even if they intend to do so. Richer individuals can afford to migrate to some countries but not necessarily to all destination countries (Hatton and Williamson, 2005). Based on the Gallup World Survey 2012 and on the database of bilateral migration stocks built by Artuc et al. (2015), Docquier et al. (2015) estimate about 386.1 million the number of *potential* migrants in 2010. Yet, only 28.9% of them were actual migrants, the rest were individuals who *desired* migrating but did not migrate.

Recent contributions make use of the Random Utility Maximisation framework to analyse individual migration decisions[1]. In this framework, an individual selects his destination country in order to maximise his utility across all potential destinations, including his home country. His utility is made of a deterministic component that the researcher can estimate and an error term. The deterministic component includes variables which are identical across individuals such as the expected wage or the bilateral migration cost. The error term consists in a random variable which accounts for unobserved heterogeneity among individuals, such as preferences over destination countries. The number of potential destinations is the same across individuals and includes any country open to immigration. Once the model solved, the assumption of independence from irrelevant alternatives (IIA) holds: the bilateral migration rate between two countries only depends on the attributes of both origin and destination countries, and on the bilateral migration cost, and does not depend on other countries characteristics and policies.

In this chapter, we explicitly introduce the role of the budget constraint in the migration decision. In our RUM model, bilateral migration costs depend on the migration policy of destination countries. As standard in the literature, individuals choose their migration destination in order to maximise their utility across all possible destinations, including their home country. However, only individuals who can afford the migration cost to a potential destination country are able to migrate to that country. The number of potential destinations thus differs across individuals. Once we analytically solve the model, we find that the bilateral migration rate between two countries depends on the attributes of both origin and destination countries, the bilateral migration cost, and a budget constraint effect. Interestingly, the latter effect depends on attributes of alternative destination countries. Thus,

[1] RUM models find their origin in the income maximisation framework of Roy (1951), and discrete choice models in particular logit type models developed by McFadden (1974) and McFadden (1984). They have been introduced in the economics of migration by Borjas (1987) and Borjas (1999) to study the determinants of migration flows. His work forms the basis for a recent body of theoretical and empirical studies of migration; among others see Grogger and Hanson (2011) and Beine et al. (2015a).

when considering individual budget constraints in a standard RUM model, the IIA assumption does not hold anymore and *multilateral resistance to migration* arises.

In order to derive some insights from our RUM model, we propose a numerical experiment based on the European case. In 2011, 9.7% of the total European Union population were foreign-born individuals; one third of them were intra-EU migrants (Simon, 2015). Over time, intra-EU migration for work purposes has been facilitated by several agreements between European states. Yet, when some eastern European countries joined the EU in 2004[2], they did not have a straight access to labour markets of the first fifteen EU members called "Old member states" countries in the rest of this chapter. Old member states had the possibility to restrict access to their labour markets to immigrants coming from these new member states, for a maximum period of 7 years. Some did restrict entrance, some did not. We can then wonder what would have been the consequences on intra-European migration if all western countries had opened their borders to immigrants coming from new member states in 2004.

To tackle this question, we calibrate a standard RUM model and a RUM model with budget constraint on 25 European countries in 2008, when part of western European countries did not implement restrictions anymore, while another part was still protecting its labour market from immigration from eastern Europe. We show that introducing the budget constraint does improve the explanatory power of the RUM model.

We then simulate a complete relaxation of the German migration policy toward eastern European states. Our results confirm that the budget constraint matters. In line with our theoretical model, we show that a loosening of the German migration policy increases (or leaves unchanged) the migration rate from new member states toward Germany. We also find that migration rates from new eastern European member states toward other destination countries decrease (or remain unchanged).

The contribution of this chapter to the economic literature is twofold. First, our work contributes to the literature on the role of individual budget constraints on migration decisions. According to Beine et al. (2015a), there is an empirical literature asserting the role of credit constraints on migration decisions. These papers estimate gravity models assuming that the bilateral migration cost is negatively correlated with the income of the origin country. However, to the best of our knowledge, no RUM model explicitly takes into account the role of budget constraints on migration decisions. Second, our work corroborates the importance to consider *multilateral resistance to migration* when analysing bilateral migration, in line with the studies of Bertoli and Fernández-Huertas Moraga (2013) and Bertoli et al. (2013).

[2]Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia.

This result calls, in a way, for more dialogue between countries implementing unilateral or bilateral migration policies, and the rest of the world.

The rest of the chapter is organised as follows. In section 5.2 we survey the related literature. In section 5.3 we present a RUM model of migration in which we introduce a budget constraint. In section 5.4 we present a numerical experiment. Section 5.5 concludes.

5.2 Credit constraints, migration policies and migration flows

Our work is related to different strands of literature. First, it contributes to the literature on the importance of budget constraints on migration decisions. Second, this chapter contributes to the literature on the determinants of migration. More precisely, we analyse how migration policies partly determine migration flows taking into account the concept of multilateral resistance to migration.

5.2.1 Credit constraints and migration decisions

Empirical studies carried out so far clearly establish that bilateral migration flows are mainly determined by the wealth differential between origin and destination countries and by the related bilateral migration cost (Hatton and Williamson, 2005; Mayda, 2010; Beine et al., 2015a). On the one hand, the wealth differential is often captured by economic, social, political and demographic variables related to the origin and the destination countries. The latter are often referred to as *push* and *pull* factors, which respectively determine the power of repulsion of the origin country and the power of attraction of the destination country. On the other hand, the migration cost depends on the geographic distance between the origin and the destination countries (the distance in kilometres and the existence of a common border), the cultural distance (the existence of a common language, a common religion and/or colonial ties), the size of the diaspora in the destination country[3], and institutional variables such as the general migration policy implemented in each country and bilateral agreements implemented between the related two countries. These institutional costs arise from various sources: official fees for documents and clearances, payments to intermediaries, travel expenses, payments of bribes, etc. (UNDP, 2009).

[3]Through relationships of solidarity or reciprocity, former migrants decrease the migration costs of new migrants by facilitating their arrival, their administrative procedures, their access to employment and housing, etc. (Beine et al., 2011a).

A rather large literature highlights that there is a high discrepancy between migration intentions and migration decisions, due to financial constraints: many people would like to migrate but cannot afford the migration cost. In their extensive study on the determinants of world migration, Hatton and Williamson (2005) have shown that potential migrants may be constrained by their poverty. Similarly, in a theoretical and empirical contribution based on Gallup World Poll data, Dustmann and Okatenko (2014) show that when the credit constraint is binding (which is the case in Sub-Saharan Africa and in Asia), migration decisions increase with income; in the opposite case (in Latin America for instance), migration decisions are not much affected by wealth. Several empirical analysis focusing on different countries confirm the fact that budget constraints are binding in terms of international migration flows from developing countries; it seems to be the case in Bangladesh (Mendola, 2008), Mexico (McKenzie and Rapoport, 2007; McKenzie and Rapoport, 2010; Angelucci, 2013), and El Salvador (Halliday, 2006) but not in Norway (Abramitzky et al., 2013). In their survey of empirical studies on the determinants of migration flows, Beine et al. (2015a) conclude that credit constraints do hinder migration flows.

Thus, migration decisions are determined not only by the characteristics of origin and destination countries (*e.g.* in terms of wealth differentials) and by the preferences of the individuals, but also by the capacity of the latter to afford their migration. The budget constraint of a potential migrant is determined by his income on the one hand, and by the bilateral migration cost on the other hand. It may be relaxed either when the financing capacity of the individual increases – the individual can get richer, save or borrow money through the banking system of his origin country or through familial and network relationships – or when the migration cost decreases – for instance when the diaspora gets larger in the targeted destination country or when that country loosens its immigration policy regime.

More precisely, the cost of migrating from a country k toward a destination country k' depends on the migration policies implemented by both countries. First, it could be impacted by the unilateral migration policies implemented by country k. Yet, impediments to emigration have become rather small, most countries now recognising the right to emigrate (Wihtol de Wenden, 2013). Second, unilateral migration policies implemented by country k' have a more important impact on the bilateral cost. This cost increases with any impediment to immigration (quota limitations, admission restrictions, cost of the visa, etc.). Finally, the bilateral cost can be impacted by any bilateral agreement. For instance, it is negatively related with the implementation of pro-migration programmes between country k and country k' (guest-worker programmes, policies aiming at better informing would-be migrants on the living conditions and work opportunities at destination, etc.).

When a country tightens its migration policy, it impacts the cost of migrating to that country and thus migration to that destination. Does it also impact migration flows to other countries?

5.2.2 Credit constraints and multilateral resistance to migration

In order to model how push and pull factors and migration costs impact migration flows, economists estimate dyadic gravity models. Beine et al. (2015a) review the theoretical foundation of dyadic gravity models of international migration, the RUM model, and the main challenges arising when taking this model to the data. One issue underlined by the authors is the need to account for *multilateral resistance to migration*: bilateral migration is determined not only by the characteristics of origin and destination countries, but also by both countries' interactions with the rest of the world.

The concept of *multilateral resistance* comes from the trade literature and was first introduced by Anderson and Van Wincoop (2003). In their pioneering paper, they reconcile the gravity equation extensively used in the empirical literature with the theoretical model proposed by Anderson (1979). They show that the theory lying behind the gravity equation requires to consider *multilateral resistance* in gravity type estimations. This concept relates the idea that trade between two countries depends on *relative* trade barriers. In other words, trade from a country i toward a destination j not only depends on the *absolute* bilateral costs existing between the two countries, but also on their *relative* importance with respect to other bilateral costs (between any supplier country i' and destination j, and between country i and any potential destination j'). Omitting multilateral resistance when estimating a gravity equation potentially leads to biased results (Anderson and Van Wincoop, 2003; Anderson and van Wincoop, 2004; Anderson, 2011). Yet, the concept remains, in a lot of empirical papers, sort of a black box filled in with different unobservable factors and captured by various sets of fixed-effects (Behar and Nelson, 2014).

Coming back to migration, population movements from a country k toward a country k' may be impacted by a change in the characteristics of a third country k'' (in terms of wealth, demography, migration policies, etc.) and especially by a change in the bilateral migration policy between country k and k''. Migration policies may be the most time-varying factors (as compared to wealth and demography) and therefore the most important to consider when analysing bilateral migration flows over time.

Theoretically, Beine et al. (2015a) explain that multilateral resistance to migration may arise in a RUM model either *(i)* from the assumption made on the distribution of the error term defined in the utility function associated to the migration decision (Bertoli and Fernández-Huertas Moraga, 2013), or *(ii)* from explicitly modelling the sequential nature of migration decisions in the RUM model (Bertoli et al., 2013).

In their study, Bertoli and Fernández-Huertas Moraga (2013) estimate a nested logit model, which allows them to relax the assumption that the error term is independent and identically distributed (iid.) over individuals and destinations (assumption usually used in standard RUM models in order to estimate logit models). By doing so, they do not impose the IIA assumption. Their framework allows them to show that the bilateral migration rate between two countries depends not only on their relative attractiveness, but also on those of alternative destinations (static multilateral resistance to migration). Using the CCE estimator with high-frequency data on Spanish immigration flows over the period 1997-2009, they find that neglecting such multilateral resistance to migration biases downward the estimated effect of GDP at origin and biases upward the estimated effect of visa policies on migration flows to Spain.

Bertoli et al. (2013) also exhibit dynamic multilateral resistance to migration but with a sequential RUM model of migration. In their model, the bilateral migration rate between two countries depends on the present attractiveness of both countries, the future attractiveness of alternative destinations, and the whole structure of time-invariant bilateral migration costs. The authors use migration data from the countries of the European Economic Association toward Germany over the period 2006-2012. They show that the European crisis diverted migration flows away from countries in difficulties toward Germany. Making use of the CCE estimator, they find that variations in the unemployment rate at origin positively influences bilateral migration toward Germany, and note that this effect is overestimated by standard specifications which do not control for the presence of multilateral resistance to migration.

To the best of our knowledge, the latter papers are the only ones explicitly dealing with multilateral resistance to migration. Our work contributes to this emerging literature. As in trade, multilateral resistance to migration is indeed a large concept which refers to any third-country effects on bilateral migration flows. In this chapter, we show that multilateral resistance to migration also arises when considering that individuals are financially constrained in their migration choices.

5.3 A RUM model of migration with budget constraint

In this section, we model the migration decision of an individual i considering P destinations, including his country of actual residence, country k. Following the literature on migration decisions, we start from a standard RUM model of migration, in which we introduce the budget constraint faced by potential migrants.

5.3.1 A standard RUM model

To decide whether or not he wants to migrate and where, individual i maximises his utility subject to his budget constraint.

Following Beine et al. (2015a), we assume that individual i takes myopic decisions, deciding whether or not to migrate and where at each period of his life-time. His utility of migrating from country k to country k' can be written:

$$U_i^{k,k'} = W^{k,k'} - C^{k,k'} + \epsilon_i^{k,k'} \tag{5.1}$$

where $W^{k,k'}$ represents a deterministic component of the utility in country k' (for instance the expected average revenue), $C^{k,k'}$ is the deterministic financial cost of migration paid before migrating (with $C^{k,k} = 0$), and $\epsilon_i^{k,k'}$ is an individual-specific stochastic term. The bilateral migration cost between two countries is composed of two parts: a financial cost of migration *per se* (here denoted $C^{k,k'}$) and a psychological cost of being away from home. In the present chapter, we consider that the psychological cost differs across individuals; it is then included in the individual-specific stochastic term.

The gross utility (before subtracting the bilateral financial migration cost) is given by: $V_i^{k,k'} \equiv W^{k,k'} + \epsilon_i^{k,k'}$.

As standard in the migration literature, we assume that $\epsilon_i^{k,k'}$ is independent and identically distributed over individuals and destinations, and follows a univariate Extreme Value Type-1 distribution with a unit scale parameter. Assuming that the ϵ's are iid. imposes the IIA property.

In a standard RUM model, individual i *intends* and *decides* to migrate to country h if and only if this destination maximises his utility. Thus, individual i migrates to country h if:

$$\arg\max_{l=1...P} U_i^{k,l} = h \tag{5.2}$$

Following the results of McFadden (1974) and McFadden (1984), the unconditional probability that an individual relocates from country k to destination k' is given by:

$$p^{k,k'} = \Pr\left(U_i^{k,k'} = \max_{l=1...P} U_i^{k,l}\right) = \frac{e^{\left(W^{k,k'} - C^{k,k'}\right)}}{\sum_{q=1}^{P} e^{(W^{k,q} - C^{k,q})}} \tag{5.3}$$

Similarly, the unconditional probability that an individual remains in country k is given by:

$$p^{k,k} = \Pr\left(U_i^{k,k} = \max_{l=1...P} U_i^{k,l}\right) = \frac{e^{W^{k,k}}}{\sum_{q=1}^{P} e^{(W^{k,q} - C^{k,q})}} \tag{5.4}$$

The bilateral migration rate is given by the ratio of these two probabilities:

$$M^{k,k'} = \frac{p^{k,k'}}{p^{k,k}} = \frac{e^{\left(W^{k,k'} - C^{k,k'}\right)}}{e^{W^{k,k}}} = \frac{e^{\left(W^{k,k'} - W^{k,k}\right)}}{e^{C^{k,k'}}} \tag{5.5}$$

As underlined by Beine et al. (2015a), this bilateral migration rate depends only on the characteristics of origin and destination countries, and on the bilateral migration cost. This is representative of the IIA property: any change in the attractiveness or accessibility of other destinations will not impact the bilateral migration rate from country k to country k'. In other words, there is a proportional substitution across alternative destinations.

5.3.2 A RUM model with budget constraint

However, the literature shows that migration intentions and migration decisions differ, partly because individuals are financially constrained. Thus, credit constraints must be introduced in the model: individual i will be able to reach his favourite destination only if he can afford the related migration cost. In other words, individual i *decides* to migrate to country h if and only if he *intends* to go to country h *and* he can pay for the migration cost: $w_i^k \geq C^{k,h}$, where w_i^k denotes the financial resources of individual i in country k.

To account for the fact that budget constraints may be binding, we do not introduce any credit market in our model. Doing so, we assume that individuals cannot finance the cost of migrating thanks to a banking system or family solidarity. Individuals can only afford destinations for which the bilateral migration cost is lower than their wealth[4].

We assume that the income of individual i located in country k $\left(w_i^k\right)$ follows a distribution φ with parameters μ^k and σ^k. The corresponding cumulative distribution function is denoted by Φ. Thereby, the probability that individual i cannot afford the cost to migrate from

[4]This assumption is coherent with the fact that individuals are myopic.

country k to destination k' is given by $\Pr\left(w_i^k < C^{k,k'}\right) = \Phi\left(C^{k,k'}\right)$. *A contrario*, the probability that he can migrate is given by: $\Pr\left(w_i^k \geq C^{k,k'}\right) = 1 - \Phi\left(C^{k,k'}\right)$.

The decision tree

Figure 5.1 represents the decision tree of individual i. The sequence of decisions goes like this:

- At first, Nature attributes an income to the individual i located in country k, w_i^k.
- Then, individual i is able to rank all destinations (his current country of residence included) from the worst to the best one. The individual's favourite destination maximises his utility. h denotes the first-best destination of the individual, such that:

$$\arg\max_{l=1...P} U_i^{k,l} = h \tag{5.6}$$

  If $h = k$, individual i stays in country k because staying is the utility-maximising option. If $h \neq k$, he migrates to country h only if he can afford the bilateral migration cost, *i.e.* if $w_i^k \geq C^{k,h}$. In this last case, he pays the cost of his migration $\left(C^{k,h}\right)$ and migrates to country h. If destination h is the utility-maximising option but is not affordable, the individual looks at his second-best destination, denoted h', such that:

$$\arg\max_{l=1...P\,;\,l\neq h} U_i^{k,l} = h' \tag{5.7}$$

  The individual then checks if he can afford his second-best destination. If he can, he migrates to that destination. If not, he goes through the process all over again, until he finds the best affordable destination.

- At the end of the process, individual i gets the utility corresponding to his country of residence. If he is located in country k, he gets $U_i^{k,k}$; if he is located in country h, he gets $U_i^{k,h}$; and so forth.

Equivalently, individual i could first identify affordable destinations, and then choose among this set of countries the one that maximises his utility. Although this sequence of decisions is more straightforward, such a presentation partly dissimulates the effect of the budget constraint on the migration decision. It does not allow to see whether the chosen destination is the one that maximises the utility of individual i, or a second order choice.

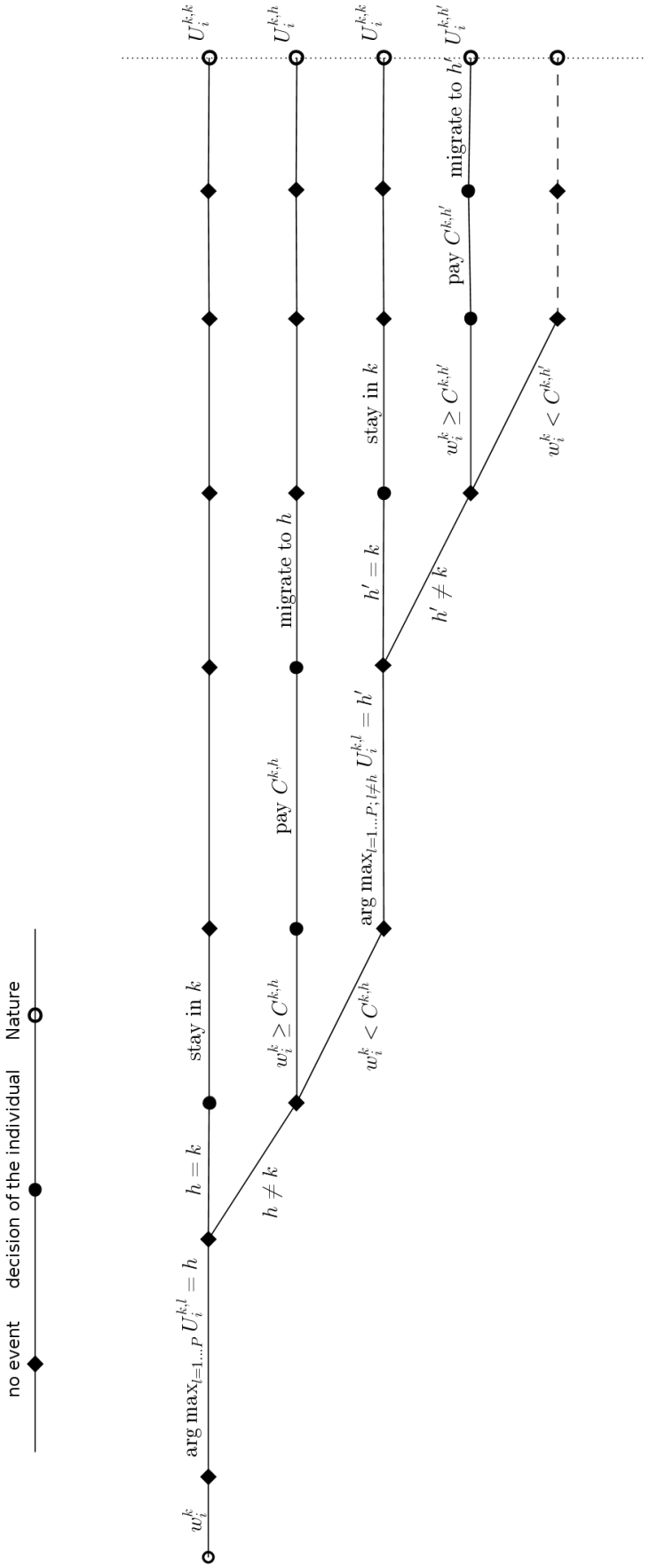

Figure 5.1.: Decision tree of individual i

Taking into account the budget constraint has important consequences. Depending on their resources, individuals do not face the same set of possible destinations. Simply said, very poor people cannot afford to migrate at all (although migrating to some destinations would probably enhance their utility), while very rich people can probably afford almost all or all the destinations of the world. The unconditional probabilities of migrating to any country must reflect these differences in the set of affordable destinations. Hereafter, these probabilities are denoted with the subscript BC when we take into account the Budget Constraint (BC).

Probabilities and migration rates with BC

The migration cost being different over destinations, individual i is able to rank the potential destinations (his current country of residence, country k, included) from the less to the most costly one. Let $\theta(k,k')$ be the rank of country k' when destinations are ranked in increasing order of migration cost from country k:

$$\forall k,k',k'' \in \{1,\ldots,P\}^3,\ \theta(k,k') < \theta(k,k'') \Longleftrightarrow C^{k,k'} < C^{k,k''} \tag{5.8}$$

For every k, $\theta(k,k')$ is a permutation from $\{1,\ldots,P\}$ to $\{1,\ldots,P\}$. Note that, as there is no cost for an individual to stay in his current country of residence $\left(C^{k,k}=0\right)$, country k is the least costly destination from country k, thus $\theta(k,k)=1$.

Let $\kappa(k,l)$ be the inverse permutation of $\theta(k,k')$: $\theta(k,k')=l \Longleftrightarrow \kappa(k,l)=k'$. $\kappa(k,l)$ is the country ranked l by increasing order of migration cost. The fact that $\theta(k,k)=1$ implies that $\kappa(k,1)=k$.

Following the results of McFadden (1974) and McFadden (1984), the unconditional probability that individual i relocates from country k to destination k', taking into account the BC, is given by:

$$p_{BC}^{k,k'} = A^{k,k'} e^{W^{k,k'}-C^{k,k'}} \tag{5.9}$$

with:

$$A^{k,k'} = \sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right]-\Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} \tag{5.10}$$

where we use the convention $C^{k,\kappa(k,P+1)}=\infty$ so that $\Phi\left[C^{k,\kappa(k,P+1)}\right]=1$.

Similarly, the unconditional probability that individual i stays in country k, taking into account the BC, is given by:

$$p_{BC}^{k,k} = A^{k,k} e^{W^{k,k}} \tag{5.11}$$

with:

$$A^{k,k} = \sum_{l=1}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \tag{5.12}$$

Calculations of these probabilities are presented in appendix D.1.

The bilateral migration rate with BC between country k and country k' is given by the ratio of the probability that individual i migrates to country k' over the probability that he does not migrate:

$$M_{BC}^{k,k'} = \frac{p_{BC}^{k,k'}}{p_{BC}^{k,k}} = f^{k,k'} \frac{e^{W^{k,k'} - W^{k,k}}}{e^{C^{k,k'}}} = f^{k,k'} M^{k,k'} \tag{5.13}$$

where:

$$f^{k,k'} = \frac{A^{k,k'}}{A^{k,k}} = \frac{\sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}}{\sum_{l=1}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}} < 1 \tag{5.14}$$

and denotes the *budget constraint effect*.

The migration rate with BC is equal to the migration rate without BC (equation 5.5) times a term summarising the budget constraint effect: $f^{k,k'}$. In standard RUM models without BC, the budget constraint term equals unity.

We can illustrate the difference between the two rates with a simple example of a two-country world. Imagine an individual i living in country k and receiving the income w_i^k. He has the choice between staying in country k or migrating to country h. If he stays in country k, he gets utility $U_i^{k,k} = V_i^{k,k}$ (since $C^{k,k} = 0$); if he migrates to country h, he gets the gross utility $V_i^{k,h}$ minus the bilateral migration cost $C^{k,h}$. Assume that: $w_i^k < C^{k,h} < V_i^{k,h} - V_i^{k,k}$. This implies that the individual intends to migrate to country h (since $V_i^{k,k} < V_i^{k,h} - C^{k,h}$) but cannot afford the migration cost (since $w_i^k < C^{k,h}$). Thus, if the BC is not taken into account, this individual will be counted as a migrant in the bilateral migration rate; if the BC is taken into account, he will not.

For two countries k' and k'' such that $C^{k,k'} < C^{k,k''}$, we know that $\theta(k,k') < \theta(k,k'')$. The ratio of migration rates equals (*cf.* appendix D.1):

$$\frac{M_{BC}^{k,k''}}{M_{BC}^{k,k'}} = \frac{p_{BC}^{k,k''}}{p_{BC}^{k,k'}} = \frac{f^{k,k''}}{f^{k,k'}} \frac{M^{k,k''}}{M^{k,k'}} < \frac{M^{k,k''}}{M^{k,k'}} \tag{5.15}$$

Thus, the budget constraint decreases relatively more the attractiveness of the most costly destinations compared to the less costly ones.

The term summarising the budget constraint effect depends not only on the attributes of countries k and k', but also on the attributes of alternative destinations. In standard RUM models, the IIA assumption implies that the bilateral migration rate does not depend on other destinations' characteristics. Here, even if we assume that the individual-specific stochastic term, $\epsilon_i^{k,k'}$, follows an iid. Extreme Value Type-1 distribution and that individuals are myopic, the bilateral migration rate depends on the attributes of alternative countries thanks to the introduction of the individual budget constraint in the modelling of the migration decision. Multilateral resistance to migration thus arises.

5.3.3 Comparative statics

Income, substitution and budget constraint effects: studying migration probabilities

The RUM model (standard or with BC) allows us to determine the unconditional probabilities to migrate to any destination country. The migration probability toward a destination depends on the attributes of the origin and destination countries, but also on the attributes of other potential destinations. We can then anticipate the consequences of a change in the migration policy of one destination on migration rates to that country and to other destinations.

In a standard RUM model

When destination k' tightens its migration policy toward country k, it increases the related bilateral migration cost $C^{k,k'}$. In turn, the probability of migrating toward country k' decreases because that country becomes less attractive. From equation (5.3) we find:

$$\frac{\partial p^{k,k'}}{\partial C^{k,k'}} = p^{k,k'}\left(p^{k,k'} - 1\right) < 0 \tag{5.16}$$

In addition, when migrating toward country k' becomes more expensive, alternative countries become relatively more attractive than country k'. From equation (5.3) we find:

$$\frac{\partial p^{k,k''}}{\partial C^{k,k'}} = p^{k,k'} p^{k,k''} > 0 \ \forall k'' \neq k' \tag{5.17}$$

In particular, when the migration cost increases, staying in country k becomes relatively more attractive. Thus, the probability to stay in country k increases. Indeed, from equation (5.4) we find:

$$\frac{\partial p^{k,k}}{\partial C^{k,k'}} = p^{k,k'} p^{k,k} > 0 \ \forall k' \tag{5.18}$$

These changes in the probabilities are linked to the fact that the *attractiveness* of one destination depends not only on its characteristics (wealth, amenities...) but also on its migration policy. If one destination country relaxes its migration policy, then that country becomes relatively more attractive because the bilateral migration cost decreases. Thus, the country attracts more migrants. Conversely, if that country tightens its migration policy, then the country becomes less attractive relatively to other destination countries because the bilateral migration cost increases. Thus, the country attracts less migrants.

In a RUM model with budget constraint

The results are qualitatively similar but quantitatively different in a RUM model with BC. Calculations of the derivatives presented hereafter are detailed in appendix D.2.1.

First, when destination k' tightens its migration policy toward country k, the probability of migrating toward country k' decreases because that destination becomes less attractive, but also because the individual budget constraint becomes more binding (the capacity of the individual to afford this migration decreases). From equation (5.9) we find:

$$\frac{\partial p_{BC}^{k,k'}}{\partial C^{k,k'}} = \left(\frac{\partial A^{k,k'}}{\partial C^{k,k'}} - A^{k,k'} \right) e^{\left(W^{k,k'} - C^{k,k'}\right)} \leq 0 \tag{5.19}$$

Any increase in the bilateral migration cost between country k and country k' increases the *relative attractiveness* of any other country k'' $(\neq k')$, but also the *relative capacity* of the

individual to afford migration toward these alternative destinations. From equation (5.9) we find:

$$\frac{\partial p_{BC}^{k,k''}}{\partial C^{k,k'}} = \frac{\partial A^{k,k''}}{\partial C^{k,k'}} e^{\left(W^{k,k''} - C^{k,k''}\right)} > 0 \ \forall k'' \neq k' \tag{5.20}$$

In particular, when the cost of migrating increases, staying in country k becomes relatively more attractive and less expensive. The probability to stay in country k increases when the cost of migrating toward any destination increases. From equation (5.11) we find:

$$\frac{\partial p_{BC}^{k,k}}{\partial C^{k,k'}} = \frac{\partial A^{k,k}}{\partial C^{k,k'}} e^{W^{k,k}} > 0 \ \forall k' \tag{5.21}$$

These changes in the migration probabilities can be related to changes in the relative attractiveness of destination countries like in a standard RUM model, but also to *income* and *substitution* effects.

When a country tightens its immigration policy, it increases the *price* of migrating toward that country. On the one hand, destination k' becomes relatively less attractive than other countries, thus the individual may find more interesting to migrate to another destination. On the other hand, because the budget constraint of the individual is binding, an increase in the price of destination k' may prevent him from migrating toward country k' even if k' remains his maximising option, and constrain him to choose an alternative destination.

Individual i can either migrate to one destination or to another, but not to both destinations at the same time. Migration to one country is thus "perfectly substitutable" to migration to another country. In that case, the income effect is quite small whereas the substitution effect can be very high:

- For any increase in the cost of migrating toward country k', each would-be migrants considering migration to country k' sees his real income decrease; emigration toward the country tightening its migration policy may thus decrease. This income effect is already partly taken into account in the standard RUM model since the individual considers the *net* utility of migration to take his decision.

- In addition, potential migrants are subject to a substitution effect. For a sufficient price increase, the cost of migrating to country k' relative to the cost of migrating to another country may become so high that individual i substitutes migration to another country to migration to country k'. Emigration toward country k' should decrease,

whereas emigration toward other destinations (including the origin country) should increase.

Let us go back to our previous example of a two-country world where individual i had the choice between staying in country k or migrating to country h. Assume that: $C^{k,h} < w_i^k < V_i^{k,h} - V_i^{k,k}$. Because migrating is the utility maximising option and because the budget constraint is not binding, individual i intends and decides to migrate from country k to country h.

Assume now that the bilateral migration cost from country k to country h increases because the former tightens its migration policy. In that case, there are three possibilities:

- First, if the bilateral migration cost increases such that the previous inequality remains unchanged ($C^{k,h[1]} < w_i^k < V_i^{k,h} - V_i^{k,k}$), then individual i will still migrate from country k to country h. Whether the BC is included or not in the model, individual i's predicted behaviour is the same.

- Second, if the bilateral migration cost increases such that $w_i^k < C^{k,h[2]} < V_i^{k,h} - V_i^{k,k}$, then individual i intends to migrate from country k to country h (since $V_i^{k,k} < V_i^{k,h} - C^{k,h[2]}$) but cannot afford this migration (since $w_i^k < C^{k,h[2]}$); thus he will not migrate. In that case, individual i's predicted behaviour is not the same whether the BC is included or not in the model.

- Third, if the bilateral migration cost increases so much that $w_i^k < V_i^{k,h} - V_i^{k,k} < C^{k,h[3]}$, then individual i does not intend to migrate to country h anymore as migrating is not the utility maximising option anymore. Whether the BC is included or not in the model, individual i's predicted behaviour is the same.

In the second and third cases, individual i changes his migration decision because of the increase in the bilateral migration cost from country k to country h. In the second case, h is still the most attractive destination but he cannot afford to reach that destination anymore; in the third case, h is not the most attractive destination anymore.

In the last two cases, the question remains as to where this individual would go instead. In our example, he only had the choice between two countries. But if he had had the choice between several countries, instead of staying in country k, he may have decided to go to a third destination h' more attractive than country k ($V_i^{k,h'} - C^{k,h'} > V_i^{k,k}$) and affordable ($C^{k,h'} < w_i^k$), either because country h' becomes more attractive than country h ($V_i^{k,h'} - C^{k,h'} > V_i^{k,h} - C^{k,h}$), or because country h has become unaffordable ($V_i^{k,h'} - C^{k,h'} < V_i^{k,h} - C^{k,h}$ and $C^{k,h'} < w_i^k < C^{k,h}$).

To conclude, as long as the bilateral migration cost only slightly increases (case 1), the income effect is negligible and there is no substitution effect; individual i still migrates to country h. On the other hand, when the migration cost increases sufficiently (such that $w_i^k < C^{k,h}$, case 2 and 3), the income and substitution effects are such that the individual substitutes migration to another country to migration to country h.

Impact of migration policies on bilateral migration rates

The RUM model allows us to determine the bilateral migration rate between any country-pair. Without BC, the bilateral migration rate depends only on the characteristics of origin and destination countries and on their relative accessibility. However, when we include the BC, the bilateral migration rate also depends on the attractiveness and accessibility of other potential destinations.

One question then arises: how does a change in the migration policy of one potential destination country impact migration rates to that country, and to other destination countries? In other words, what is the importance of *multilateral resistance to migration* in our model?

In a standard RUM model

The answer to that question is straightforward when the BC is not taken into account. When country k' tightens its migration policy toward country k, the bilateral migration cost increases. Consequently, less individuals find migration toward country k' interesting and the bilateral migration rate from country k to country k' decreases. Indeed, from equation (5.5), we find that:

$$\frac{\partial M^{k,k'}}{\partial C^{k,k'}} = -M^{k,k'} \leq 0 \tag{5.22}$$

When country k' tightens its migration policy toward country k, the bilateral migration rate from country k to any alternative country k'' $(\neq k')$ does not change. From equation (5.5), we find that:

$$\frac{\partial M^{k,k''}}{\partial C^{k,k'}} = \frac{\partial}{\partial C^{k,k'}}\left(\frac{p^{k,k''}}{p^{k,k}}\right) = 0 \;\; \forall k'' \neq k' \tag{5.23}$$

The ratio of migration probabilities remains constant when the migration policy of destination k' changes, because the two probabilities ($p^{k,k}$ and $p^{k,k''}$) change in the same propor-

tion. Here we observe a proportional substitution across alternative destinations; the model exhibits the IIA assumption.

In a RUM model with budget constraint

However, the results are different when the BC is explicitly taken into account in the RUM model. Calculations of the derivatives presented hereafter are detailed in appendix D.2.2.

First, when the bilateral migration cost from country k to country k' increases at the margin, then among those who would have migrated from country k to country k' before the increase, some may not intend to migrate anymore to country k', and some may still intend to migrate to country k' but not be able to afford this migration anymore. From equation (5.13), we get:

$$\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} = M_{BC}^{k,k'} \left(\frac{1}{p_{BC}^{k,k'}} \frac{\partial p_{BC}^{k,k'}}{\partial C^{k,k'}} - \frac{1}{p_{BC}^{k,k}} \frac{\partial p_{BC}^{k,k}}{\partial C^{k,k'}} \right) \leq 0 \tag{5.24}$$

Intuitively, we expect that $\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} \leq \frac{\partial M^{k,k'}}{\partial C^{k,k'}} (\leq 0)$. Without considering the budget constraint, a marginal change in the bilateral migration cost from country k to country k' reduces the corresponding bilateral migration rate because destination k' becomes unattractive for some individuals. But when we account for the budget constraint, the bilateral migration rate from country k to country k' should reduce even more because destination k' becomes unattractive for some individuals, and unaffordable for some others (who still consider country k' as their utility maximising option).

Then, when country k' tightens its immigration policy toward country k, it also affects the bilateral migration rates from country k to any other country. From equation (5.9), we get:

$$\frac{\partial M_{BC}^{k,k''}}{\partial C^{k,k'}} = M_{BC}^{k,k''} \left(\frac{1}{A^{k,k''}} \frac{\partial A^{k,k''}}{\partial C^{k,k'}} - \frac{1}{A^{k,k}} \frac{\partial A^{k,k}}{\partial C^{k,k'}} \right) \forall k'' \neq k' \tag{5.25}$$

In case the alternative destination k'' is less expensive than destination k' $\left(C^{k,k''} < C^{k,k'}\right)$, we find that:

$$\frac{\partial M_{BC}^{k,k''}}{\partial C^{k,k'}} = M_{BC}^{k,k''} \left(\frac{1}{A^{k,k''}} - \frac{1}{A^{k,k}} \right) \frac{\partial A^{k,k}}{\partial C^{k,k'}} \geq 0 \tag{5.26}$$

This implies that when country k' tightens its migration policy toward country k, then among those who would have migrated to k' before the policy change, more decide to migrate to another country k'' less expensive than country k' than to stay in country k.

Unfortunately, we are unable to sign the derivative when $C^{k,k'} < C^{k,k''}$. If $\exists\, k'' \neq k'$ s.t. $C^{k,k'} < C^{k,k''}$ and $\frac{\partial M_{BC}^{k,k''}}{\partial C^{k,k'}} > 0$, this would mean that among those who would have migrated to country k' before the policy change, more decide to migrate to country k'' than to stay in country k. Conversely, if $\exists\, k'' \neq k'$ s.t. $C^{k,k'} < C^{k,k''}$ and $\frac{\partial M_{BC}^{k,k''}}{\partial C^{k,k'}} < 0$, this would mean that among those who would have migrated to k'' before the policy change, more decide to stay in country k than to migrate to country k'.

In the RUM model with BC, the IIA assumption does not hold anymore: when country k' tightens its migration policy toward country k, it impacts the bilateral migration rate from country k to other countries. This effect relates to the presence of multilateral resistance to migration.

5.4 Numerical experiment

In order to derive some insights from our theoretical model and to see whether a RUM model with BC has a better explanatory power than a standard RUM model, we propose a numerical experiment based on the European Union. The advantage of such approach is twofold.

First, simulation techniques are less data demanding than an econometric approach. More precisely, the analytic expression of the bilateral migration rate with BC (equation 5.13) cannot be estimated with a standard econometric approach, the effect of the budget constraint on migration decisions being unobserved. In addition, this unobserved factor is much likely to be correlated with some observable regressors, to be serially correlated, and to be spatially correlated across origin-destination dyads. In such a case, one may use the CCE estimator of Pesaran (2006), as proposed by Bertoli and Fernández-Huertas Moraga (2013) and Bertoli et al. (2013) in their papers on the *static* and *dynamic* multilateral resistance to migration. This estimator allows the unobserved term to be heteroskedastic, serially and spatially correlated, and correlated with other regressors. In their papers, Bertoli and Fernández-Huertas Moraga (2013) and Bertoli et al. (2013) show that the results obtained with the CCE estimator are more consistent than those obtained with standard econometric techniques simply introducing fixed-effects to control for the presence of unobserved factors.

Thus, using this estimator seems the most appropriated manner to deal with *multilateral resistance to migration*[5].

This estimator requires balanced panel data on bilateral migration flows toward at least one destination country, from at least 30 origin countries and for at least 20 time periods. Unfortunately, high-frequency panel data on bilateral migration flows are poorly available. The quality of annual (or decennial) flow data is not sufficient enough to use this estimator.

Second, a simulation exercise allows us to deepen our theoretical analysis, in particular to identify the sign of equation (5.25) in case $C^{k,k'} < C^{k,k''}$.

Of course, this approach also presents some drawbacks, the main one being that our results cannot be compared to the few existing studies on the multilateral resistance to migration.

Our numerical experiment is based on the European Union. In 1957, the Treaty of Rome established the right for European citizens to circulate freely within the European area. This right was further affirmed in 1985 by the Schengen convention that abolished border controls within signatory states, and in 1997 by the Treaty of Amsterdam. The latter treaty can be seen as the first concrete step toward a common EU migration policy (Simon, 2015)[6]. Within the EU, no restriction to migration for work purposes are implemented[7].

When eight eastern European countries joined the EU in 2004, old member states had the possibility to restrict access to their labour markets to immigrants coming from these new member states, for a maximum period of seven years. In return, new member states could also implement restrictions. Ireland, Sweden and the United Kingdom did not implement any restriction. Finland, Greece, Italy, Portugal and Spain implemented some restrictions until 2006; Luxembourg and the Netherlands until 2007; France until 2008; Belgium, Denmark, and Norway until 2009, and Austria, Germany and Switzerland until 2011 (Pytliková, 2014). Therefore, between 2004 and 2011, some restrictive bilateral migration policies were still in place between some old members and the new EU states. We propose to take advantage of the disparities in migration policies within European countries between 2004 and 2011 to develop our numerical exercise.

Our objective is to analyse the consequences of a change in the migration policy of old members toward new EU states, on intra-European migration. To this end, we specify equations (5.5) and (5.13) to simulate the bilateral migration rates without and with BC

[5] See Beine et al. (2015a) for a review of alternative econometric techniques, their advantages and their limitations.

[6] The Schengen area does not perfectly overlap with the European Union area. Within each zone, people can circulate freely across borders. No border controls are implemented within the Schengen area.

[7] Within the Schengen area, individuals can move freely for work purposes for a maximum of 90 days.

between 25 European countries in 2008. We then look at what happens to European migration when one western country, for instance Germany, softens its migration policy. Finally, we realise a number of robustness tests.

5.4.1 Model specification

We perform a calibration exercise using 25 European countries in 2008[8]. This sample includes Switzerland, Norway and all EU member states (in 2007) but Luxembourg[9], Malta, Romania and Bulgaria. This sample of countries exhibits variations in terms of migration policies (in 2007): two countries are not part of the EU, and 12 countries are not in the Schengen area (*cf.* appendix D.3).

Our exercise consists in calibrating two models. First, we calibrate the standard RUM model in order to generate bilateral migration rates as close as possible to real data. Second, we repeat this exercise for the RUM model with BC.

In the next sub-sections, we present the data we use to calibrate our models. Then, we present the specification of the *theoretical* bilateral migration rates without and with BC. More precisely, we specify the deterministic component of the utility ($W^{k,k'}$), the bilateral migration cost ($C^{k,k'}$), and the income distribution in country k.

Observed bilateral migration rates

We denote the *observed* bilateral migration rate between country k and country k' by $M_{obs}^{k,k'}$. We approximate this rate by taking the ratio of the immigration flow from country k to country k' in 2008, over the population of country k in 2008.

Population data come from the World Population Prospects (2012 Revision) of the United Nations Development Programme (UNPD).

Immigration flows of foreign citizens in 2008 by reporting countries are not available for all studied country-pairs. When possible, we use the International Migration Flows to and from Selected Countries (2010 Revision) of the UNPD. For Ireland and the United Kingdom,

[8] Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), the Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), the United Kingdom (GBR).

[9] Although data are available for Luxembourg and although it is an important host country – in 2013, immigrants represented about 43% of its population (Simon, 2015) – we exclude this country from the analysis because it generates incoherent results in our simulations. Luxembourg is a very small country both in terms of population and area, and its GDP per capita is more than twice the average EU GDP per capita. Therefore, when we simulate migration rates within Europe, we find that this country attracts an extremely large number of migrants, which is not true in the real world.

we use data from the International Migration Database of the OECD[10]. No immigration data are available for Belgium and Greece. Appendix D.4 summarises immigration data for each reporting country. Over the 625 country-pairs studied, we can recompose 413 *observed* bilateral migration rates.

Theoretical bilateral migration rates

To specify equations (5.5) and (5.13), we first assume that the deterministic component of the utility of individuals living in country k and intending to migrate toward country k', $W^{kk'}$, is akin to the expected average revenue in country k' in 2008 ($W^{k,k'} = W^{k,k'}_{2008}$). We further assume that this average revenue is the same for all individuals, regardless of their origin countries, such that: $W^{k,k'}_{2008} = W^{k'}_{2008} \forall k$.

We assume that individuals forecast their expected wage in 2008 by following a basic reasoning[11]:

$$W^{k'}_{2008} = E\left(W^{k'}_{2008}\right) = (1+r)\, W^{k'}_{2007} \tag{5.27}$$

where $r = \frac{W^{k'}_{2007} - W^{k'}_{2006}}{W^{k'}_{2006}}$ is the growth rate of $W^{k'}$ between 2006 and 2007. We respectively approximate $W^{k'}_{2007}$ and $W^{k'}_{2006}$ by the GDP per capita (in purchasing power parity in constant 2011 international $) of country k' in 2007 and 2006 (from the World Development Indicators of the World Bank).

Then, we specify the bilateral migration cost between country k and country k' as follows:

$$C^{k,k'} = \bar{W}\left(\theta_1 \ln \text{dist}^{k,k'} + \theta_2 \ln \text{lang}^{k,k'} + \theta_3 \ln \text{pol}^{k,k'} + \theta_4 \ln \text{mig}^{k,k'}\right) \tag{5.28}$$

where $\bar{W}$ denotes the European average revenue in 2007 and allows us to scale the bilateral migration cost to the average revenue of the studied countries. This cost function depends on four variables (in logarithm) that are known to be important determinants of international migration flows:

- $\text{dist}^{k,k'}$ denotes the distance in kilometres between the most populated cities of countries k and k'. This dyadic variable comes from the CEPII GeoDist database (Mayer and Zignago, 2011). We expect the bilateral distance to positively impact the bilateral migration cost.

[10] The two sources of immigration flow data use the same definition of an international migrant (an individual is considered as a migrant if he does not have the citizenship of the country where he lives). Dropping Ireland and the United Kingdom from our sample does not change the results of the simulations.

[11] The average wage of country k' in 2008 is endogenous to the number of individuals deciding to migrate in 2007 toward country k'. Thus, we cannot approximate $W^{k'}_{2008}$ by the GDP per capita of country k' in 2008.

- $\text{lang}^{k,k'}$ represents the linguistic distance between country k and country k'. From the CEPII Language database (Melitz and Toubal, 2012), we get the probability that two individuals respectively from country k and country k' understand one another in some language. $\text{lang}^{k,k'}$ is the inverse of this probability. We expect the bilateral migration cost to increase with the linguistic distance.

- $\text{pol}^{k,k'}$ denotes the migration policy implemented by the destination country k' toward country k in 2007. This variable ranges from unity to two, highest scores denoting strictest regulations. This variable equals unity when country k' does not implement any migration restriction toward country k. This can happen in three cases: (i) when both countries are Schengen members, (ii) when both countries are old EU members, and (iii) when country k is a new EU member state and country k' is an old member which does not implement any migration restriction toward country k. In any other case, restrictive bilateral migration policies are implemented. For instance, when country k is a new EU member state and country k' is an old member which implements migration restrictions toward country k, we use the Migrant Integration Policy Index (MIPEX) to measure the migration policy implemented by country k'[12]. More precisely, we use the overall index that approximates integration policies implemented by host countries. Unfortunately, this index is not bilateral and only captures globally policies implemented by host countries. This index ranges from zero to 100, highest scores referring to a positive attitude toward immigrants. For our specification, we use the MIPEX such that:

$$\text{pol}^{k,k'} = 2 - \frac{\text{MIPEX}^{k'}}{100} \ \forall k \tag{5.29}$$

  Gest et al. (2014) propose a survey of existing estimates of immigration admission, naturalisation and integration policies[13]. In the light of their paper, it seems that the MIPEX is the only indicator available for a large number of European countries and close to what we want to capture[14]. We expect the bilateral migration cost to increase with $\text{pol}^{k,k'}$.

- $\text{mig}^{k,k'}$ measures the stock of migrants from country k staying in country k' in 2000. This variable comes form the Global Bilateral Migration database proposed by the

[12] Conversely, when country k is an old member which implements migration restrictions toward country k', which is a new EU member state, then country k' implements in return migration restrictions toward country k.

[13] Gest et al. (2014) highlight the limitations of existing migration policy indexes and conclude on the need for a new database. They present the International Migration Policy And Law Analysis (IMPALA) project, which, once achieved, will provide an improved dataset of immigration laws and policies across 20 OECD countries and across time.

[14] We do not use the MIPEX to calculate $\text{pol}^{k,k'}$ for countries implementing liberal migration policies between each other, because this index is not bilateral and thus does not reflect these liberal bilateral agreements.

World Bank. We expect the bilateral migration cost to decrease with $\text{mig}^{k,k'}$, since migration networks are known to ease future migration by decreasing the migration costs of would-be migrants.

θ_1, θ_2, θ_3 and θ_4 are semi-elasticities to be estimated.

Finally, we need to make some additional assumptions on the income distribution in country k. We assume that the financial resources (or income) of an individual i living in country k follows a Log-Normal distribution such that:

$$w_i^k \rightsquigarrow \ln \mathcal{N}\left[\mu^k, \left(\sigma^k\right)^2\right] \ \forall\, i \tag{5.30}$$

where μ^k denotes a country-specific scale and σ^k denotes a country-specific shape. The scale parameter of this Log-Normal distribution is given by: $\mu^k = \ln\left[\frac{\left(m^k\right)^2}{\sqrt{s^k+\left(m^k\right)^2}}\right]$ and the shape parameter is given by: $\sigma^k = \sqrt{\ln\left[\frac{s^k}{\left(m^k\right)^2}+1\right]}$, where m^k denotes the mean and equals the GDP per capita in country k in 2007, and s^k denotes the standard deviation of the distribution and is approximated by the level of inequalities in country k. We use the GINI coefficient of equivalised disposable income in 2007 from Eurostat[15].

Then, using the Log-Normal cumulative distribution function of incomes in country k, we get the probability that an individual located in country k can afford the migration cost toward country k': $1-\Phi\left(C^{k,k'}\right) = \Pr\left(w_i^k \geq C^{k,k'}\right)$.

We provide some descriptive statistics in Table 5.1. The linguistic distance presents only 600 observations because the probability that an individual from country k and an individual from country k' understand each other when $k' = k$ is not considered in the CEPII Language database. This has no impact for our simulation exercise since $C^{k,k} = 0$.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Bilateral migration flow	413	1,818	7,536	0	119,867
Population	625	19,209	23,418	1,077	83,379
$M_{obs}^{k,k'}$	413	1.2e-04	3.2e-04	0	3.1e-03
$E\left(W_{2008}^{k'}\right)$	625	36,638	10,487	20,230	65,990
$\bar{W}$	625	35,374	0	35,374	35,374
$\text{dist}^{k,k'}$	625	.455	.253	0	1
$\text{lang}^{k,k'}$	600	.402	.218	.073	.999
$\text{pol}^{k,k'}$	625	.173	.258	0	.697
$\text{mig}^{k,k'}$	625	.112	.249	0	1
m^k	625	35,374	10,644	18,934	64,954
s^k	625	.291	.041	.232	.368

Table 5.1.: Descriptive statistics

[15] Statistics on Income and Living Conditions, 16.02.2015 Revision.

5.4.2 Model calibration

In order to generate *theoretical* bilateral migration rates, either $M^{k,k'}$ or $M_{BC}^{k,k'}$, as close as possible to real data, we implement a Least Mean Squares algorithm which iteratively searches for values of the parameters that minimise the squared distance between the *observed* bilateral migration rates and the corresponding *theoretical* rates. The algorithm minimises $J(\theta)$ with respect to $\theta = \{\theta_1, \theta_2, \theta_3, \theta_4\}$, with:

$$J(\theta) = \frac{1}{2} \sum_{n=1}^{N} \left[M_{theo}^{(n)} - M_{obs}^{(n)} \right]^2, \text{ with } M_{theo}^{(n)} = \{M^{(n)}; M_{BC}^{(n)}\} \tag{5.31}$$

where N is the number of training examples (413 *observed* bilateral migration rates).

More precisely, the algorithm implements a batch gradient descent and can be written as follows:

```
repeat until convergence{
```

$$\theta_x := \theta_x - \alpha \frac{\partial J(\theta)}{\partial \theta_x} \; \forall x = 1; 2; 3; 4$$

```
}
```

where α is set to 0.1 and denotes the learning rate, and where the sign $:=$ means that we *replace* θ_x by $\theta_x - \alpha \frac{\partial J(\theta)}{\partial \theta_x}$ at each iteration. The update of the parameters is done simultaneously at each iteration.

Once convergence reached, we obtain optimal values of the parameters that enable us to calculate the *theoretical* bilateral migration rates between the 25 countries studied.

5.4.3 Model evaluation

We present here how we evaluate the performance of each model we calibrate. First, we perform a paired t-test to determine whether or not there is a statistically significant difference between the *observed* and the *theoretical* bilateral migration rates.

Second, we need to ensure that our model does not over-fit our dataset, that is to verify that the results can be generalised to an independent dataset. To this end, we can randomly partition our dataset of 413 *observed* rates into two sub-samples. The first one comprises 90% of observation and is used as a *training* set to calibrate our model. The second one comprises the last 10% of observations and is used as a *testing* set to evaluate the performance of our calibrated model, that is to measure how well our model predicts real data. Usually,

the mean squared error (MSE) and the root mean squared error (RMSE) are computed over the *testing* set. The lower these indicators, the better the performance of the model.

However, because our dataset is rather small, the error calculated on the *testing* set may not properly represent the performance of the model. Thus, we perform a 10-fold cross-validation: we randomly partition our data into 10 equal sized sub-samples, and repeatedly use 9 of them as a *training* set and the last one as a *testing* set, such that each sub-sample is used exactly once as a *testing* set. To obtain evaluation measures, we calculate the mean and the standard deviation of the MSE and the RMSE over the 10 testing folds.

5.4.4 Results

Baseline simulation

In a standard RUM model

After calibration of the standard RUM model (equation 5.5), we obtain the following semi-elasticities of the bilateral migration cost with respect to:

- the geographic distance: $\theta_1 = 6.3345$;
- the linguistic distance: $\theta_2 = 4.8309$;
- the bilateral migration policy: $\theta_3 = 2.127$;
- and the size of the diaspora: $\theta_4 = 3.2888$.

In line with the existing literature, the geographic and the linguistic distance between the origin and the destination countries are the main determinants of the bilateral migration cost.

The results obtained with these parameters are reported in Tables 5.2 and 5.3 (columns 1 and 2). These tables present the results respectively for Germany as a destination country and Slovakia as a source country. We chose to focus on Germany because it implemented restrictions toward all new member states until 2011 (as well as Austria and Switzerland), and on Slovakia which is one of the new member states.

In Table 5.2, we report the bilateral migration rates from the 25 potential source countries (Germany included) toward Germany. Source countries are ranked in increasing order of migration costs toward Germany. The new eastern European member states are in bold in

the table. For instance, the simulated cost for a Dutch citizen to migrate toward Germany is about 36 thousands US dollars. The simulated bilateral migration rate from the Netherlands to Germany is about 1.80e-02.

		Baseline simulation		**Scenario 1**		
source	destination	(1)	(2)	(3)	(4)	(5)
country k	country k'	$C_0^{k,k'}$	$M_0^{k,k'}$	$C_1^{k,k'}$	$M_1^{k,k'}$	$\frac{M_1^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$
DEU	DEU	0	1	0	1	0
NLD	DEU	35,708	1.80e-02	35,708	1.80e-02	0
AUT	DEU	65,381	1.07e-03	65,381	1.07e-03	0
CHE	DEU	104,868	8.56e-06	104,868	8.56e-06	0
BEL	DEU	118,150	7.03e-06	118,150	7.03e-06	0
DNK	DEU	118,157	4.90e-06	118,157	4.90e-06	0
FRA	DEU	124,987	5.25e-06	124,987	5.25e-06	0
NOR	DEU	130,752	1.70e-07	130,752	1.70e-07	0
GBR	DEU	134,108	1.98e-06	134,108	1.98e-06	0
SVN	**DEU**	**149,728**	**8.13e-07**	**123,186**	**1.16e-05**	**1.32e+01**
CZE	**DEU**	**156,165**	**5.87e-07**	**129,623**	**8.34e-06**	**1.32e+01**
SWE	DEU	163,669	6.48e-08	163,669	6.48e-08	0
LVA	**DEU**	**177,127**	**9.80e-08**	**150,585**	**1.39e-06**	**1.32e+01**
EST	**DEU**	**177,178**	**8.15e-08**	**150,636**	**1.16e-06**	**1.32e+01**
POL	**DEU**	**177,970**	**1.47e-07**	**151,428**	**2.09e-06**	**1.32e+01**
LTU	**DEU**	**185,833**	**4.21e-08**	**159,291**	**5.98e-07**	**1.32e+01**
HUN	**DEU**	**186,532**	**4.70e-08**	**159,990**	**6.68e-07**	**1.32e+01**
IRL	DEU	187,363	3.17e-09	187,363	3.17e-09	0
ITA	DEU	189,768	8.21e-09	189,768	8.21e-09	0
ESP	DEU	194,911	6.57e-09	194,911	6.57e-09	0
PRT	DEU	196,170	1.21e-08	196,170	1.21e-08	0
GRC	DEU	204,491	3.02e-09	204,491	3.02e-09	0
SVK	**DEU**	**220,322**	**1.22e-09**	**193,780**	**1.74e-08**	**1.32e+01**
FIN	DEU	229,242	9.58e-11	229,242	9.58e-11	0
CYP	DEU	268,196	4.54e-12	268,196	4.54e-12	0

Table 5.2.: Migration rates toward Germany derived from the standard RUM model

Table 5.3 presents the results for Slovakia. Destination countries are ranked in increasing order of the migration cost from Slovakia. For instance, the simulated cost for a Slovak citizen to migrate toward Czech Republic is about 137 thousands US dollars. Czech Republic is the second less expensive destination country for Slovak citizens (the most expensive destination is Portugal, and the less expensive is Slovakia). The simulated bilateral migration rate from Slovakia to Czech Republic is about 1.49e-06.

Let us now analyse the performance of the standard RUM model. The paired t-test indicates that we cannot conclude that theoretical data are significantly different from real data (p-value $= 0.1257$). In Table 5.4, we report some summary statistics for both the MSE and the RMSE computed over a 10-fold cross-validation. The mean of these indicators are low enough to indicate a correct performance of the model, that is a good explanatory power. In

source country k	destination country k'	Baseline simulation (1) $C_0^{k,k'}$	(2) $M_0^{k,k'}$	Scenario 1 (3) $C_1^{k,k'}$	(4) $M_1^{k,k'}$	(5) $\frac{M_1^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$
SVK	SVK	0	1	0	1	0
SVK	CZE	136,588	1.49e-06	136,588	1.49e-06	0
SVK	AUT	193,479	2.43e-08	193,479	2.43e-08	0
SVK	HUN	218,495	2.47e-10	218,495	2.47e-10	0
SVK	DEU	220,322	1.22e-09	193,780	1.74e-08	1.32e+01
SVK	SVN	227,952	2.20e-10	227,952	2.20e-10	0
SVK	NLD	234,592	4.59e-10	234,592	4.59e-10	0
SVK	ITA	252,752	3.33e-11	252,752	3.33e-11	0
SVK	POL	254,800	4.93e-12	254,800	4.93e-12	0
SVK	CHE	257,163	1.00e-10	257,163	1.00e-10	0
SVK	SWE	259,812	2.83e-11	259,812	2.83e-11	0
SVK	DNK	261,493	3.00e-11	261,493	3.00e-11	0
SVK	GBR	265,160	1.04e-11	265,160	1.04e-11	0
SVK	BEL	271,756	7.50e-12	271,756	7.50e-12	0
SVK	LTU	272,805	1.30e-12	272,805	1.30e-12	0
SVK	GRC	277,652	1.73e-12	277,652	1.73e-12	0
SVK	FIN	281,950	2.97e-12	281,950	2.97e-12	0
SVK	LVA	283,333	4.65e-13	283,333	4.65e-13	0
SVK	FRA	288,745	9.27e-13	288,745	9.27e-13	0
SVK	IRL	291,614	2.25e-12	291,614	2.25e-12	0
SVK	EST	293,215	2.07e-13	293,215	2.07e-13	0
SVK	NOR	297,716	6.55e-12	297,716	6.55e-12	0
SVK	CYP	311,281	6.80e-14	311,281	6.80e-14	0
SVK	ESP	320,315	2.90e-14	320,315	2.90e-14	0
SVK	PRT	344,185	1.28e-15	344,185	1.28e-15	0

Table 5.3.: Migration rates from Slovakia derived from the standard RUM model

addition, the standard deviation is small enough to indicate that our results do not depend on the sample of countries chosen for our study.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
MSE	10	1.3e-04	2.6e-04	0	7.5e-04
RMSE	10	6.4e-03	1.0e-02	1.3e-04	2.7e-02

Table 5.4.: Performance of the standard RUM model

In a RUM model with budget constraint

After calibration of the RUM model with BC (equation 5.13), we obtain the following semi-elasticities: $\theta_1 = 5.5894$, $\theta_2 = 4.3249$, $\theta_3 = 2.127$ and $\theta_4 = 3.2612$. Compared to those obtained when simulating the standard RUM, we find that omitting the BC biases all parameters, except the bilateral migration policy semi-elasticity, upward.

We present the results obtained for Germany and Slovakia respectively in Tables 5.5 and 5.6 (columns 1, 2 and 3). Column 2 in Table 5.5 indicates the rank of Germany when destinations are ranked in increasing order of migration cost from country k. For instance, Germany is the second less expensive destination for Austrians.

Comparing the bilateral migration rates obtained with the two models, we find that migration rates are over-estimated when we omit the budget constraint effect in the modelling of the migration decision. Over the full sample, the bias is about 5.65e-05 point which is quite important given that observed bilateral migration rates range from 0 to 3.14e-03.

Let us now analyse the performance of the RUM model with BC. We perform a paired t-test and find that we cannot conclude that theoretical data are significantly different from real data (p-value $= 0.1382$). In addition, we perform a 10-fold cross-validation. The results in Table 5.7 indicate a correct performance of the model. The MSE and RMSE obtained with the RUM model with BC are slightly lower than those obtained with the standard RUM model (Table 5.4), which indicates that accounting for the budget constraint effect in the modelling of the migration decision improves the explanatory power of the model.

Scenario 1: loosening of the German migration policy toward new member states

In a standard RUM model

Using the parameters obtained with the calibration of the standard RUM model, we simulate a first scenario in which we assume that Germany completely loosens its migration policy regime toward the new EU member states. More precisely, we set $\text{pol}^{k,\text{DEU}} = 1 \, \forall k$. For new EU member states, $\text{pol}^{k,\text{DEU}}$ was previously equal to 1.423.

We report the results for Germany and Slovakia respectively in Tables 5.2 and 5.3 (columns 3 and 4). As expected, a relaxation of the German migration policy regime toward the new EU member states impacts positively and in the same proportions migration from these countries toward Germany (Table 5.2, column 5). A relaxation of the policy induces a decrease of the migration costs from these countries toward Germany. Consequently, Germany becomes more attractive for some individuals that did not consider this destination as their maximising option before the policy change.

This policy change does not impact migration toward alternative destination countries (Table 5.3, column 5). Here we observe the IIA property, that is, a proportional substitution across alternative destinations.

source country k	destination country k'	Baseline simulation (1) $C_0^{k,k'}$	(2) $\theta_0(k,k')$	(3) $M_{0,BC}^{k,k'}$	Scenario 1 (4) $C_1^{k,k'}$	(5) $\theta_1(k,k')$	(6) $M_{1,BC}^{k,k'}$	(7) $\frac{M_{1,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$
DEU	DEU	0	1	1	0	1	1	0
AUT	DEU	57,705	2	2.24e-04	57,705	2	2.24e-04	0
CHE	DEU	97,285	2	2.16e-07	97,285	2	2.16e-07	0
CZE	**DEU**	**141,964**	**2**	**2.35e-17**	**115,422**	**2**	**6.55e-14**	**2.79e+03**
HUN	**DEU**	**168,813**	**2**	**3.68e-22**	**142,271**	**2**	**8.66e-19**	**2.35e+03**
ITA	DEU	168,682	2	3.51e-14	168,682	2	3.51e-14	0
POL	**DEU**	**161,243**	**2**	**3.75e-18**	**134,701**	**2**	**2.22e-15**	**5.92e+02**
SVN	**DEU**	**135,877**	**2**	**3.43e-17**	**109,335**	**2**	**1.93e-13**	**5.62e+03**
ESP	DEU	174,677	3	2.82e-15	174,677	3	2.82e-15	0
GRC	DEU	181,544	3	2.03e-15	181,544	3	2.03e-15	0
NLD	DEU	31,802	3	2.23e-02	31,802	3	2.23e-02	0
BEL	DEU	110,473	4	5.95e-10	110,473	4	5.95e-10	0
DNK	DEU	109,247	4	1.33e-09	109,247	4	1.33e-09	0
FRA	DEU	112,693	4	1.29e-10	112,693	4	1.29e-10	0
GBR	DEU	124,081	4	2.86e-10	124,081	4	2.86e-10	0
LTU	**DEU**	**168,162**	**4**	**1.06e-16**	**141,620**	**2**	**3.23e-14**	**3.05e+02**
LVA	**DEU**	**160,380**	**4**	**3.08e-15**	**133,838**	**2**	**7.74e-13**	**2.50e+02**
NOR	DEU	116,490	4	3.47e-09	116,490	4	3.47e-09	0
PRT	DEU	175,218	4	5.08e-15	175,218	4	5.08e-15	0
SVK	**DEU**	**204,343**	**4**	**1.34e-24**	**177,800**	**3**	**1.91e-23**	**1.32e+01**
EST	**DEU**	**160,369**	**5**	**2.09e-15**	**133,827**	**3**	**6.32e-13**	**3.01e+02**
SWE	DEU	149,669	5	2.88e-15	149,669	5	2.88e-15	0
FIN	DEU	211,448	9	3.11e-20	211,448	9	3.11e-20	0
IRL	DEU	174,722	9	1.11e-13	174,722	9	1.11e-13	0
CYP	DEU	245,415	10	1.05e-22	245,415	10	1.05e-22	0

Table 5.5.: Migration rates toward Germany derived from the RUM model with BC

		Baseline simulation			Scenario 1			
source	destination	(1)	(2)	(3)	(4)	(5)	(6)	(7)
country k	country k'	$C_0^{k,k'}$	$\theta_0(k,k')$	$M_{0,BC}^{k,k'}$	$C_1^{k,k'}$	$\theta_1(k,k')$	$M_{1,BC}^{k,k'}$	$\frac{M_{1,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$
SVK	SVK	0	1	1	0	1	1	0
SVK	CZE	125,374	2	6.59e-18	125,374	2	6.59e-18	0
SVK	AUT	184,378	3	1.34e-23	184,378	4	1.34e-23	-1.18e-07
SVK	DEU	204,343	4	1.34e-24	177,800	3	1.91e-23	1.32e+01
SVK	HUN	206,700	5	1.79e-25	206,700	5	1.79e-25	-1.38e-07
SVK	SVN	214,759	6	1.83e-25	214,759	6	1.83e-25	-6.73e-08
SVK	NLD	216,776	7	6.05e-25	216,776	7	6.05e-25	-8.14e-08
SVK	ITA	233,148	8	5.26e-26	233,148	8	5.26e-26	-1.17e-07
SVK	POL	238,833	9	5.40e-27	238,833	9	5.40e-27	-7.13e-08
SVK	SWE	239,077	10	5.00e-26	239,077	10	5.00e-26	-1.23e-07
SVK	CHE	240,749	11	1.15e-25	240,749	11	1.15e-25	-1.07e-07
SVK	GBR	243,884	12	1.94e-26	243,884	12	1.94e-26	-7.92e-08
SVK	DNK	244,096	13	3.80e-26	244,096	13	3.80e-26	-8.12e-08
SVK	BEL	252,368	14	1.16e-26	252,368	14	1.16e-26	-1.33e-07
SVK	LTU	254,766	15	1.75e-27	254,766	15	1.75e-27	-1.10e-07
SVK	GRC	255,103	16	3.65e-27	255,103	16	3.65e-27	-1.05e-07
SVK	FIN	258,818	17	6.68e-27	258,818	17	6.68e-27	-1.15e-07
SVK	LVA	264,502	18	6.78e-28	264,502	18	6.78e-28	-7.10e-08
SVK	FRA	267,167	19	1.78e-27	267,167	19	1.78e-27	-1.08e-07
SVK	IRL	267,235	20	5.73e-27	267,235	20	5.73e-27	-6.72e-08
SVK	EST	272,350	21	3.70e-28	272,350	21	3.70e-28	-6.50e-08
SVK	NOR	275,280	22	1.37e-26	275,280	22	1.37e-26	-1.12e-07
SVK	CYP	284,689	23	2.16e-28	284,689	23	2.16e-28	-1.12e-07
SVK	ESP	292,829	24	1.01e-28	292,829	24	1.01e-28	-1.20e-07
SVK	PRT	313,901	25	5.86e-30	313,901	25	5.86e-30	-1.28e-07

Table 5.6.: Migration rates from Slovakia derived from the RUM model with BC

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
MSE	10	1.0e-04	1.7e-04	0	4.6e-04
RMSE	10	5.8e-03	8.4e-03	1.3e-04	2.1e-02

Table 5.7.: Performance of the RUM model with BC

In a RUM model with budget constraint

We reproduce our experiment (scenario 1) using the parameters obtained with the calibration of the model with BC. Results for Germany and Slovakia are reported in Tables 5.5 and 5.6 (columns 4, 5 and 6).

Let us first analyse the consequences of such a policy change for Germany (Table 5.5). We observe that the cost to migrate toward Germany decreases for all new member states. In addition, the bilateral migration cost from Estonia, Latvia, Lithuania and Slovakia toward Germany decreases so much that the rank of Germany decreases.

Consequently, the migration rates from these countries toward Germany increase slightly (Table 5.5, column 7). Here, two effects may be at play. First, Germany becomes more attractive for some individuals that did not consider this destination as their maximising option before the policy change. Second, Germany becomes less expensive so that some individuals who intended to migrate to Germany before the policy change can now afford that destination. Thus, some individuals have changed their choice in the same set of potential destinations, while the set of potential destinations changed for some others.

Then, we expect the bilateral migration rate from country k to country k' to react more importantly to a change in the migration policy of country k' when we take into account the effect of the BC: $\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} \leq \frac{\partial M^{k,k'}}{\partial C^{k,k'}} \leq 0$ (*cf.* section 5.3.3).

Therefore, we compare the variation in migration rates in both models. As expected, the variation is always more important in the RUM model with BC (*cf.* Table 5.8). Thus, omitting the budget constraint effect biases downward the effect of a relaxation of the migration policy of Germany on bilateral migration rates from eastern European countries.

Let us now look at the migration rates from Slovakia toward other destination countries (Table 5.6). As expected, we find that a change in the attractiveness of Germany also impacts migration toward other destination countries, revealing the presence of multilateral resistance to migration (Table 5.6, column 7).

Following our theoretical model, we expect that a loosening of the German migration policy toward new EU member states decreases, or leaves unchanged, bilateral migration rates

source country k	destination country k'	$\frac{M_1^{k,k'}-M_0^{k,k'}}{C_1^{k,k'}-C_0^{k,k'}} - \frac{M_{1,BC}^{k,k'}-M_{0,BC}^{k,k'}}{C_{1\,(BC)}^{k,k'}-C_{0\,(BC)}^{k,k'}}$
CZE	DEU	-2.92e-10
EST	DEU	-4.06e-11
HUN	DEU	-2.34e-11
LTU	DEU	-2.09e-11
LVA	DEU	-4.88e-11
POL	DEU	-7.33e-11
SVK	DEU	-6.09e-13
SVN	DEU	-4.05e-10

Table 5.8.: Changes between the baseline simulation and scenario 1: variations across models

from these countries toward less expensive destinations ($C^{k,k'} > C^{k,k''}$, equation 5.26). Here, we find that for each alternative country that are less expensive than Germany after the policy change (Slovakia and Czech Republic), the variation of the bilateral migration rate is nil.

In addition, we find that for each destination more expensive than Germany after the policy change, the bilateral migration rate decreases. Thus, we can infer that when $C^{k,k'} < C^{k,k''}$, it is likely that $\frac{\partial M_{BC}^{k,k''}}{\partial C^{k,k'}} \geq 0$. This means that among the individuals who would have migrated to Germany before the policy change, less decided to stay in country k than to migrate to country k''.

5.4.5 Robustness checks

Migration policy index

We test the sensitivity of the RUM model without and with BC with respect to the choice of the migration policy index. The MIPEX does not properly measure the strictness of immigration policies but rather the level of integration policies, which is slightly different from what we intend to capture. Therefore, as a robustness test, we build the variable of bilateral migration policy ($pol^{k,k'}$) using either the *Labour Market Mobility* index or the *Long term residence* index, which are two sub-indexes of the MIPEX that may better capture a country's openness to immigration. The *Labour Market Mobility* index measures whether immigrants have equal rights and opportunities as natives to access jobs and improve their skills. The *Long term residence* index measures how easily immigrants can become permanent residents.

For both models, we obtain the same parameters using either the overall MIPEX, the *Labour Market Mobility* index or the *Long term residence* index[16]. The results of the paired t-test for each robustness test are identical to those obtained with the initial specification, and indicate that we cannot conclude that theoretical data are significantly different from real data. In addition, statistics on the MSE and the RMSE obtained with a 10-fold cross-validation indicate the same performance of the model for each specification tested. Thus, we can conclude that our model is robust with respect to the choice of the migration policy index.

Finally, a more appropriate index for a robustness check would have been the Inventory of migration policies of the fondazione Rodolfo Debenedetti. This index, which is a bilateral, is closer from what we intend to capture: the strictness of migration policies for newcomers. However, this index is only available for 12 western European countries[17]. Those countries are quite similar in term of revenue and, since the Treaty of Amsterdam of 1997, do not implement any migration restriction between each other. Thereby, this indicator could not be used for a robustness test.

Alternative scenarios

To ensure that the results presented previously are not conditioned by the scenario chosen, we propose two additional scenarios.

Scenario 2: loosening of the French migration policy toward new member states

We consider a second scenario in which we assume that France completely loosens its migration policy regime toward the new EU member states. More precisely, we set $\text{pol}^{k,\text{FRA}} = 1 \, \forall k$. France also implemented restrictions in 2007. For new EU member states, $\text{pol}^{k,\text{FRA}}$ was previously equal to 1.502.

We present the results of the standard RUM model respectively for France and Slovakia in appendix D.5, Tables D.3 and D.4 (columns 3 and 4). Looking at Table D.3 (column 5), we find that a relaxation of the French migration policy toward new EU member states increases, in the same proportion, the bilateral migration rates from these countries toward France. Looking at Table D.4 (column 5), we find that this policy change does not impact migration from Slovakia toward all destination countries but France.

[16] There is no visible change in the calibration of the models mostly because these sub-indexes are only a little different from the overall index, and keep the differences between countries unchanged.

[17] Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, and the United Kingdom.

Results derived from the RUM model with BC for France and Slovakia are reported in appendix D.5, Tables D.5 and D.6 (columns 4, 5 and 6). Looking at Table D.5 (column 7), we find that a relaxation of the French migration policy toward new EU member states increases the bilateral migration rates from these countries toward France, the magnitude of the effect being different for each source country.

We then compare the variation in migration rates to France induced by a loosening of the French migration policy in both models. We now find no variation between the standard RUM model and the RUM model with BC. This result is still in line with what we expected: $\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} \leq \frac{\partial M^{k,k'}}{\partial C^{k,k'}} \leq 0$. Here, results obtained with the RUM model with BC are just equal to those obtained with a standard RUM model[18].

Let us now look at the migration rates from Slovakia toward other destination countries (Table D.6). We find that a loosening of the French migration policy does not impact migration toward alternative destination countries (column 7)[19]. This result is still in line with what we expected. Even after a relaxation of its migration policy, France remains unattractive or unaffordable for would-be migrants from eastern European countries. In consequence, the policy change does no have any impact on the weight of the budget constraint on migration decisions. Since France is quite far from these countries, the bilateral migration rate is quite high even when the policy is liberal. Thus, the IIA property seems to hold for France.

Scenario 3: loosening of old member states' migration policies toward new member states

Finally, we consider a third scenario in which we generalise our experiment by looking at what happens when all western European countries open their borders to immigrants from the new member states.

We present the results of the standard RUM model respectively for France and Slovakia in appendix D.5, Tables D.3 and D.4 (columns 6 and 7). Concerning migration rates toward France, we find exactly the same results when all members states open their borders (Table D.3 column 7), than when only France does so (Table D.3 column 4). This policy change does not impact migration toward alternative destination countries that were already open before the policy change such as Italy and the United Kingdom (Table D.4, columns 2, 4 and 7).

[18] $\frac{\triangle M^{k,\text{FRA}}}{\triangle C^{k,\text{FRA}}} - \frac{\triangle M_{BC}^{k,\text{FRA}}}{\triangle C_{BC}^{k,\text{FRA}}}$ for all eastern European countries as source countries is always nil.

[19] We find the same results looking at the bilateral migration rates from other new eastern European countries.

Results derived from the RUM model with BC for France and Slovakia are reported in appendix D.5, Tables D.5 and D.6 (columns 8, 9 and 10).

A generalisation of the free circulation of people induces an increase in the bilateral migration rates from new member states toward France (Table D.5, column 11), similar to the increase observed in the second scenario, when France alone opened its borders. Other bilateral migration rates are unchanged, except for the bilateral migration rate from Austria toward France that decreases (Table D.5, column 11). In the third scenario, all countries lifted their barriers to migration; this implies that eastern European countries also stopped implementing restrictions. This policy change impacts migration decisions of Austrians: although not reported here, all bilateral migration rates from Austria toward new member states increase, while all bilateral migration rates toward other countries are either unchanged or decrease.

We then compare the variation in migration rates induced by a loosening of the French migration policy in both models. Here as expected, the variation is always more important in the RUM model with BC (*cf.* Table 5.9, in which we only report the results for France). Let us now look at the migration rates from Slovakia (Table D.6, column 11). As expected,

source country k	destination country k'	$\frac{M_1^{k,k'}-M_0^{k,k'}}{C_1^{k,k'}-C_0^{k,k'}} - \frac{M_{1,BC}^{k,k'}-M_{0,BC}^{k,k'}}{C_{1\,(BC)}^{k,k'}-C_{0\,(BC)}^{k,k'}}$
CZE	FRA	-1.26e-14
EST	FRA	-4.50e-16
HUN	FRA	-2.66e-15
LTU	FRA	-2.06e-16
LVA	FRA	-2.69e-16
POL	FRA	-2.34e-15
SVK	FRA	-6.17e-16
SVN	FRA	-9.03e-16

Table 5.9.: Changes between the baseline simulation and scenario 3: variations across models

this global policy change induces either an increase or a decrease in the bilateral migration rates, depending on the change in the bilateral migration costs, but also in the ranking of potential destinations. When the rank increases, the bilateral migration rate from eastern European countries decreases; when the rank decreases, the bilateral migration rate from new eastern European member states increases. For instance, if instead of implementing restrictions until 2009, Belgium had open its borders straight away, it would have been the 9^{th} less expensive country for Slovakians (instead of the 14^{th}) and consequently it would have attracted a lot more Slovakians.

Overall, the results found with these alternative scenarios corroborate the results presented when looking at a loosening of the German migration policy toward new member states.

5.5 Conclusion

In standard RUM models of migration, it is considered that as long as the expected net gain of migration is higher than the expected gain when staying, individuals decide to migrate. However, individuals financial resources limit their migration choices. Because of this budget constraint, individuals choose their destination country not among all destinations, but only among affordable destinations. For the poorest individuals, this reduced choice of possibilities only comprises their home country: they cannot emigrate, even if they want to. The budget constraint of individuals can be relaxed (and the choice set expanded), either when the financial resources of the individual increases, or when the migration cost toward a destination decreases, for instance when that destination relaxes its migration policy.

This chapter analyses to what extent financial constraints impact migration decisions. In the first part of this chapter, we explicitly introduce the role of the budget constraint in a RUM model of migration. We show that, contrary to the results of the standard RUM model, the bilateral migration rate between two countries depends on the attributes of both origin and destination countries, the bilateral migration cost, and on the attributes of alternative destination countries through a budget constraint effect. Therefore our model exhibits multilateral resistance to migration: when a country changes its migration policy, it impacts not only the migration rate toward that country but also toward other destinations. There is no proportional substitution across alternative destinations.

Our theoretical model confirms that the budget constraint of potential migrants must be taken into account. To build this model, we made several assumptions. In particular, we assumed that individuals were myopic when taking their migration decisions, and that they could not borrow to finance their migration. These assumptions are restrictive and could be relaxed in future research, in order to allow us to have a better insight on the weight of the budget constraint on migration decisions. Relaxing these assumptions could also enhance our understanding of the link between the development of the financial system in source countries and migration flows.

In the second part of the chapter, we calibrate a standard RUM model and a RUM model with budget constraint on 25 European countries in 2008, focusing on migration from 8 eastern European countries. We show that introducing the budget constraint does improve the explanatory power of the RUM model.

Simulating a complete relaxation of the migration policy of Germany toward eastern European states, we confirm that the budget constraint matters. In line with our theoretical model, we show that a loosening of the German migration policy increases (or leaves unchanged) the migration rate from new member states toward Germany. We also find that migration rates from new eastern European member states toward other destination countries decrease (or remain unchanged).

Interestingly, when we perform the same exercise but assuming that France, and not Germany, relaxes its migration policy, the impacts on migration rates are a little different: migration rates from eastern European countries toward France do increase, but migration rates from new eastern European member states to other destination countries do not change. In the case of France, there seems to be proportional substitution across alternative destinations. If France had not implemented any restriction toward new eastern member states, this would have had consequences for France but not for other countries; on the contrary, if Germany had not implemented any restriction, this would have had consequences for all 25 member states: they would all have seen their migration rate (from new eastern European member states) decrease, except for Germany.

Finally, when we assume that all countries implement liberal migration policies, we find that the change in migration rates depends on the change of the rank of the country (in terms of bilateral migration cost): when the rank increases, the bilateral migration rate from eastern European countries decreases; when the rank decreases, the bilateral migration rate from new eastern European member states increases.

Although these simulation results are quite instructive on the link between migration policies, migration costs and migration rates, future research could try to empirically estimate the RUM model with budget constraint, when the necessary data become available.

Our results show that the migration policy implemented by a destination country has consequences on migration rates toward all destination countries. This implies that destination countries, and especially European countries, should cooperate on this issue on a long term basis, and really implement a common European migration policy. For now, the Schengen area does not perfectly overlap with the EU area and only regulates short term migration. The community could gain to establish both a common internal and external policy for long term migration. Similarly to the common trade policy that allows the free circulation of goods and services within the EU area and sets common tariffs for imports from third countries, the common migration policy could allow the free movement of European citizens within the EU (policy already implemented) and set the same rule for entrance and long-term stay in any EU member state for citizens of third countries.

6 Restrictive migration policies and illegal migration in Europe. What do we learn from an agent-based model?

6.1 Introduction

While the right to emigrate tends to be worldly recognised, the right to immigrate seems to be more and more constrained, especially for the population of the developing world (Wihtol de Wenden, 2013). Developed economies tend to tighten their admission rules, to prevent illegal entries, to reduce the number of regularisation programmes and to reinforce repressive actions against illegal immigrants and their employers[1].

However, when a country tightens its migration policy, it may increase the number of illegal immigrants living on its soil. The media and some researchers point out that individuals refused by legal migration programmes may be forced into illegality (Bchir, 2008; Broeders and Engbersen, 2007; Castles et al., 2014). The Lampedusa shipwreck carrying migrants from Libya to Italy on the 3rd of October 2013, or the shipwreck off the Libyan coast on the 19th of April 2015 are two examples among others, showing that some individuals tend to put themselves into perilous situations to migrate toward the developed and free world even when borders are closed to them. As explained by Castles et al. (2014), this is not a new phenomenon. Boats crossing the Mediterranean sea appeared in the early 1990's when Spain and Italy started to request visas to north African migrants.

The economic literature has provided limited empirical evidence regarding this phenomenon. One reason is that illegal migration is not easily countable. Reviewing different estimates of illegal migration, Jandl (2004) highlights the poor quality and the poor comparability of data due to the illicit nature of the phenomenon and to the use of different definitions

[1] See Boswell and Straubhaar (2004), Broeders and Engbersen (2007), Stalker (2002), and Brochmann and Hammar (1999) for a review of migration policies implemented nowadays within the European Union. See Rinne (2013) for an evaluation of migration policies that intervene after the arrival of immigrants in some OECD countries.

across countries. To better define an illegal migrant, he calls to mind the taxonomy of Tapinos (1999) presented in Table 6.1. This taxonomy makes the distinction between three status not necessarily exclusive: the illegal entry, the illegal residence and the illegal work. These illegal status often overlap and are time-changing. For instance, a migrant can cross the border legally but overstay his visa period, later on he can obtain a residence permit but no work permit.

	legal residence	**illegal residence**
legal entry	work without authorisation	work without authorisation/ do not work
illegal entry	work without authorisation	work without authorisation/ do not work

Table 6.1.: Types of illegal migrants (Tapinos, 1999)

Kovacheva and Vogel (2009) attempt to quantify irregular migration in the European Union of the fifteen (EU15)[2]. They propose estimates for 2002, 2005 and 2008, along with a quality index considering the data reliability. In 2002, the authors estimate the stock of irregular foreign residents between 0.8% and 1.4% of the total EU15 population (between 3,044,877 and 5,328,536 individuals) or equivalently between 14% and 25% of the population of immigrants living in the EU15. This stock progressively decreased in 2005 (between 0.58% and 1.23% of the total EU15 population) and in 2008 (between 0.46% and 0.83% of the total EU15 population)[3]. As for the United States, the Pew Hispanic Center estimates that 8.5 million of undocumented immigrants were living in the country in 2000 (Passel, 2002).

At the micro-level, few data have been collected on migrants and especially on irregular ones. Coniglio et al. (2009) provide empirical evidence on the return decisions of illegal migrants using the 2003 Survey on Illegal Migration in Italy realised on 920 individuals. In this chapter, they show that higher skills positively impact the intention to return of undocumented migrants. The Pew Hispanic Center provides another micro database, the 2012 Survey of Mexican Migrants in the United States, which contains data on attitudes toward immigration laws.

From a theoretical perspective, migration decisions can be explained by the micro neoclassical approach[4]. In this framework, an individual chooses his migration destination in order to maximise his expected utility over time, across all possible destinations. His expected utility is determined by some personal characteristics (gender, age, education...), but also by macro-level factors. In particular, economic factors determine the expected gain (the wage

[2] Their dataset results from the CLANDESTINO Research Project funded by the European Commission.
[3] The reliability of this estimation is considered as *low* by the authors.
[4] The micro neoclassical theory of migration (and resulting empirical studies) lies on the human capital theory of Sjaastad (1962). Since then, it has been further developed thanks to the random utility maximisation framework (Beine et al., 2015a).

differential among origin and destination countries and job opportunities at destination) (Hatton and Williamson, 2005). For instance, Stalker (2000) shows that the demand for low skilled labour in the tertiary sector of developed economies increases job opportunities for would-be migrants living in developing countries. Then, geographic variables (the distance between origin and destination countries) and migration policies determine the cost of migration. For illegal would-be migrants, migration policies especially influence the probability to be caught and the cost imposed by smugglers (Castles et al., 2014). Finally, political and ethnic conflicts are also important determinants of (illegal) migration. Duvell (2009) explains that undocumented migrants often come from countries at war, but do not fulfil requirements to obtain the status of refugees[5].

The theory of illegal behaviour (Becker, 1968) also provides an interesting framework to analyse decisions to migrate illegally[6]. Based upon this theory, Entorf (2002) develops a model in which an individual takes his migration decision comparing his potential utility gain (due to a successful illegal migration) and his potential utility loss (due to possible sanctions). They formalise a market model of illegal migration and show that host governments should tolerate non-zero illegal migration. Woodland and Yoshida (2006) also propose a model of illegal migration in which they relax the assumption of risk neutrality. They find that the probability to be caught and the risk-aversion of would-be illegal migrants are two important determinants of illegal migration, but lead to the possibility of multiple and unstable equilibria in their model.

Both the micro neoclassical approach and the theory of illegal behaviour rely on the assumption of perfect information. The latter hypothesis implies that would-be migrants are able to formulate accurate expectations regarding job opportunities and earnings at destination. Yet, they are sometimes poorly informed on living conditions and opportunities at destination. As asserted by Wilson et al. (2013), by relaxing this assumption, one could provide some new understanding of economic behaviours.

In this chapter, we aim to better understand the decision to migrate illegally, in order to depict illegal migration between developing and developed countries. Our objective is twofold. We want to confirm a simple intuition: illegal migration increases when developed countries implement restrictive migration policies. Additionally, in view of the present EU political context, we want to look at what happens to illegal migration when developed countries adopt different attitudes toward the developing world (collaborative *versus* autonomous policies).

[5] See Hatton (2013) who reviews the trends in refugee and asylum migration.
[6] On the use of the theory of illegal behaviour to analyse illegal migration, see the pioneering papers of Ethier (1986a) and Ethier (1986b).

To this end, we develop a spatial agent-based model (ABM)[7]. We consider a small world under imperfect information in which backward-looking agents interact following logical rules. Agents are heterogeneous, they have different tastes and perceptions, but have identical skills. The world is divided in one developing and two developed countries. Agents are internationally mobile and can migrate legally or illegally, but migrating illegally is more costly. They choose their destinations in order to maximise their expected gains across the three possible countries (including their residence country). Their migration strategies depend on available information. They progressively adapt their strategies when more information becomes available. Their access to information depends on their geographical location. Over time, the aggregation of agent's actions gives rise to international migration.

We consider two geographical cases: in the first case, the developed countries are equally accessible from the developing country (two southern EU countries and Libya for instance); in the second case, countries are in a row (one northern EU country, one southern EU country and Libya for instance). For each case, we first study what happens when the two developed countries create a border free zone for their native populations and implement a joint migration policy toward the developing country. Then, we study what happens when the two developed countries implement a border free zone but remain autonomous regarding their migration policy toward the developing country.

Our model is parameterized to simulate legal and illegal immigration stocks in the EU15 in 2005. In the first case, when the developed countries (akin to the EU15) implement a joint migration policy, we find that the EU15 hosts about 0.9855% illegal immigrants over its native population. This result is in line with the estimates proposed by Kovacheva and Vogel (2009). We find that a tight quota reduces the number of legal migrants. This restrictive policy excludes individuals who could have migrated legally but who are not rich enough to migrate illegally, and forces those able to pay for their illegal migration into illegality. Furthermore, when the developed countries implement autonomous migration policies, we show that a developed country intending to reduce its level of illegal migration has an interest to implement a more liberal policy than its neighbour. When countries are in a row (case 2), we find that policies implemented by southern countries impact the level of immigration faced by northern countries which are geographically *protected* from immigration. The latter result calls, in a way, for more collaboration between EU member states as the immigration pressure faced by southern countries becomes more important.

[7] We follow the methodology proposed by Tesfatsion (2003) and Helbing (2012) to build our spatial ABM. We use the interface Repast Simphony 2.1 for Java (North et al., 2013).

The contribution of this chapter to the economic literature on illegal migration is the following. Our approach provides new perspectives regarding the modelling of illegal migration. Our model rests upon the micro neoclassical theory of migration, but allows us to relax some assumptions: we assume a world under imperfect information with rational but not necessarily optimising agents. Yet, we are able to reproduce some standard results of the migration literature, while proposing new insights regarding the importance of geography and information in migration decisions. Furthermore, our model requires very few data to be parameterized, which allows us to overcome the poor data availability to analyse illegal migration.

Finally, this chapter also contributes to the literature on ABM of migration. While most available ABM do not explicitly use a theoretical framework to define the micro-economic behaviours of their agents, we explicit rest upon a theoretical analysis – here the micro neoclassical theory of migration – to define the migration decisions of our agents. Thereby, we look at what happens (thanks to the ABM methodology) when we relax some assumptions of the theory. We claim that, by doing so, we can more easily learn from and build upon the existing literature.

The rest of the chapter is organised as follows. In the next section, we present a brief review of existing ABMs of migration. In section 6.3 we introduce our spatial agent-based model. In section 6.4 we present the parameterization of our model and our results. Section 6.5 concludes.

6.2 Related ABM of migration

Agent-based modelling is a new methodology which enables researchers to explore complex systems with a temporal scale, a spatial dimension and heterogeneous agents interacting with each others (Tesfatsion, 2003; Tesfatsion and Judd, 2006). Agents are intelligent and adaptive but not necessarily rational. In such a model, the aggregation of micro-economic behaviours allows to reproduce macro-economic phenomena.

The development of ABMs of migration is at an early stage[8]. At first, researchers have used ABMs to reproduce standard results of the migration theory. In particular, the ABM of Espindola et al. (2006) and Silveira et al. (2006) reproduce the results of the urban-rural migration model of Harris and Todaro (1970).

[8] Since the segregation model of Schelling (1971), agent-based computational economics has been used in a lot of fields such as macroeconomics and finance (Duffy, 2001; Gallegati et al., 2003), and game theory and social sciences (Helbing, 2012). Our work is in line with (and largely inspired by) the modelling of artificial societies (Epstein and Axtell, 1996; Epstein, 2001; Wilson et al., 2013).

Then, researchers have used the modelling properties of ABMs to propose new insights on migration. In particular, Klabunde (2014) develops an ABM of migration with an endogenous network of individuals. She shows that expected earnings and relationships with other individuals determine migration and return decisions. Her model is calibrated for the case of Mexican migrants in the US from 1955 to 1965. In the same vein, Filho et al. (2011) show how migration and wage equalisation dynamics change when they consider an environment under imperfect information. In their ABM, access to information of a would-be migrant depends on his geographical position and his connection to a network of individuals. The model is calibrated for the Brazilian internal migration between two similar regions, with the demographic census of 2000. Rehm and Naqvi (2013) develop an ABM focusing on migration from rural and urban areas of Ecuador to the city of New York in 2010. Agents are able to migrate between the three areas, remit and return, and are embedded in a family network. The model reproduces some stylised facts such as the geographical repartition of the population between the three areas, the ratio of gross to net migration, and the shape of remittances between the three regions. Our work is in line with the latter papers which use migration networks as the core framework of their analyses. In our model, both legal and illegal migration decisions are taken according to available information, and information only circulates among individuals who are part of the same network.

The paper of Willekens (2012) further focuses on the migration decision making process. He develops an ABM resting upon the behavioural theory in order to explain patterns of emigration. His model describes the time needed to develop an intention to migrate and the time required to plan a migration. The model reproduces the migration age profile of individuals documented in the literature.

Finally, some papers use the agent-based methodology to forecast population movements due to climate change. Kniveton et al. (2011) develop an ABM to forecast migration in Burkina Faso. They show that climate change could strengthen regional and international migration flows by influencing political, social and economic drivers of migration. Along the same lines, Hassani-Mahmooei and Parris (2012) develop an ABM to study internal migration due to climate change in Bangladesh. They show that areas vulnerable to natural disasters could generate migration toward safer zones such as northern and eastern districts over the next 40 years.

6.3 The agent-based model

The world is formalised by a non-toric rectangular space. We place a grid on this space to obtain a discrete environment. We divide it in three equal parts to create three identical countries. Each country is populated with a given number of native individuals[9].

Each individual n native from country i is randomly placed in that country at the beginning of the simulation. Individuals are internationally mobile. Over time, they can migrate legally or illegally. They are self-interested and perfectly autonomous in their migration decisions (their actions are not governed by any central authority). They take myopic decisions based on their personal characteristics, their environment and their perception of their environment. The migration decision process of an individual n is detailed in the following sub-sections.

6.3.1 Wage and expected wage in the residence country

The log-wage of an individual n living in country i at time t follows a Normal distribution:

$$\ln w^i_{n,\,t} \rightsquigarrow \mathcal{N}\left[\mu^i_t, \left(\sigma^i\right)^2\right] \;\; \forall i;\; \forall\, n,\, n = 1, ..., N;\; \forall\, t,\, t = 1, ..., T \tag{6.1}$$

where σ^i denotes a country-specific standard deviation corresponding to the level of wage inequalities in country i. We assume a small standard deviation in order to model one single skill category. μ^i_t denotes a country-specific mean and relates the average labour productivity in country i at time t. The latter is determined by an auto-regressive stationary process:

$$\mu^i_t = \mu^i_{t-1} + b^i \left(\mu^i_{t-1} - \mu^i_{t-2}\right) \tag{6.2}$$

where b^i is a positive constant greater than unity and denotes the persistence of productivity variations over time[10]. This macro-economic adjustment is unobserved by individual n, who only observes the evolution of his own wage over time. Based upon the theory of expectations, we consider that individual n approximates his expected log-wage such that:

$$\left(\ln w^i_{n,\,t+1}\right)^E = \ln w^i_{n,\,t} + b_n \left(\ln w^i_{n,\,t} - \ln w^i_{n,\,t-1}\right) \tag{6.3}$$

[9] The world population is constant over time as this study consists in a short term analysis of migration policies on illegal migration.
[10] A stationary state exists for all b^i larger or equal to zero, and lower than unity.

where b_n denotes an individual-specific constant between zero and unity and reflects the value individual n concedes to the past evolution of his wage. Thereby, the expected wage of individual n is given by:

$$\left(w^i_{n,\,t+1}\right)^E = w^i_{n,\,t}\left(\frac{w^i_{n,\,t}}{w^i_{n,\,t-1}}\right)^{b_n} \tag{6.4}$$

Because the environment (the wage distribution) may change over time and because of his believes (b_n), his expectations are always imperfect.

Note that at time $t = 1$, individual n needs to know his previous wages ($w^i_{n,\,-1}$ and $w^i_{n,\,0}$) to approximate his expected wage. Similarly, at $t = 2$, he needs to know $w^i_{n,\,0}$ and $w^i_{n,\,1}$. As wages are unknown prior to the first period, we assume that: $w^i_{n,\,-1} \equiv w^i_{n,\,0} \equiv w^i_{n,\,1}$.

6.3.2 Network and expected wage at destination

At each time period, individuals explore their environment moving randomly (at no cost) within their Moore neighbourhood[11]. For instance, Figure 6.1 shows a Moore neighbourhood of eight cells for each of the four individuals represented. An individual located at the border may have a part of his neighbourhood abroad (see individuals 2 and 4, Figure 6.1). In this case, he is not allowed to move to that part of his neighbourhood.

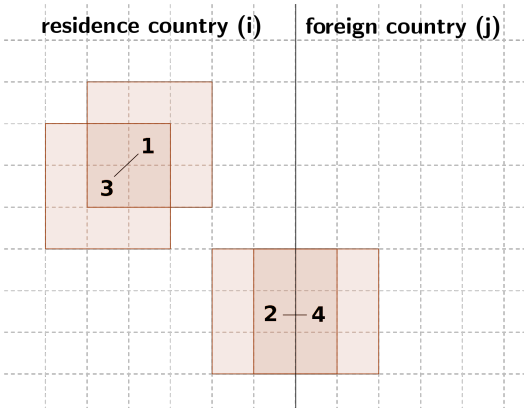

Figure 6.1.: Moore neighbourhood

Individuals nourish social relationships with a limited number of agents. At each time period, individual n creates a link with each individual q located in his neighbourhood (see individuals 1 and 3, Figure 6.1). Notice that an individual located at the border creates a

[11] The Moore neighbourhood of a given point, given its range x, is formed by the $(2x+1)^2 - 1$ surrounding cells at a Chebyshev distance of x.

link with each individual located in his neighbourhood including those located abroad (see individuals 2 and 4, Figure 6.1)[12].

To each link is associated a weight representing the quality of the relationship unifying the two persons. Let us denote the weight of the link between individual n and individual q at time t by $\Omega_{nq,\,t}$. The weight is set to unity at its creation. At the next period, if the two individuals stay in the neighbourhood of each other, the quality of their relationship increases by $\triangle_\Omega$, such that: $\Omega_{nq,\,t+1} = \Omega_{nq,\,t} + \triangle_\Omega$. If they move too far away from each other, their relationship deteriorates by $\triangle_\Omega$ such that: $\Omega_{nq,\,t+1} = \Omega_{nq,\,t} - \triangle_\Omega$. When the weight drops to zero, the link between the two individuals vanishes.

We denote $R_{n,\,t}$ the set of individuals with whom individual n is connected at time t: $R_{n,\,t} = \{q : \Omega_{nq,\,t} > 0\}$. The connectivity pattern of a network is random – individuals move randomly inside their neighbourhood – and local – individuals need proximity to create a link. Here, we assume a small world. In other words, the world is large enough so that an individual cannot explore it all (and meet all other individuals), but small enough so that it can be nearly completely explored by all individuals.

We assume individuals living in country i have no public information on foreign countries. To collect information on wages in a potential destination country denoted j, individual n interrogates all persons living in that country he knows: $M^j_{n,\,t}$ such that $M^j_{n,\,t} \subseteq R_{n,\,t}$. Then, he calculates the approximated average wage he could have get in country j at time t. Because information may be noisy and incomplete, he weights information he collects from an individual q by the weight of the link existing between them:

$$\tilde{w}^j_{n,\,t} = \frac{\sum_{q=1}^{M^j_{n,\,t}} \Omega_{nq,\,t}\, w^j_{q,\,t}}{\sum_{q=1}^{M^j_{n,\,t}} \Omega_{nq,\,t}} \;\forall\, M^j_{n,\,t} > 0 \tag{6.5}$$

When individual n knows no one abroad ($M^j_{n,\,t} = 0$), he has no information on foreign wages so that $\tilde{w}^j_{n,\,t} \equiv 0$.

At time t, individual n forms an expectation on his wage in country j at time $t+1$, using information he has gathered from his peers:

$$\left(w^j_{n,\,t+1}\right)^E = \begin{cases} \tilde{w}^j_{n,\,t} \left(\frac{\tilde{w}^j_{n,\,t}}{\tilde{w}^j_{n,\,t-1}}\right)^{b_n} & \text{if } \tilde{w}^j_{n,\,t-1} > 0 \\ \tilde{w}^j_{n,\,t} & \text{if } \tilde{w}^j_{n,\,t-1} = 0 \end{cases} \tag{6.6}$$

[12] Borders do not prevent individuals to communicate. Information may circulate regionally thanks to the media, and thanks to commercial transactions and investments between the two countries.

We assume individual n knows no one abroad prior to period $t = 1$, so that $\tilde{w}^j_{n,-1} \equiv \tilde{w}^j_{n,0} \equiv 0 \ \forall j \neq i$.

Because the environment (the wage distribution of the foreign country) may change over time, because of his believes (b_n) and because he is imperfectly informed, his expectations are always imperfect.

6.3.3 The migration utility

The utility of individual n to migrate legally from his residence country i to a destination country j at time t is given by:

$$\mathrm{U}^{ij\mathrm{leg}}_{n,t} = \frac{1}{\alpha_n}\left[\left(w^j_{n,t+1}\right)^E - \left(w^i_{n,t+1}\right)^E\right] - \mathrm{C}^{ij\mathrm{leg}}_{n,t} \tag{6.7}$$

where α_n denotes the preference for the present of individual n and $\mathrm{C}^{ij\mathrm{leg}}_{n,t}$ denotes the legal-migration cost such that:

$$\mathrm{C}^{ij\mathrm{leg}}_{n,t} = \bar{w}_t\left[c + \beta\left(1 - \frac{S^j_{n,t}}{D^j_{n,t}}\right)\right] \tag{6.8}$$

where:

- $\bar{w}_t$ denotes the world average wage[13];
- c is a positive constant and may denote a transport cost identical across individuals;
- $\beta\left(1 - \frac{S^j_{n,t}}{D^j_{n,t}}\right)$ is akin to an informational cost where β is a weighting coefficient. $S^j_{n,t}$ denotes all individuals living in country j whom individual n knows, and with whom he shares the same origin country: $S^j_{n,t} \subseteq M^j_{n,t} \subseteq R_{n,t}$. These persons can minimise his migration cost by easing his access to employment or housing in the destination country (Massey and Espana, 1987; Beine et al., 2011b). $D^j_{n,t}$ denotes the whole diaspora *i.e.* the set of immigrants from the origin country of individual n living in country j. T+ ľë he bigger is a diaspora, the less solidarity there is for new migrants. Thereby, the ratio $\frac{S^j_{n,t}}{D^j_{n,t}}$ shows to what extent the relationships of individual n can decrease his informational cost.

In case of return migration, the migration cost is also given by $\mathrm{C}^{ij\mathrm{leg}}_{n,t}$. In doing so, we assume that migrants progressively lose contact with their origin country, so they also have to pay an informational cost to return.

[13] The world average wage is not observed by individual n. The composition of the migration cost does not need to be known by individual n. The agent considers it as given.

The utility of individual n to migrate illegally from his residence country i to a destination country j at time t is given by:

$$\mathrm{U}_{n,t}^{ij\text{illeg}} = \frac{1}{\alpha_n}\left[\left(w_{n,t+1}^{j}\right)^{E} - \left(w_{n,t+1}^{i}\right)^{E}\right] - \mathrm{C}_{n,t}^{ij\text{illeg}} \tag{6.9}$$

where the illegal-migration cost is:

$$\mathrm{C}_{n,t}^{ij\text{illeg}} = \bar{w}_t\left[c + c_i + \beta\left(1 - \frac{S_{n,t}^{j}}{D_{n,t}^{j}}\right)\right] \tag{6.10}$$

Here, c_i denotes an exogenous constant greater than zero akin to a constant cost. It may include the risk of being caught or robbed on the road and extra payments to smugglers[14]. Thereby, we assume that migrating unlawfully is more costly than migrating legally.

Let m denotes the migration modality (migrating legally/migrating illegally) such that $m = \{\text{leg}, \text{illeg}\}$. We can now write the utility of individual n to migrate under modality m from his residence country i to a destination country j at time t by:

$$\mathrm{U}_{n,t}^{ijm} = \frac{1}{\alpha_n}\left[\left(w_{n,t+1}^{j}\right)^{E} - \left(w_{n,t+1}^{i}\right)^{E}\right] - \mathrm{C}_{n,t}^{ijm} \tag{6.11}$$

where $\mathrm{C}_{n,t}^{ijm}$ denotes the cost for individual n to migrate under modality m. The utility to stay (when $i = j$) equals zero ($\mathrm{U}_{n,t}^{iim} \equiv 0 \; \forall m$) because the cost to stay equals zero ($\mathrm{C}_{n,t}^{iim} \equiv 0 \; \forall m$).

6.3.4 The migration decision

Necessary conditions to migrate

Because the utility of staying equals zero ($\mathrm{U}_{n,t}^{iim} = 0 \; \forall m$), individual n is willing to migrate at time t from his neighbourhood in country i to a random location in a destination country j under modality m, only if his utility to migrate is strictly positive: $\mathrm{U}_{n,t}^{ijm} > 0$. In other words, he would never migrate to a country where his utility would deteriorate. He will be able to do so, only if he meets the following necessary conditions:

1. We assume that individual n faces a liquidity constraint[15]. He will be able to reach a given destination j only if he can afford the migration cost: $w_{n,t}^{i} - \mathrm{C}_{n,t}^{ijm} \geq 0$.

[14] Here, we define a smuggler as a person bringing a technical assistance in crossing a border. More generally, a smuggler is a person or an organisation serving as an intermediary, assisting migrants in crossing international borders (technical or/and financial assistance). These illegal acts may range from altruism to organised crime actions. See IOM (2003) for a more detailed definition of the concept.

[15] Due to financial constraints (caused by an underdeveloped banking system for instance), we assume that individuals cannot borrow, thus they can only afford destinations for which the bilateral migration cost is lower than their income. See Hatton and Williamson (2005), Djaji and Vinogradova (2014), and Beine et al. (2015a).

2. If individual n intends migrating legally, he should obtain a visa from the destination country authorities before migrating. Of course, this condition does not hold for returning migrants (who are native from the destination country). If he intends migrating illegally, his destination country and his residence country should share a common border. As evidenced by the report of Monzini (2010), air routes account for the high-cost segment while land routes account for the low-cost segment of the market of irregular migration. The author also mentions that few studies are available on sea routes. In view of the European case and the repeated shipwrecks in the Mediterranean sea, we are especially interested in land and sea routes, that is the low-cost segment.

3. In case individual n chooses to migrate illegally and succeeds in doing so, the legal migration path becomes closed to him. It implies that, at each time period, he can either stay in his residence country (keeping his status of illegal immigrant), return to his origin country, or migrate illegally toward another country.

The decision making process

Individual n intends to maximise his utility. To do so, he orders his utilities such that his first-best solution (destination/modality pair) is given by: $\max_{m,j} \mathrm{U}_{n,t}^{ijm} \ \forall m \forall j$, whereas his worst option is given by: $\min_{m,j} \mathrm{U}_{n,t}^{ijm} \ \forall m \forall j$.

Figure 6.2 describes the decision process faced by individual n at each time period. He first tries to migrate toward the destination and under the modality of his first-best solution. If he is unable to do so because he does not meet the necessary conditions, he tries to migrate toward his next-best solution, and so on until he decides either to migrate or to stay. When he tries migrating illegally, he faces a certain probability to fail (for instance due to border patrols). The probability to succeed in crossing the frontier is individual-specific and is drawn from a binomial distribution with an average probability of success denoted p.

At the end of each time period, individual n spends his wage in consumption. Here, we assume that (i) he gets the same satisfaction from consumption than from paying a migration cost, and that (ii) he cannot save money to pay for a future migration.

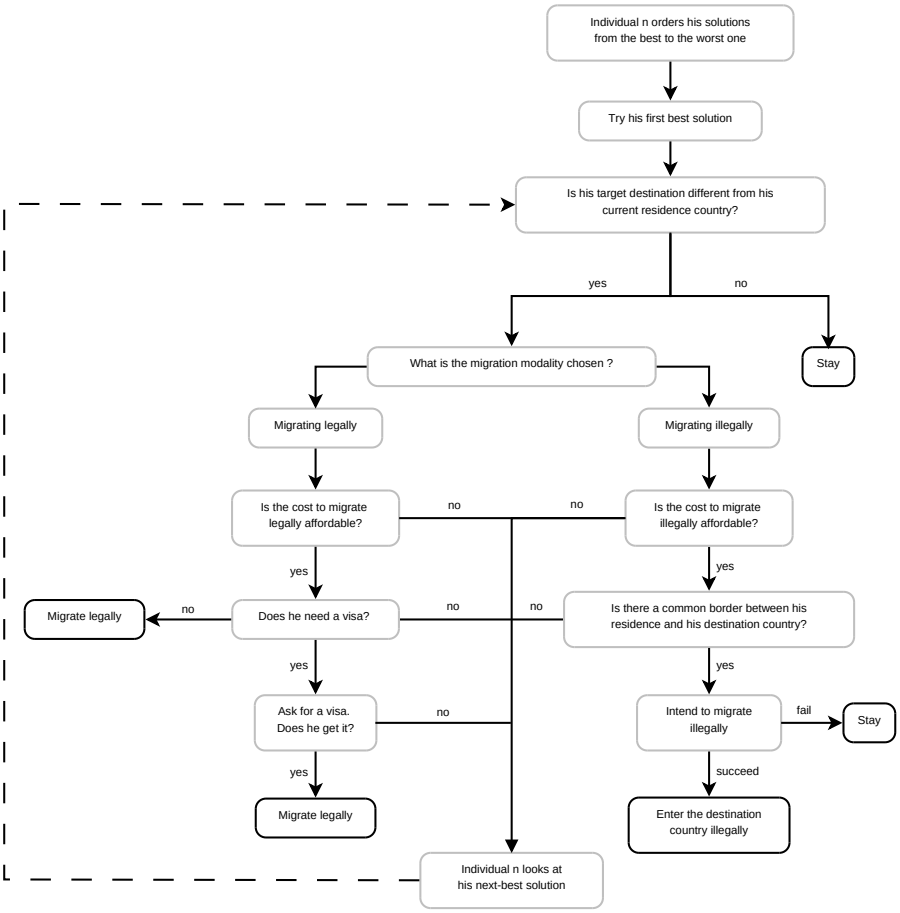

Figure 6.2.: Migration decision process faced by an individual n

6.4 Experiment

In this section, we first parameterize our model and check its robustness. Then, we check whether it is able to reproduce standard results of the migration literature. Finally, we study the impact of different migration regimes on legal and illegal migration.

6.4.1 Parameterization of the model

We simulate two developed economies, denoted i and j (akin to the EU15) and a developing one, denoted k (akin to the low and middle income country group as defined by the World Bank). Each country is initially populated with 1,000 native individuals. We consider the geography presented in Figure 6.3.

Figure 6.3.: Geography n°1: interconnected countries

We parameterize our model on the year 2005[16]. Let us remind that the mean of the log-wage distribution in each country at time t is given by: $\mu_t^x = \mu_{t-1}^x + b^x \left(\mu_{t-1}^x - \mu_{t-2}^x\right)$ $\forall x = \{i\,,\,j\,,\,k\}$. For now, we assume the average wage is constant over time so that $\mu_{t-2}^x = 0$ and $b^x = 0$. To obtain a value for μ_{t-1}^x we use the logarithm of the GDP per capita in 2005. Wage data come from the World Development Indicators of the World Bank and are presented in appendix E.1.

Together, the developed economies create a border free zone for their native populations. They agree on a joint external migration policy *i.e.* they decide to implement the same quota regime toward the developing economy. They both accept 6.3% of immigrants over their native populations. To set this quota, we follow Eurostat estimates according to which legal immigrants living in the EU15 in 2005 represented about 6.31% of the population (Kovacheva and Vogel, 2009). In our model, a country simply attributes visas until it reaches its

[16] We parameterize our model in order to compare our results to the estimates of illegal migration proposed by Kovacheva and Vogel (2009). Although these estimates are available for 2008, we choose the year 2005 to avoid the crisis period.

quota. If the number of demands outstrips the number of visas it can attribute, the country randomly selects its candidates. Furthermore, no restriction to immigration is implemented by the developing economy, and no country implements restriction to emigration.

An individual willing to migrate unlawfully has a 90% chance to succeed. To the best of our knowledge, no in-depth study has been quantifying the probability of success associated to illegal migration. Fargues and Di Bartolomeo (2015) propose an estimation of the probability of dying at sea on maritime routes to the EU. Over the period 1998-2015, this probability ranges from 0.02% to 0.07%. In is paper, Djaji (2014) develops a model of optimising behaviour of asylum seekers. He studies the decision of refugees intending to reach an advanced country to either use the services of human smugglers and then request asylum in the destination country, or to apply for resettlement to an advanced country with the aid of the UNHCR[17]. For simulation purpose, the author sets the probability of successful illegal migration (entering the country and being able to work in the underground economy) to 70%. Yet, as mentioned by the author, there is very little evidence on the value of this parameter.

The full parameter set is presented in appendix E.2. With these parameters, we perform 100 simulations of 50 time periods each. Figure 6.4 presents the evolution of the migration stocks over time in the developed area. We do not report intra-EU migration on the graphics. After 20 periods, the number of regular migrants in the developed zone reaches its maximum (left graphic). After what, a number of individuals who were refused by legal migration programmes and who can afford to migrate illegally, start crossing the border unlawfully (right graphic).

Table 6.2 presents some descriptive statistics. At the end of the simulation, the developed area hosts an average stock of 6.282% legal immigrants and an average stock of 0.9855% illegal immigrants over its native population. The latter result is in line with Kovacheva and Vogel (2009) who estimate that illegal immigration represented between 0.58% and 1.23% of the EU15 population in 2005. As expected, we observe no migration from the developed area toward the developing country. Finally, the 95% confidence interval shows that our model is robust with respect to seeds[18].

As a robustness test, we perform a sensitivity analysis to look at what happens when the probability to succeed in migrating unlawfully varies. Results are presented in appendix E.3, and show that our model is robust to a change in this parameter.

[17] United Nations High Commissioner for Refugees
[18] A seed is a random integer taken at the start of a simulation to calculate pseudo-random numbers.

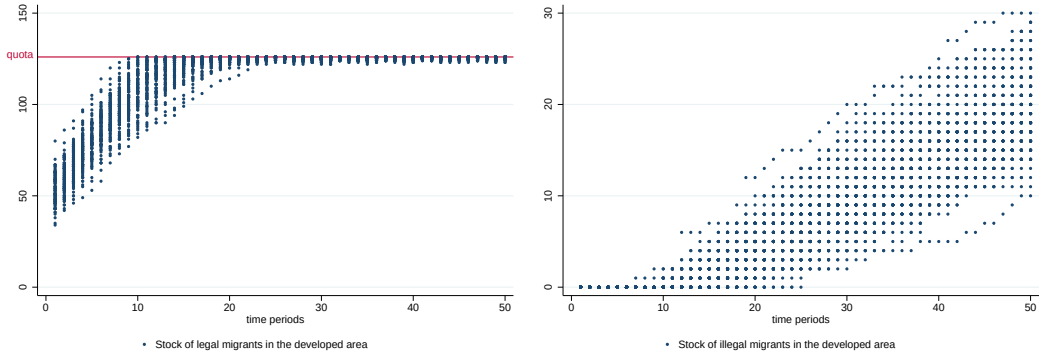

Figure 6.4.: Migration stocks in the developed area (100 simulations plotted)

	Period	Obs.	Mean	[95% Conf.	Interval]
stock of legal migrants in country i	50th	100	62.87	62.80293	62.93707
stock of legal migrants in country j	50th	100	62.77	62.6613	62.8787
stock of legal migrants in country k	50th	100	0	0	0
stock of illegal migrants in country i	50th	100	10.21	9.583617	10.83638
stock of illegal migrants in country j	50th	100	9.5	8.86969	10.13031
stock of illegal migrants in country k	50th	100	0	0	0

Table 6.2.: Descriptive statistics

6.4.2 Standard results

Migration decisions are negatively related to the wage differential between origin and destination countries

We start looking at what happens when the average wage of the developing economy increases over time. Let us remind that the mean of the log-wage distribution in the developing country at time t is given by: $\mu_t^k = \mu_{t-1}^k + b^k\left(\mu_{t-1}^k - \mu_{t-2}^k\right)$. To initialise the model, we use the logarithm of the GDP per capita of the low and middle income country group in 2003 and 2004 to obtain values for μ_{t-2}^k and μ_{t-1}^k respectively. To test different wage variations, we gradually change the value of b^k. Results are presented in Figure 6.5. When b^k increases, the average wage of the developing country converges toward a higher value, thus illegal migration toward the developed area increases. In other words, when the wage differential between the two areas reduces, individuals refused by legal migration programmes and who were previously caught in a poverty trap, get the mean to afford their illegal migration toward the developed world.

Similarly, we investigate what happens when the average wage of the developed area increases over time. Results are presented in Figure 6.6. As expected, when the wage of the developed region increases, less individuals from the developing economy can migrate

illegally because the cost to do so becomes more expensive. In other words, when the wage differential among the two areas gets larger, more individuals fall into a poverty trap.

From Figures 6.5 and 6.6 we can conclude that the number of illegal migrants in the developed area is, *ceteris paribus*, negatively related to the wage differential between countries. In our model, the wage differential exerts a *positive direct effect* (increasing incentives to migrate) and a *negative indirect effect* (increasing the migration cost) on migration decisions. Here, the direct effect appears to be smaller than the indirect one. The latter result is in line with the findings of chapter 5 and with studies showing the possible discrepancy between migration intentions and migration decisions due to financial constraints existing in developing countries (Hatton and Williamson, 2005; Djaji and Vinogradova, 2014; Beine et al., 2015a).

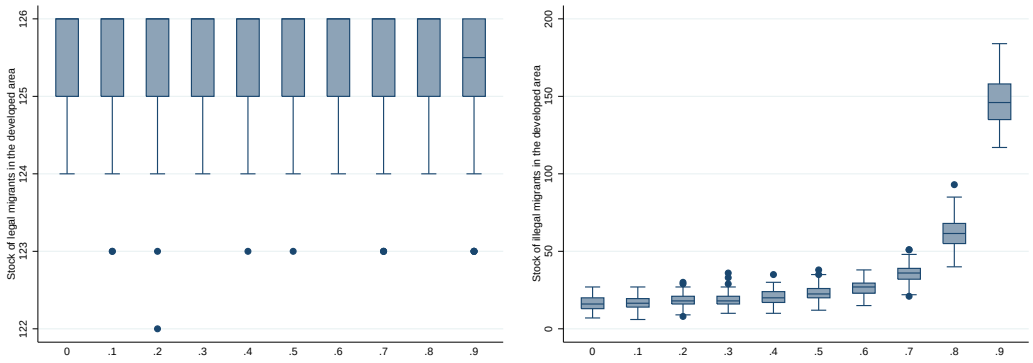

Figure 6.5.: Migration stocks in the developed area after 50 time periods for different values of b^k (100 simulations plotted for each scenario)

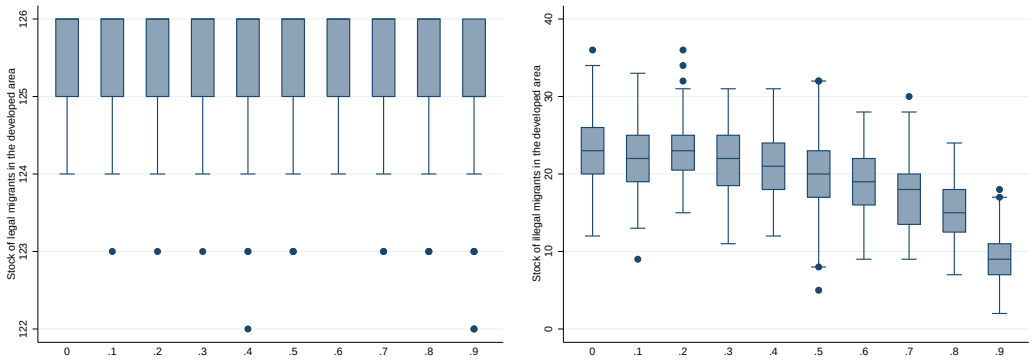

Figure 6.6.: Migration stocks in the developed area after 50 time periods for different values of $b^i \left(= b^j\right)$ (100 simulations plotted for each scenario)

Migration decisions are positively related to the level of communication among agents

We follow our analysis studying how the communication intensity among individuals determines migration. We first look at what happens when we gradually change the range of

the Moore neighbourhood. Results are presented in Figure 6.7. We find that a reduced mobility is associated with smaller legal and illegal migration stocks in the developed area, and conversely. A small Moore neighbourhood limits the mobility of individuals and their capacity to build a network. Yet, belonging to a network allows individuals to share valuable information to take their migration decisions.

Then, to test the robustness of this result, we gradually change the value by which a relationship can increase or decrease over time ($\triangle_\Omega$). Results are presented in Figure 6.8. We find that illegal migration in the developed area is positively related to the communication intensity among individuals: when $\triangle_\Omega$ is small, relationships do not vary much over time.

We can conclude that illegal migration is positively related to the communication intensity among agents, in terms of both mobility and social interactions. In presence of large networks, pioneering migrants help a large number of their relatives to migrate in the following periods, whereas in presence of small networks we observe isolated migration cases. This result corroborates studies showing that diaspora determine migration flows toward developed countries (Beine et al., 2011b; Filho et al., 2011).

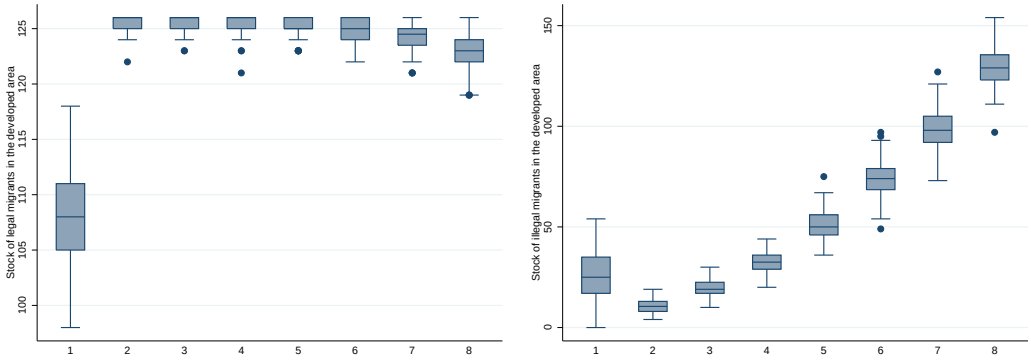

Figure 6.7.: Migration stocks in the developed area after 50 time periods for different ranges of the Moore neighbourhood (100 simulations plotted for each scenario)

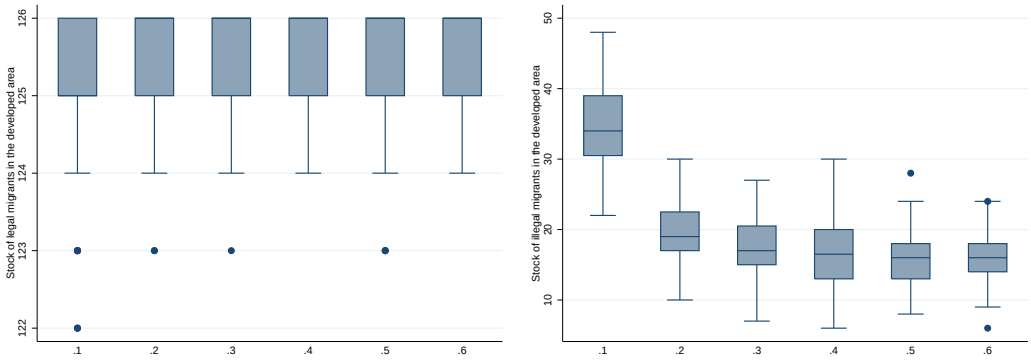

Figure 6.8.: Migration stocks in the developed area after 50 time periods for different values of $\triangle_\Omega$ (100 simulations plotted for each scenario)

6.4.3 Analysis of different migration policies

Joint migration policy

In this part, we analyse the consequences of an exogenous change in the joint migration regime implemented by the developed area toward the developing country. Results are presented in Figure 6.9. As expected, when the joint quota decreases, less individuals from the developing world are accepted as legal immigrants in the developed area. Consequently, would-be migrants excluded from legal migration programmes have to take illegal migration paths which is more costly than migrating legally. Among them, some are still rich enough to migrate illegally toward the developed area, others are not rich enough to migrate illegally. Thus, a restrictive policy decreases the total number of immigrants hosted by the developed area (left graphic), but does force some individuals into illegality (right graphic). The latter result corroborates the analysis of Broeders and Engbersen (2007). Although not reported on the graphics, the number of illegal immigrants is approximatively equally spread between the two developed countries.

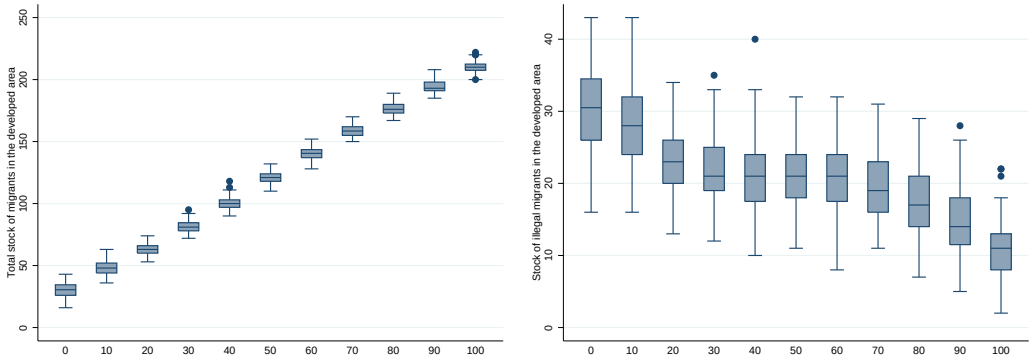

Figure 6.9.: Migration stocks in the developed area after 50 time periods for different joint quota regimes (100 simulations plotted for each scenario)

Autonomous migration policies

Let us investigate what happens when the two developed countries remain autonomous regarding the migration policy they implemented toward the developing country. To do so, we gradually change the quota implemented by country i, holding the quota of country j constant to 60 visas. Results are presented in Figure 6.10. As expected, we find that when country i implements a restrictive migration policy, the number of illegal immigrants living on its soil increases. Interestingly, when the quota of country i is lower than the quota of country j (60 visas), illegal migration decreases in country j. Conversely, when the quota of country i is larger than the quota of country j, illegal migration increases in country j.

In other words, when country i implements a tighter migration policy than country j, it reduces the level of illegal immigration faced by country j.

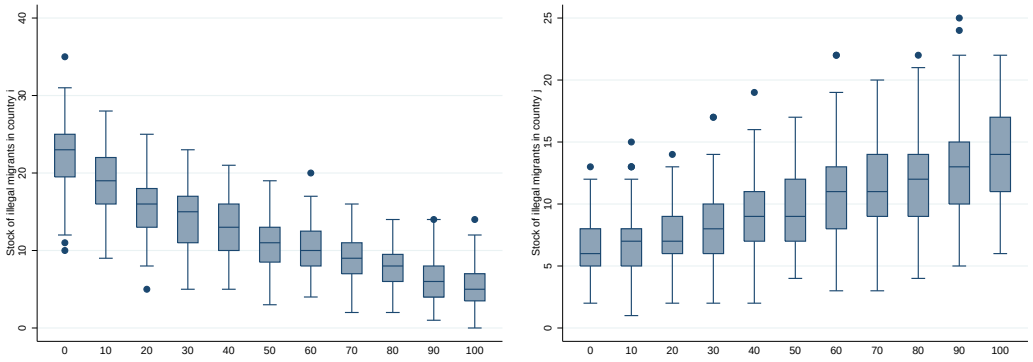

Figure 6.10.: Illegal migration stocks in the developed countries after 50 time periods for different quota regimes implemented by country i (100 simulations plotted for each scenario)

How can we explain this result? Let us look at an extreme case, say when country i implements a zero-immigration policy. Results are presented in Figure 6.11. Because of imperfect and noisy information, it may well be the case that some individuals willing to migrate to country i but refused by legal programmes, decide as a second-best solution to migrate illegally to country i, instead of trying to migrate legally to country j. It may also be the case that an individual has information on both foreign countries but migrates illegally toward country i because he has stronger ties in that country. Thus, when country i implements a zero-immigration policy, it refuses visa demands and generates illegal migration from the beginning of the simulation. On the other hand, country j accepts visa demands until it reaches its quota, which limits illegal entries for a time. The number of individuals able to migrate illegally toward country j happens to be smaller because most of the individuals willing and able to migrate toward that country have done so legally.

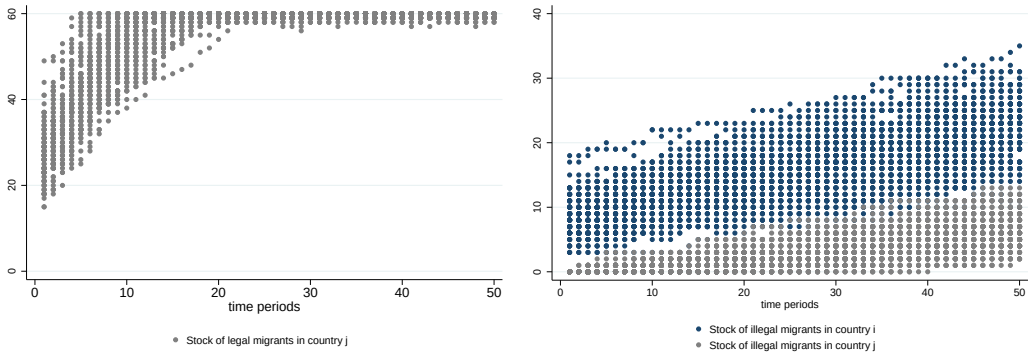

Figure 6.11.: Migration stocks in the developed countries when country i implements a zero-immigration policy (100 simulations plotted for each scenario)

Thus, a developed country intending to reduce its level of illegal migration has an interest to implement a slightly softer migration policy than its neighbour. On the long run, a non

collaborative game can appear: if each developed country intends to reduce the number of illegal migrants living on its soil, then each one of them would successively decrease its quota which would lead to the complete openness of borders. However, developed countries also intend to limit their stocks of legal immigrants. The benefit of a joint migration policy appears thus straightforward. Implementing a joint quota would equally limit their levels of illegal immigration, while allowing them to reach their joint objective in terms of legal immigration.

The geographic disposition chosen here refers to southern EU countries that *equally* face the arrival of undocumented migrants. Our results imply that those countries, guardians of *Fortress Europe*, may find a long term interest to collaborate to create a joint migration regime.

6.4.4 Analysis of different migration policies with an alternative geographical space

Up to now, we have assumed that the two developed countries are equally accessible for individuals of the developing country (two southern EU countries and Libya for instance). However, reality can be different. Some northern EU countries are only accessible through southern EU countries (for a Libyan intending to migrate illegally, France may only be accessible through Italy for instance). Consequently, some southern EU countries assume alone the arrival of illegal migrants willing to establish in the EU. Those countries, like Italy, are asking northern EU members for more cooperation and more solidarity regarding the management of undocumented migrants. Yet, a number of northern countries does not seem ready to recognise their responsibility to do so.

Thereby, we now consider an alternative geography, presented in Figure 6.12. We assume countries in a row, which changes the set of possible destinations of would-be illegal migrants. If an individual from the developing country (k) wants to enter the developed area illegally, he can only enter through country j. Consequently, country i is geographically *protected* from illegal entries.

Joint migration policy

Let us go back to the case in which the two developed countries implement a joint migration policy toward the developing country (they implement identical quota regimes). We analyse what happens when their joint migration policy changes. Results are presented in

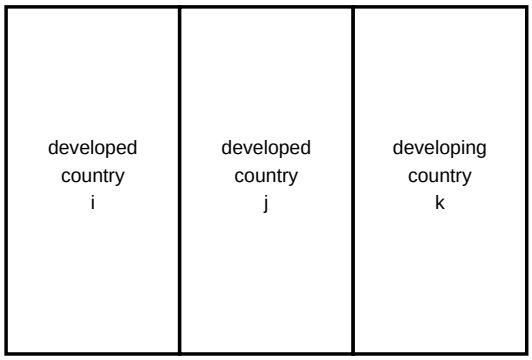

Figure 6.12.: Geography n°2: countries in a row

Figure 6.13. First, we observe that, because geography limits the transmission of information between individuals living in the developing country and individuals living in country i, potential legal migrants from the developing country choose to emigrate primarily toward country j. Then, because the wage differential between the two developed countries is closed to zero, only a minority of them migrates legally toward country i. When some migrants have reached country i, because they maintain relationships with their relatives stayed home, they may generate migration directly from country k to country i. We observed here what we may call *step-by-step* migration. Then, it appears that no matters the quota jointly decided, it is always binding in country j but never binding in country i.

Second, we find that when the joint migration policy becomes more restrictive, the stock of illegal immigrants increases in both developed countries. We have assumed in our model that would-be illegal migrants can only migrate toward a country sharing a border with their country of residence. As a result, illegal migrants are mainly located in country j; only few of them continue their journey toward country i.

Autonomous migration policies

Let us now look at what happens when the two developed countries remain autonomous regarding their migration policies toward the developing country. First, we gradually change the quota implemented by country j (which shares a border with the developing country), holding the quota of country i constant to 60 visas. Results are presented in appendix E.4, and are highly similar to the joint policy case presented previously in Figure 6.13. As expected, we find that the migration policy of country j has an impact on the level of immigration faced by country i. When country j limits its quota, a smaller share of those accepted as legal migrants by that country will demand a visa to migrate toward country i, which decreases legal migration toward country i. Regarding illegal migration, when country j tightens its migration policy, the number of illegal migrants in that country in-

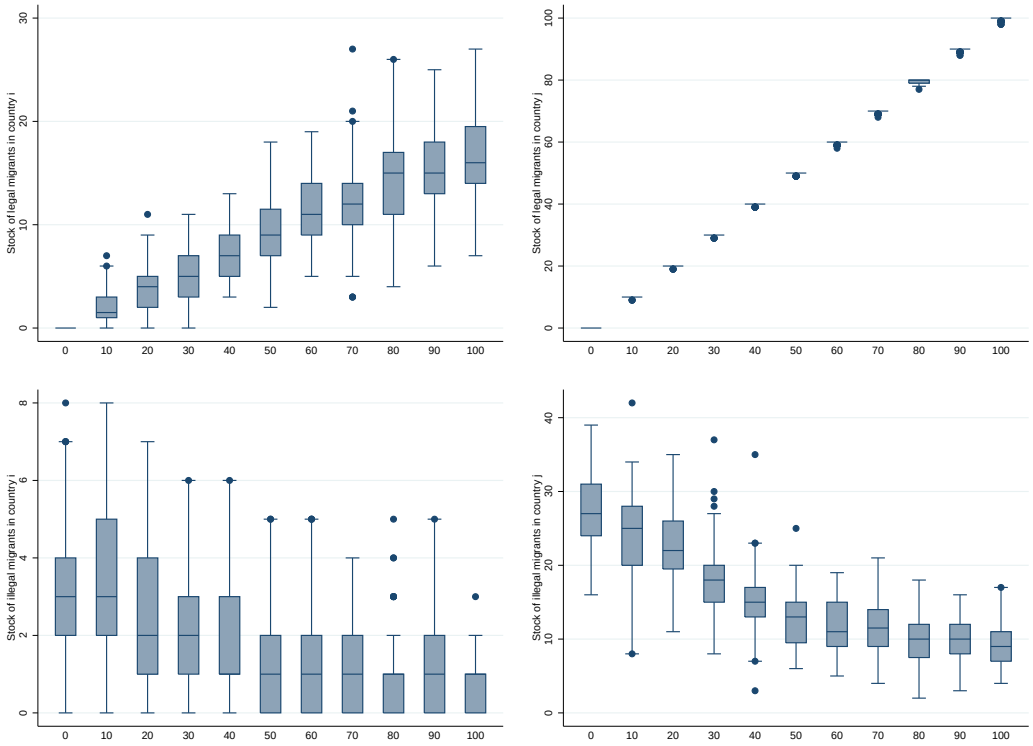

Figure 6.13.: Migration stocks in the developed countries after 50 time periods for different joint quota regimes (100 simulations plotted for each scenario)

creases. Furthermore, when the quota of country j gets lower than the quota of country i (60 visas), illegal migration slightly increases in country i. Conversely, when the quota of country j gets larger than the quota of country i, illegal migration decreases in country i. Thus, country i seems dependent from the policy implemented by country j.

Then, we gradually change the quota implemented by country i (which is geographically *protected* from immigration coming from the developing world), holding the quota of country j constant to 60 visas. Results are presented in Figure 6.14. We find that the migration policy of country i is only *effective* (reducing its stock of total immigrants but increasing its stock of illegal immigrants) when it gets close to a zero-immigration policy. Otherwise, the migration policy implemented by country i does not appear to have any effect on its level of immigration. Furthermore, we find that a change in the migration policy of country i has no effect on the level of immigration faced by country j. This result is due to the geographic positions of country i and country j with respect to country k.

Thereby, as long as southern EU countries can manage illegal entries while keeping their objectives in terms of legal immigration, they will find poor interest in collaborating with northern EU countries. Yet, when the immigration pressure becomes too important, those countries may ask northern EU governments to support them to manage undocumented immigrants. On the other hand, northern EU countries are naturally *protected* from legal

and illegal immigration. Yet, although quite contained, their levels of legal and illegal immigration do depend on the policies implemented by southern countries.

A partnership between southern and northern EU countries can appear if the immigration pressure becomes high. In such a case, southern EU countries have an interest to collaborate with northern countries (*i.e.* to jointly decide the migration policy that southern countries should implement), in exchange for the support of northern EU countries to manage illegal entries. However, as long as the migration policy of southern EU governments accommodates northern countries, the latter have no interest to collaborate with southern EU countries.

In a nutshell, our results explain, in a way, why EU countries implement quite autonomous migration policies toward developing countries. Some northern countries show a poor interest in collaborating with southern countries to manage undocumented migrants. Those countries are, indeed, naturally *protected* from legal and illegal immigration. In case immigration flows toward south Europe would further increase, then the stock of illegal migrants in northern countries would also increase. Thereby, northern countries may find an interest to help southern countries to manage their immigration.

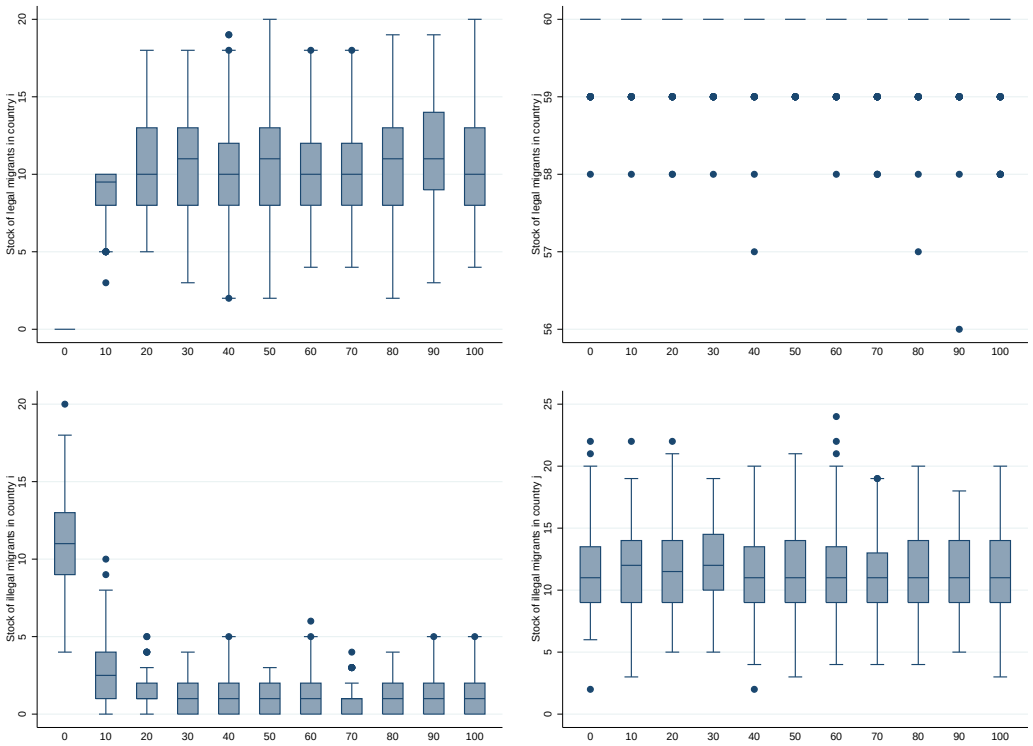

Figure 6.14.: Migration stocks in the developed countries after 50 time periods for different quotas implemented by country i (100 simulations plotted for each scenario)

6.5 Conclusion

European countries have come a long way since the Treaty of Rome of 1957, for which signatory states committed to create a border free zone. The right to migrate within the EU area is now recognised. However, migration policies regarding third countries remain under the sovereignty of the states. Since 2004, EU members have been collaborating within a joint agency for external border security named FRONTEX. This agency aims, among other things, at coordinating border patrols and deportations of undocumented migrants.

The efficiency of migration policies is crucial for EU countries facing a slow down of their economic activity and for which migration has become a political matter. In history, the restrictiveness of migration policies has been oscillating with economic and political-ideological cycles. Periods of economic expansion have often been associated with liberal migration policies, while periods of recession have often been associated with restrictive migration policies in developed countries (Castles et al., 2014).

To analyse the consequences of a restrictive migration regime, we use a spatial agent-based model with one developing and two developed countries. Our model is parameterized on the EU15 for the year 2005. We derive three main results from our analysis: (i) When developed countries tighten their quota regimes, illegal migration increases. Would-be migrants excluded from legal immigration programmes have to take illegal migration paths which is more costly than migrating legally. Thus, this policy prevents individuals not rich enough to migrate illegally, but forces those able to pay for their migration into illegality. (ii) In case developed countries are equally accessible from the developing country (two southern EU countries and Libya for instance), a developed country intending to reduce its level of illegal migration has an interest to implement a more liberal migration policy than its neighbour. This result implies that, if countries do not want to end up perfectly open because of a repeated non collaborative game, they have a long term interest to implement a joint migration policy toward third countries. Finally, (iii) in case countries are in a row (one northern EU country, one southern EU country and Libya for instance), we find that policies implemented by the southern country impact the level of immigration faced by the northern country, even if the latter is geographically *protected* from immigration. This result calls, in a way, for more collaboration between EU member states as the immigration pressure faced by southern countries becomes more important.

Over history, immigrants have proved to be a real added value for their host society, both economically and culturally speaking (Goldin et al., 2011). Nonetheless, undocumented migrants can be seen as undesired and unlawful by their host society which can implement

different repressive actions against them. The gain for the host society may no longer be positive, if illegal migrants are associated with expenses in terms of police resources and social care.

Thereby, in order to reduce the number of illegal migrants on their soil, our study suggests that member states could jointly soften their migration programmes by relaxing their visa requirements and increasing their quotas. Yet, such a policy induces a rise of legal immigration that may also be undesired by governments. Alternatively, member states could implement a joint toleration policy which could ameliorate the living conditions of undocumented immigrants. That being said, further economic analyses are needed to study whether the gain of a toleration policy may outstrips the cost to manage non tolerated undocumented immigrants for the EU society. Occasional regularisation programmes would achieve to recognise illegal immigrants as part of the civil society – thanks to voting rights – and as part of the economic society – by neutralising some negative effects of the informal economy. Again, further economic research seems needed to study those programmes.

7 General conclusion

Understand why people migrate and the consequences of migration for host and origin countries is crucial for policy makers in charge of managing present and future migration. On the one hand, measuring the impact of migration on host and origin countries is important to establish whether or not migration flows need to be controlled, and to design the objectives of such migration policies. On the other hand, improving our knowledge of the determinants of international migration decisions is important to design efficient policies.

This thesis, studying how migrants interacts with trade and FDI, contributes to the literature analysing whether immigration is positive or not for origin and destination countries. The answer to that question depends on the skills, gender, age and legal status of international migrants. The first three chapters of this thesis show that economic migration flows, just as trade and FDI flows, are one channel of economic adjustment (chapters 2 and 3), and even a channel of economic growth (chapter 4) for origin and destination countries. Our conclusions thus open a broader question: what would be the gains retrieved from allowing people to circulate freely across developed and developing countries?

Furthermore, this thesis contributes to the analysis of international migration decisions taken in a context of increasing globalisation, that is in a world where countries are highly interdependent (chapters 5 and 6). The identification of the mechanisms by which an individual decides to migrate is crucial to know which types of policies origin and/or host countries should implement.

In the following section, we underline more precisely the contributions of this thesis to the economics of international migration, from which we derive some general policy recommendations. Finally, we present a number of research perspectives on the topic of migration.

7.1 Contributions to the economics of migration

Each chapter of this thesis contributes to the research agenda presented in our Introductory chapter. Chapters 2 and 3 highlight the bidirectional relationship between migration and FDI. Most existing studies on the FDI-migration nexus show how migrants foster FDI, while

we focus on the reverse link, namely how FDI may generate or orient migration flows. We propose both a theoretical and an empirical analysis of this issue. The originality of our approach lies in the fact that we consider separately skilled and unskilled workers. It allows us to show that the nature of the relationship between migration and FDI flows depends on the qualification of the migrants.

In particular, chapter 2 explains the nature of the interdependency between international factor flows taking place between developed and developing countries: capital and skilled labour flows are complements, while capital and unskilled labour flows are substitutes. The main contribution of this chapter is to show that standard trade models, especially the standard Heckscher-Ohlin (1919, 1933) framework, are still valid to understand contemporary factor movements. In addition, this chapter fills a major gap in the literature by proposing a theoretical insight to the existing empirical literature.

Chapter 3 further investigates the relation of complementarity existing between FDI and skilled migration flows toward developing countries. Analysing a dataset of domestic and foreign firms operating in 16 Sub-Saharan Africa in 2008, we find that the employment of foreign skilled workers depends positively on the capital intensity of the employing firm, and positively on the scarcity of skilled labour in the firm's operating country. These empirical results corroborate the theoretical predictions of chapter 2.

Although quite intuitive, the conclusions of chapters 2 and 3 justify why migration and foreign investment policies should be designed together to take into consideration their interdependence. For instance, if a developing country implements policies aiming at attracting foreign investments (alleviating taxes, developing infrastructures...), it should also implement policies aiming at increasing its stock of human capital in order to satisfy the increase in demand for skilled labour potentially induced by the arrival of foreign firms. Such policies could prevent the emigration of skilled workers, promote the immigration of qualified workers and develop the educational system of the country.

In chapter 4, we focus on the trade-migration nexus. Although there is a rather large literature on this topic, only few studies adopt a micro-level approach to investigate to what extent foreign workers may impact their firm's activities. In this chapter, we investigate whether foreign workers, according to their level of qualification, influence the export decisions of their firms. One originality of our theoretical work is to analyse both margins of trade. We show that foreign workers (and especially skilled foreign workers) foster exports at both the intensive and the extensive margins of trade. We confirm these results empirically using a French firm-level dataset over 1995-2008. This result is of crucial interest for policy makers, because migration policies, if not designed in a coherent manner with the

country's trading objectives, may have unexpected effects on the country's trading performance. For instance, implementing a very restrictive migration policy could have a negative effect on the trade balance.

Overall, chapters 2, 3 and 4 show that the analysis of migration cannot be disconnected from the analysis of other international flows. Our results imply that migration and migrant integration policies ought to be designed in a coherent manner with trade and foreign investment policies. One of our future objectives is to popularise our results, hoping to be heard by policy designers.

In chapters 5 and 6, we focus on migration policies and their impact on migration flows. The common objective of these chapters is to understand how the growing integration of economies impact the patterns of migration flows. In both chapters we adopt a bottom-up approach, where we explain migration flows taking place between countries by modelling the individual migration decision. Such an approach allows us to improve our understanding of migration decisions, and thus to understand the mechanisms lying behind international migration flows.

More precisely, chapter 5 shows that the immigration policy implemented by one country with respect to a specific source country impacts migration from this source country to that destination country, but also toward other destinations. The mechanism at play is the following: migration policies impact the migration costs and thereby the attractiveness of destination countries, and the budget constraints of would-be migrants in the source country. This, in turn, determines their decisions to migrate and their choices of destination country. We build a RUM model incorporating this budget constraint effect which we calibrate on a dataset of 25 European countries in 2008. The simulation shows that this budget constraint effect is not negligible in the migration decision. This chapter proposes a new theoretical contribution on the concept of *multilateral resistance to migration*, the literature on that topic being still at an early stage.

In chapter 6, we analyse more in depth to what extent developed countries may find an interest collaborating on migration issues, in particular regarding illegal migration. We build an agent-based model to analyse the individual decision to migrate legally *versus* illegally, and the choice of the destination country. On the one hand, we find that neighbouring developed countries close to source countries have a natural interest to collaborate because the migration policy of one destination country has an important impact on the level of illegal immigration to this country and its neighbours. On the other hand, this interest to elaborate a joint immigration policy falls apart when one country is geographically far from the source countries: developed countries that are geographically *protected* from immigra-

tion only find an interest to help the main immigrant-receiving countries, if the immigration pressure becomes so important that illegal immigration *overflows* through their walls. Another contribution of this chapter is to show that computational economics may open new research perspectives. The agent-based methodology proposes interesting modelling properties and allows to perform simulations that are not data-demanding, which is valuable in a context of scarcity of accurate migration data.

Overall, chapters 5 and 6 emphasise the potential gain for open economies to further collaborate on migration issues. Each country's migration policy may impact its and others' levels of immigration (both legal and illegal) and thereby, in the light of the results proposed in chapters 2, 3 and 4, their economies.

7.2 Research perspectives

- **Toward a better understanding of migration decisions**

  This thesis has investigated a number of *new* determinants of international migration. In particular, we have shown that the interdependency of countries has an important impact on migration decisions. We have underlined the importance of financial constraints, information and geography on individuals' migration choices.

  A number of potentially crucial determinants of migration, and especially illegal migration, have not been studied in this thesis. The determinants on which we intend to work in the future are all related to the level of poverty of source countries. As underlined by Galbraith (1979), migration is "*the oldest action against poverty*" (Goldin et al., 2011). Although this is now common knowledge, it seems important to deepen our analysis of a number of contemporary factors that determine poverty, and thus migration decisions.

  A burgeoning literature looks at how emigration reacts to official development aid received by developing countries (Berthélemy et al., 2009). Similarly to FDI inflows, development aid is expected to improve infrastructures, education and healthcare systems... of the recipient economies. Such structural transformations may, in turn, impact migration incentives. The impact of aid on the volume and the composition of migration flows has not been clearly evidenced yet, although this is an important question for developed countries which could use aid as a tool for managing their immigration flows.

Climatic shocks, which are most likely to increase in the coming decades, are another important determinant of poverty. Such an increase in poverty may, in turn, produce climatic migration flows (Beine et al., 2015a). The nature of this population movement is likely to be different from migration for economic purposes and needs to be better analysed in collaboration with geographers.

The recent increase in illegal migration flows from a number of African and Middle-East countries toward the European Union, also sheds light on the need to analyse to what extent political and religious conflicts impact migration flows. These push factors may be particularly important for illegal migration and asylum-type migration. Here again, it would be beneficial to further build on the work of sociologists, political scientists and historians to better understand this movement of people across borders.

Overall, it is unclear if our knowledge of *legal* migration for economic purposes can be directly transposed to other types of migration, in particular *illegal* migration due to war or climatic disasters. One line of research we intend to analyse in a near future is the *step-by-step* process associated to illegal migration.

- **A thorough exploration of the role played by foreign workers in their host country's economy**

The large number of macro-level studies on the trade-migration nexus has conducted to the scientific consensus that migrants foster trade between their origin and host countries. An emerging literature reinforces the idea that migrants enhance business activities, showing that migration also fosters bilateral foreign investments. On the other hand, migration is influenced by international commercial transactions. These interactions between factor flows are now well documented by economists analysing macro-level data (although the literature on the FDI-migration nexus could be enriched from further contributions).

However, the role played by foreign workers within their firm is still to be explored by economists, this topic being mainly studied by management specialists. Regarding the influence of foreign workers on their firm's investment decisions, the economic literature is almost non existing. With respect to the management literature, one surprising result obtained in chapter 4 is that high skilled workers have no significant impact of their firm's export behaviour. We intend to further explore this issue by studying more precisely how high skilled workers, executives and top-managers, may influence their firm's strategic decisions, according to their birth-, education- and/or residence countries.

Then, a number of studies shows that immigrant workers, and especially skilled foreign workers, foster trading activities at both margins of trade. Our thesis contributes to this literature. Nonetheless, beyond their impact on their firm's imports and exports of final goods, immigrant workers could impact their firm's imports of intermediate goods and FDI. This may, in turn, impacts their firm's exports of final goods. The literature on this issue is still at its premisses (Mundra, 2005). Therefore, this question presents an interesting line of research.

Finally, the impact of cultural diversity within the firm's workforce needs to be further explored. Evidence from the management literature are mixed (Nielsen and Nielsen, 2011), and results from the few existing economic papers are rather ambiguous. These economic papers find a positive impact of diversity on export performance (Parrotta et al., 2014b), but a negative impact on productivity (Parrotta et al., 2014a). In chapter 4, we find a positive impact of diversity on exports at both margins of trade. This paradox needs to be further questioned.

- **Toward a better construction of migration policies**

Overall, research on migration seems to be driven by one common objective: better understand the nature and consequences of migration, in order to feed the public debate that should allow civil society to determine whether or not their is a need to restrict migration flows.

Migration has never been so regulated. For Goldin et al. (2011), the objective of our century is to craft a more human and more open migration system, because this is both ethically and economically desirable. The actual refugee crisis in Europe shows that ethic positions are difficult to defend and that the human right of free movement is far from being a reality. Besides, the economic consequences of migration for host countries is a vivid topic for debate in civil society and among economists. There is no clear-cut consensus on the fact that the benefits generated by migration flows overcome their costs. This thesis and the majority of the economic literature on that topic show a positive (or neutral) effect of migration for host and origin countries, showing that economics and ethics could go hand in hand. However some economists, for instance Collier (2013), underline the negative impact of migration on origin and host countries. Because ethics often comes after economic reasons, the costs and benefits of migration for each actor (source countries, host countries, migrants themselves, left-behind families, host-country's workers and firms) should be further clarified. As long as there will be no consensus on this issue, and since global coordin-

ation implies further limits on states' sovereignty, international migration agreements between developed and developing countries will remain rare.

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Appendix to Chapter 2

A

A.1 Single country (interior solution)

We assume that both factors are employed in the traditional sector, so that $u_1 > 0$ and $s_1 > 0$. Combining equations (2.3), (2.4) and (2.6), we obtain:

$$l = \frac{(1-\beta)\,p}{(1+c)\,A} \tag{A.1}$$

Then, using equations (2.2), (2.5) and (2.9), we obtain:

$$k = B^{-\frac{1}{\beta}} l^{1-\frac{1}{\beta}} \tag{A.2}$$

$$\rho = \beta p k^{-1} = \beta B^{\frac{1}{\beta}} p l^{\frac{1}{\beta}-1} \tag{A.3}$$

$$Q_2 = k^{-1} K = K B^{\frac{1}{\beta}} l^{\frac{1}{\beta}-1} \tag{A.4}$$

where l is given by equation (A.1). The wages are given by equations (2.3) and (2.4). Combining (A.1) with the equilibrium conditions (2.7) and (2.8) we get:

$$U = u_1 Q_1 + l Q_2 = u_1 Q_1 + K B^{\frac{1}{\beta}} l^{\frac{1}{\beta}} \tag{A.5}$$

$$S = s_1 Q_1 + l Q_2 = s_1 Q_1 + K B^{\frac{1}{\beta}} l^{\frac{1}{\beta}} \tag{A.6}$$

Using the production function (2.1):

$$U + cS = (u_1 + c s_1)\, Q_1 + (1+c)\, K\, (Bl)^{\frac{1}{\beta}} = A^{-1} Q_1 + (1+c)\, K\, (Bl)^{\frac{1}{\beta}} \tag{A.7}$$

hence:

$$Q_1 = A\left[U + cS - (1+c)\, K\, (Bl)^{\frac{1}{\beta}}\right] \tag{A.8}$$

and:

$$u_1 = \frac{U - K\,(Bl)^{\frac{1}{\beta}}}{Q_1} = \frac{U - K\,(Bl)^{\frac{1}{\beta}}}{A\left[U + cS - (1+c)\, K\, (Bl)^{\frac{1}{\beta}}\right]} \tag{A.9}$$

$$s_1 = \frac{S - K\,(Bl)^{\frac{1}{\beta}}}{Q_1} = \frac{S - K\,(Bl)^{\frac{1}{\beta}}}{A\left[U + cS - (1+c)\, K\, (Bl)^{\frac{1}{\beta}}\right]} \tag{A.10}$$

The conditions $u_1 > 0$ and $s_1 > 0$ imply:

$$K\,(Bl)^{\frac{1}{\beta}} = K\left[\frac{(1-\beta)\,Bp}{(1+c)A}\right]^{\frac{1}{\beta}} < \min\,(U, S) \tag{A.11}$$

A.2 Single country (corner solutions)

Let us first look at the case $u_1 > 0$ and $s_1 = 0$, which happens when:

$$S < K\left(Bl\right)^{\frac{1}{\beta}} = K\left[\frac{\left(1-\beta\right)Bp}{\left(1+c\right)A}\right]^{\frac{1}{\beta}} < U \tag{A.12}$$

Then, skilled labour is scarce enough for being employed in the capitalist sector only; the traditional sector employs unskilled labour only. If the wage of unskilled workers is still given by (2.3), the fact that skilled workers are no longer employed by the traditional sector implies that their wage is no longer given by (2.4). Knowing that $s_1 = 0$, and using equations (2.8) and (2.7), we get:

$$lQ_2 = S \tag{A.13}$$

$$u_1 Q_1 = U - lQ_2 = U - S \tag{A.14}$$

Then, using the production function (2.1) and the fact that $s_1 = 0$, we find:

$$Q_1 = A(u_1 + cs_1)Q_1 = Au_1 Q_1 = A\left(U - S\right) \tag{A.15}$$

and combining equations (2.9), (2.2) and (2.8):

$$Q_2 = BK^{\beta} l Q_2^{1-\beta} = BK^{\beta} S^{1-\beta} \tag{A.16}$$

$$k = \frac{K}{Q_2} = B^{-1}\left(\frac{K}{S}\right)^{1-\beta} \tag{A.17}$$

$$l = \frac{S}{Q_2} = B^{-1}\left(\frac{S}{K}\right)^{\beta} \tag{A.18}$$

Last, using (2.3), (2.5) and (2.6), we get the wage of skilled workers and the returns to capital:

$$w_s = \frac{\left(1-\beta\right)p}{l} - w_u = \left(1-\beta\right)Bp\left(\frac{K}{S}\right)^{\beta} - A > cA \tag{A.19}$$

$$\rho = \beta p k^{-1} = \beta B p\left(\frac{S}{K}\right)^{1-\beta} \tag{A.20}$$

Let us now look at the case $u_1 = 0$ and $s_1 > 0$, which happens when:

$$U < K\left(Bl\right)^{\frac{1}{\beta}} = K\left[\frac{\left(1-\beta\right)Bp}{\left(1+c\right)A}\right]^{\frac{1}{\beta}} < S \tag{A.21}$$

Now, unskilled labour is scarce enough for being employed in the capitalist sector only; the traditional sector employs skilled labour only. The wage of skilled workers is still given by equation (2.4), but unskilled workers are no longer employed by the traditional sector, which implies that their wage is no longer given by (2.3). Knowing that $u_1 = 0$, and using (2.8) and (2.7), we get:

$$lQ_2 = U \tag{A.22}$$

$$s_1 Q_1 = S - lQ_2 = S - U \tag{A.23}$$

Then, using the production function (2.1) and the fact that $u_1 = 0$, we find:

$$Q_1 = A(u_1 + cs_1)Q_1 = Acs_1 Q_1 = Ac\,(S - U) \tag{A.24}$$

and combining equations (2.9), (2.2) and (2.8):

$$Q_2 = BK^{\beta} l Q_2^{1-\beta} = BK^{\beta} U^{1-\beta} \tag{A.25}$$

$$k = \frac{K}{Q_2} = B^{-1} \left(\frac{K}{U}\right)^{1-\beta} \tag{A.26}$$

$$l = \frac{U}{Q_2} = B^{-1} \left(\frac{U}{K}\right)^{\beta} \tag{A.27}$$

Last, using (2.4) and (2.5), we get the wage of skilled workers and the returns to capital:

$$w_u = \frac{(1-\beta)\,p}{l} - w_s = (1-\beta)\,Bp \left(\frac{K}{U}\right)^{\beta} - cA > A \tag{A.28}$$

$$\rho = \beta p k^{-1} = \beta B p \left(\frac{U}{K}\right)^{1-\beta} \tag{A.29}$$

A.3 Impact of a marginal transfer of capital on outputs and prices (small transfer case)

Let us look at the impact of a marginal transfer of capital from the North to the South on outputs and prices, when capital is abundant in the North and scarce in the South (case developed in section 2.3.3).

Using the equilibrium condition (2.45), we get:

$$(1-\gamma)\left[A\left(U+cS\right)+Q_1^*\right]=\left(1-\beta+\beta\gamma\right)pQ_2+\gamma pQ_2^* \tag{A.30}$$

$$\begin{aligned}\Leftrightarrow (1-\gamma)A\left[U+c\left(\bar{S}-U^*\right)\right]&=\left(1-\beta+\beta\gamma\right)\left(Bp\right)^{\frac{1}{\beta}}\left[\frac{1-\beta}{\left(1+c\right)A}\right]^{\frac{1}{\beta}-1}K\\&\quad+\gamma Bp\left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta}\end{aligned} \tag{A.31}$$

Let us remind the outputs of each country:

$$Q_1=A\left\{U+cS-\left(1+c\right)K\left[\frac{B\left(1-\beta\right)p}{\left(1+c\right)A}\right]^{\frac{1}{\beta}}\right\}=A\left(U+cS\right)-\left(1-\beta\right)pQ_2 \tag{A.32}$$

$$Q_2=KB^{\frac{1}{\beta}}\left[\frac{\left(1-\beta\right)p}{\left(1+c\right)A}\right]^{\frac{1}{\beta}-1} \tag{A.33}$$

$$Q_1^*=Ac\left(S^*-U^*\right) \tag{A.34}$$

$$Q_2^*=B\left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{A.35}$$

Differentiating the equilibrium condition (2.45), we get:

$$0=\left[\left(1-\beta+\beta\gamma\right)\frac{\partial\left(pQ_2\right)}{\partial p}+\gamma\frac{\partial\left(pQ_2^*\right)}{\partial p}\right]dp+\left[\left(1-\beta+\beta\gamma\right)p\frac{\partial Q_2}{\partial K}+\gamma p\frac{\partial Q_2^*}{\partial K}\right]dK \tag{A.36}$$

and then, using the expressions of the sectoral outputs:

$$0=\left[\left(1-\beta+\beta\gamma\right)\frac{1}{\beta}Q_2+\gamma Q_2^*\right]dp+\left[\left(1-\beta+\beta\gamma\right)\frac{Q_2}{K}-\beta\gamma\frac{Q_2^*}{\bar{K}-K}\right]pdK \tag{A.37}$$

where:

$$\frac{\partial\left(pQ_2\right)}{\partial p}=\frac{1}{\beta}Q_2,\ \frac{\partial Q_2}{\partial K}=\frac{Q_2}{K} \tag{A.38}$$

$$\frac{\partial\left(pQ_2^*\right)}{\partial p}=Q_2^*,\ \frac{\partial Q_2^*}{\partial K}=-\beta\frac{Q_2^*}{\bar{K}-K} \tag{A.39}$$

Therefore, the derivative of the price of the industrial good with respect to capital is:

$$\frac{dp}{dK} = \frac{\beta p\left[\beta\gamma\frac{Q_2^*}{\bar{K}-K} - (1-\beta+\beta\gamma)\frac{Q_2}{K}\right]}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*} \tag{A.40}$$

Now, using the small investment condition (2.42):

$$\frac{Q_2^*}{\bar{K}-K} < \frac{Q_2}{K} \tag{A.41}$$

we find that the price of the industrial good decreases with a small transfer of capital:

$$\frac{dp}{dK} = \frac{\beta p\left[\beta\gamma\left(\frac{Q_2^*}{\bar{K}-K} - \frac{Q_2}{K}\right) - (1-\beta)\frac{Q_2}{K}\right]}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*} < 0 \tag{A.42}$$

The impact of this transfer of capital on the sectoral outputs in each country, is given by:

$$\frac{dQ_1}{dK} = -(1-\beta)\frac{d(pQ_2)}{dK} < 0 \tag{A.43}$$

$$\frac{dQ_2}{dK} > 0 \tag{A.44}$$

$$\frac{dQ_1^*}{dK} = 0 \tag{A.45}$$

$$\frac{dQ_2^*}{dK} = -\beta\frac{Q_2^*}{\bar{K}-K} < 0 \tag{A.46}$$

the second equality coming from:

$$\frac{dQ_2}{Q_2} = \frac{dK}{K} + \left(\frac{1}{\beta}-1\right)\frac{dp}{p} \tag{A.47}$$

$$\begin{aligned}\frac{1}{Q_2}\frac{dQ_2}{dK} &= \frac{1}{K} + \left(\frac{1}{\beta}-1\right)\frac{1}{p}\frac{dp}{dK} \\ &= \frac{1}{K} + \frac{(1-\beta)\left[\beta\gamma\frac{Q_2^*}{\bar{K}-K} - (1-\beta+\beta\gamma)\frac{Q_2}{K}\right]}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*}\end{aligned} \tag{A.48}$$

$$\frac{dQ_2}{dK} = \frac{\left(\frac{1-\beta}{\bar{K}-K} + \frac{1}{K}\right)\beta\gamma Q_2^* + \beta(1-\beta+\beta\gamma)\frac{Q_2}{K}}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*}Q_2 > 0 \tag{A.49}$$

while the first equality comes from:

$$\frac{d(pQ_2)}{pQ_2} = \frac{dK}{K} + \frac{1}{\beta}\frac{dp}{p} \tag{A.50}$$

$$\begin{aligned}\frac{1}{pQ_2}\frac{d(pQ_2)}{dK} &= \frac{1}{K} + \frac{1}{\beta p}\frac{dp}{dK} \\ &= \frac{1}{K} + \frac{\beta\gamma\frac{Q_2^*}{\bar{K}-K} - (1-\beta+\beta\gamma)\frac{Q_2}{K}}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*}\end{aligned} \tag{A.51}$$

$$\frac{d(pQ_2)}{dK} = \frac{\beta\gamma\left(\frac{Q_2^*}{\bar{K}-K} + \frac{Q_2^*}{K}\right)}{(1-\beta+\beta\gamma)Q_2 + \beta\gamma Q_2^*}pQ_2 > 0 \tag{A.52}$$

The transfer decreases the world output of the traditional sector:

$$\frac{d\left(Q_1+Q_1^*\right)}{dK}=\frac{dQ_1}{dK}<0 \tag{A.53}$$

and increases the world output of the industrial sector:

$$\begin{aligned}\frac{d\left(Q_2+Q_2^*\right)}{dK}&=Q_2\frac{\left(\frac{1-\beta}{\bar{K}-K}+\frac{1}{K}\right)\beta\gamma Q_2^*+\beta\left(1-\beta+\beta\gamma\right)\frac{Q_2}{K}}{\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*}-\beta\frac{Q_2^*}{\bar{K}-K}\\&=\beta\frac{\left(\frac{1-\beta}{\bar{K}-K}+\frac{1}{K}\right)\gamma Q_2Q_2^*+\left(1-\beta+\beta\gamma\right)Q_2\frac{Q_2}{K}-\frac{Q_2^*}{\bar{K}-K}\left[\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*\right]}{\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*}\\&=\beta\frac{\left[\left(\frac{\bar{K}}{K}-\beta\right)Q_2-\beta Q_2^*\right]\gamma\frac{Q_2^*}{\bar{K}-K}+\left(1-\beta+\beta\gamma\right)\left(\frac{Q_2}{K}-\frac{Q_2^*}{\bar{K}-K}\right)Q_2}{\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*}\\&=\beta\frac{\left[\left(\bar{K}-\beta K\right)\frac{Q_2}{K}-\beta\left(\bar{K}-K\right)\frac{Q_2^*}{\bar{K}-K}\right]\gamma\frac{Q_2^*}{\bar{K}-K}+\left(1-\beta+\beta\gamma\right)\left(\frac{Q_2}{K}-\frac{Q_2^*}{\bar{K}-K}\right)Q_2}{\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*}\\&=\beta\frac{\left(1-\beta\right)\bar{K}\gamma\frac{Q_2}{K}\frac{Q_2^*}{\bar{K}-K}+\left(\beta\gamma Q_2^*+\left(1-\beta+\beta\gamma\right)Q_2\right)\left(\frac{Q_2}{K}-\frac{Q_2^*}{\bar{K}-K}\right)}{\left(1-\beta+\beta\gamma\right)Q_2+\beta\gamma Q_2^*}>0\end{aligned} \tag{A.54}$$

The wages in the South and the skilled wage in the North are unchanged. Only the unskilled wage in the North changes:

$$w_u^*=(1-\beta)Bp\left(\frac{\bar{K}-K}{U^*}\right)^{\beta}-cA=(1-\beta)p\frac{Q_2^*}{U^*}-cA \tag{A.55}$$

$$\frac{dw_u^*}{dK}=\frac{(1-\beta)}{U^*}\frac{d\left(pQ_2^*\right)}{dK}=\frac{(1-\beta)}{U^*}\left(\frac{dp}{dK}Q_2^*+\frac{dQ_2^*}{dK}p\right)<0 \tag{A.56}$$

The decrease in the production of the Northern capitalist sector generated by the capital transfer to the South decreases the ability of Northern unskilled workers to extract a scarcity rent.

A.4 Impact of a marginal transfer of unskilled labour on outputs and prices (small transfer case)

Let us look at the impact of a marginal transfer of unskilled labour from the South to the North on outputs and prices, when capital is fully invested in the North, and unskilled labour is transferred from the South to the North (case developed in section 2.3.3). Then, in the North, the labour force increases from U^* to $U^* + dU^*$, with $dU^* > 0$, while in the South the labour force decreases from U to $U - dU$, with $-dU = -dU^* < 0$.

Let us remind that, as long as unskilled labour is scarce in the North and abundant in the South, the outputs of each country and the price of the industrial good are given by:

$$Q_1 = A\left(U + cS\right) \tag{A.57}$$

$$Q_2 = 0 \tag{A.58}$$

$$Q_1^* = Ac\left(S^* - U^*\right) \tag{A.59}$$

$$Q_2^* = B\left(\bar{K}\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{A.60}$$

$$p = \frac{1-\gamma}{\gamma}\frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{(1-\gamma)}{\gamma}\frac{A\left[U + c\left(\bar{S} - U^*\right)\right]}{B\left(\bar{K}\right)^{\beta}\left(U^*\right)^{1-\beta}} \tag{A.61}$$

Using logarithmic derivatives, we get the derivative of the price of the industrial good with respect to a small transfer from the South to the North:

$$\frac{1}{p}\frac{dp}{dU^*} = \left(-\frac{dQ_1}{dU} + \frac{dQ_1^*}{dU^*}\right)\frac{1}{Q_1 + Q_1^*} - \frac{1}{Q_2^*}\frac{dQ_2^*}{dU^*} \tag{A.62}$$

$$\frac{dp}{dU^*} = \left[-\left(1+c\right)\frac{1}{U + c\left(\bar{S} - U^*\right)} - \left(1-\beta\right)\frac{1}{U^*}\right]p < 0 \tag{A.63}$$

The output changes are:

$$-\frac{dQ_1}{dU} = -A < 0 \tag{A.64}$$

$$\frac{dQ_1^*}{dU^*} = -cA < 0 \tag{A.65}$$

$$-\frac{dQ_2}{dU} = 0 \tag{A.66}$$

$$\frac{dQ_2^*}{dU^*} = \left(1-\beta\right)\frac{Q_2^*}{U^*} > 0 \tag{A.67}$$

and:

$$\frac{d\left(Q_1+Q_1^*\right)}{dU^*} = -\left(1+c\right)A < 0 \tag{A.68}$$

$$\frac{d\left(Q_2+Q_2^*\right)}{dU^*} = \left(1-\beta\right)\frac{Q_2^*}{\left(U^*+M\right)} > 0 \tag{A.69}$$

Let us remind the expression of the wage of unskilled workers in the North:

$$w_u^* = \left(1-\beta\right)Bp\left(\frac{\bar{K}}{U^*}\right)^{\beta} - cA = \frac{1-\beta}{U^*}pQ_2^* - cA \tag{A.70}$$

Using logarithmic derivatives, we find that the wage of unskilled workers decreases in the North:

$$\begin{aligned}\frac{dw_u^*}{dU^*} &= \frac{1-\beta}{U^*}\left(\frac{dp}{dU^*}Q_2^* + \frac{dQ_2^*}{dU^*}p\right) = \frac{1-\beta}{U^*}\left[\frac{d\left(pQ_2^*\right)}{dU^*}\right] \\ &= \frac{1-\beta}{U^*}\left[-\left(1+c\right)\frac{B\left(\bar{K}\right)^{\beta}\left(U^*\right)^{1-\beta}}{U+c\left(\bar{S}-U^*\right)}\right]p \\ &= -\frac{1-\beta}{U^*}\frac{\left(1-\gamma\right)}{\gamma}A\left(1+c\right) < 0\end{aligned} \tag{A.71}$$

Let us remind the expression of capital returns in the North:

$$\rho^* = \beta Bp\left(\frac{U^*}{\bar{K}}\right)^{1-\beta} = \beta p\frac{Q_2^*}{\bar{K}} \tag{A.72}$$

Using logarithmic derivatives we find that returns decrease in the North:

$$\begin{aligned}\frac{d\rho^*}{dU^*} &= \frac{\beta}{\bar{K}}\left(\frac{dp}{dU^*}Q_2^* + \frac{dQ_2^*}{dU^*}p\right) \\ &= \frac{\beta}{\bar{K}}\left[-\left(1+c\right)\frac{B\left(\bar{K}\right)^{\beta}\left(U^*\right)^{1-\beta}}{U+c\left(\bar{S}-U^*\right)}\right]p \\ &= -A\left(1+c\right)\frac{\beta}{\bar{K}}\frac{\left(1-\gamma\right)}{\gamma} < 0\end{aligned} \tag{A.73}$$

A.5 Impact of a marginal transfer of capital on outputs and prices (large transfer case with abundant capital endowment)

Let us look at the impact of a marginal transfer of capital from the North to the South on outputs and prices, when the global capital stock is large enough for capital to become abundant in both countries (case developed in section 2.3.4).

Let us remind the expressions of the outputs in each country and the price of the industrial good:

$$Q_1 = A\left(U - S\right) \tag{A.74}$$

$$Q_2 = BK^{\beta}S^{1-\beta} \tag{A.75}$$

$$Q_1^* = Ac\left(S^* - U^*\right) \tag{A.76}$$

$$Q_2^* = B\left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta} \tag{A.77}$$

$$p = \frac{1-\gamma}{\gamma}\frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{1-\gamma}{\gamma}\frac{A\left(U - S + cS^* - cU^*\right)}{B\left[K^{\beta}S^{1-\beta} + \left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta}\right]} \tag{A.78}$$

Using logarithmic derivatives, we get the derivative of the price of the industrial good with respect to capital.

$$\frac{1}{p}\frac{dp}{dK} = -\beta\frac{\left(\frac{S}{K}\right)^{1-\beta} - \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}{K^{\beta}S^{1-\beta} + \left(\bar{K} - K\right)^{\beta}\left(U^*\right)^{1-\beta}} \tag{A.79}$$

$$\frac{dp}{dK} = -\beta p\frac{\left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}\right)}{Q_2 + Q_2^*} < 0 \tag{A.80}$$

The impact of a marginal transfer of capital on outputs is:

$$\frac{dQ_1}{dK} = 0 \tag{A.81}$$

$$\frac{dQ_1^*}{dK} = 0 \tag{A.82}$$

$$\frac{dQ_2}{dK} = \beta\frac{Q_2}{K} = \beta B\left(\frac{S}{K}\right)^{1-\beta} > 0 \tag{A.83}$$

$$\frac{dQ_2^*}{dK} = -\beta\frac{Q_2^*}{\bar{K} - K} = -\beta B\left(\frac{U^*}{\bar{K} - K}\right)^{1-\beta} < 0 \tag{A.84}$$

Globally, the output of the traditional sector is not affected by a marginal transfer of capital:

$$\frac{d\left(Q_1+Q_1^*\right)}{dK}=0 \tag{A.85}$$

Note that the feasibility condition (2.32) does not allow us to determine the sign of:

$$\frac{d\left(Q_2+Q_2^*\right)}{dK}=\beta B\left[\left(\frac{S}{K}\right)^{1-\beta}-\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}\right] \tag{A.86}$$

However, we know that the price of the industrial good decreases $\left(\frac{dp}{dK}<0\right)$, which implies that the good becomes more abundant. Thus, we can deduct that the global input of the industrial good increases, so that unskilled labour is more scarce in the North than skilled labour is in the South. The industrial production is more efficient in the South, and the increase in production in the South is larger than the decrease in the North. Then, the world industrial output increases $\left(\frac{d(Q_2+Q_2^*)}{dK}>0\right)$.

The impact on the wage of skilled workers in the South is positive, as $w_s=(1-\beta)\,Bp\left(\frac{K}{S}\right)^{\beta}-A=(1-\beta)\,p\frac{Q_2}{S}-A$ implies:

$$\begin{aligned}
\frac{dw_s}{dK}&=\frac{(1-\beta)}{S}\left(\frac{dp}{dK}Q_2+\frac{dQ_2}{dK}p\right)\\
&=(1-\beta)\,B\left[\left(\frac{K}{S}\right)^{\beta}\frac{dp}{dK}+\beta\frac{p}{K}\left(\frac{K}{S}\right)^{\beta}\right]\\
&=(1-\beta)\,B\left(\frac{K}{S}\right)^{\beta}\left(\frac{dp}{dK}+\beta\frac{p}{K}\right)\\
&=(1-\beta)\,B\left(\frac{K}{S}\right)^{\beta}\beta\frac{p}{K}\left[1-\frac{\left(\frac{S}{K}\right)^{1-\beta}-\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}{\left(\frac{S}{K}\right)^{1-\beta}+\left(\frac{\bar{K}}{K}-1\right)\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}\right]\\
&=(1-\beta)\,B\left(\frac{K}{S}\right)^{\beta}\beta p\frac{\bar{K}\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}{\left(\frac{S}{K}\right)^{1-\beta}+\left(\frac{\bar{K}}{K}-1\right)\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}>0
\end{aligned} \tag{A.87}$$

The impact on the wage of unskilled workers in the North is negative, as:

$$w_u^*=(1-\beta)\,Bp\left(\frac{\bar{K}-K}{U^*}\right)^{\beta}-cA=(1-\beta)\,p\frac{Q_2^*}{U^*}-cA \tag{A.88}$$

implies:

$$\begin{aligned}\frac{dw_u^*}{dK} &= \frac{(1-\beta)}{U^*}\left(\frac{dp}{dK}Q_2^* + \frac{dQ_2^*}{dK}p\right)\\ &= (1-\beta)\,B\left(\frac{\bar{K}-K}{U^*}\right)^{\beta}\left(\frac{dp}{dK} - \beta\frac{p}{\bar{K}-K}\right)\\ &= -(1-\beta)\,B\left(\frac{\bar{K}-K}{U^*}\right)^{\beta}\frac{\beta p}{\bar{K}-K}\left[\frac{\left(\frac{S}{\bar{K}}\right)^{1-\beta} - \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}{\frac{K}{\bar{K}-K}\left(\frac{S}{\bar{K}}\right)^{1-\beta} + \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}} + 1\right]\\ &= -(1-\beta)\,B\left(\frac{\bar{K}-K}{U^*}\right)^{\beta}\beta p\frac{\bar{K}\left(\frac{S}{\bar{K}}\right)^{1-\beta}}{\frac{K}{\bar{K}-K}\left(\frac{S}{\bar{K}}\right)^{1-\beta} + \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}} < 0\end{aligned} \tag{A.89}$$

Let us remind the expression of the returns in the South:

$$\rho = \beta B p\left(\frac{S}{K}\right)^{1-\beta} \tag{A.90}$$

Using logarithmic derivatives, we get the derivative of the returns to capital in the South with respect to a capital variation:

$$\frac{1}{\rho}\frac{d\rho}{dK} = \frac{1}{p}\frac{dp}{dK} - \frac{(1-\beta)}{K} < 0 \tag{A.91}$$

the negative sign coming from the fact that $\frac{dp}{dK} < 0$.

In the North, returns to capital are:

$$\rho^* = \beta B p\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta} \tag{A.92}$$

Using logarithmic derivatives, we get the derivative of the returns to capital in the North with respect to a capital variation:

$$\frac{1}{\rho^*}\frac{d\rho^*}{dK} = \frac{1}{p}\frac{dp}{dK} + \frac{(1-\beta)}{\bar{K}-K} \tag{A.93}$$

and, after straightforward calculations:

$$\frac{d\rho^*}{dK} = \frac{\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}\left\{1 + \left[(1-\beta)\frac{K}{\bar{K}-K} - \beta\right]\left(\frac{S}{U^*}\frac{\bar{K}-K}{K}\right)^{1-\beta}\right\}}{K^{\beta}S^{1-\beta} + \left(\bar{K}-K\right)^{\beta}\left(U^*\right)^{1-\beta}}\rho^* \tag{A.94}$$

Unhappily, this derivative cannot be signed.

Notice that capital has no more incentive to flow from the North to the South when returns equalise in both countries ($\rho^* = \rho$), which happens when:

$$K = \left(\frac{S}{U^*} + 1\right)\bar{K} \Leftrightarrow \frac{U^*}{\bar{K} - K} = \frac{S}{K} \tag{A.95}$$

In other words, at the equilibrium the relative scarcity of unskilled labour compared to the capital stock in the North equalises the relative scarcity of skilled labour compared to the capital stock in the South. This capital allocation among countries maximises the production of the industrial sector.

A.6 Impact of a risk premium and a migration cost variation on the factor allocation (small transfer case)

Let us look at the impact of a risk premium and an unskilled migration cost variations on the factor allocation among countries, for a small investment to the South (case developed in section 2.3.3).

Let us remind the equilibrium equations:

$$\tau = \beta B p \left\{ \left[\frac{(1-\beta)\, Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta} \right\} = \beta p \left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K} \right) \tag{A.96}$$

$$\mu_u = (1-\beta)\, pB \left(\frac{\bar{K}-K}{U^*} \right)^{\beta} - (1+c)\, A = (1-\beta)\, p \frac{Q_2^*}{U^*} - (1+c)\, A \tag{A.97}$$

The logarithmic derivatives of these equilibrium conditions are:

$$\begin{aligned}
\frac{d\tau}{\tau} =& \frac{dp}{p} + \frac{d\left\{ \left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta} \right\}}{\left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta}} \\
=& \frac{dp}{p} + \frac{\left(\frac{1}{\beta}-1 \right) \left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} \frac{dp}{p} - (1-\beta) \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta} \left(\frac{dU^*}{U^*} + \frac{dK}{\bar{K}-K} \right)}{\left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta}} \\
=& \left\{ 1 + \frac{\left(\frac{1}{\beta}-1 \right) \left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1}}{\left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta}} \right\} \frac{dp}{p} \\
& - \frac{(1-\beta) \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta}}{\left[\frac{(1-\beta)Bp}{(1+c)A} \right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K} \right)^{1-\beta}} \left(\frac{dU^*}{U^*} + \frac{dK}{\bar{K}-K} \right)
\end{aligned} \tag{A.98}$$

$$\frac{d\mu_u}{\mu_u + (1+c)\, A} = \frac{dp}{p} - \beta \left(\frac{dK}{\bar{K}-K} + \frac{dU^*}{U^*} \right) \tag{A.99}$$

which may be written as:

$$\frac{d\tau}{\tau} = \left(1 + \beta^{-1} D \right) \frac{dp}{p} - C \left(\frac{dU^*}{U^*} + \frac{K}{\bar{K}-K} \frac{dK}{K} \right) \tag{A.100}$$

$$\frac{d\mu_u}{\mu_u + (1+c)\, A} = \frac{dp}{p} - \beta \left(\frac{K}{\bar{K}-K} \frac{dK}{K} + \frac{dU^*}{U^*} \right) \tag{A.101}$$

where:

$$C = \frac{(1-\beta)\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}}{\left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1} - \left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta}} = (1-\beta)\frac{\beta Bp}{\tau}\left(\frac{U^*}{\bar{K}-K}\right)^{1-\beta} > 0 \tag{A.102}$$

$$D = \frac{(1-\beta)\left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1}}{\left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{\frac{1}{\beta}-1} - \left[\frac{U^*}{\bar{K}-K}\right]^{1-\beta}} = (1-\beta)\frac{\beta Bp}{\tau}\left[\frac{(1-\beta)Bp}{(1+c)A}\right]^{\frac{1-\beta}{\beta}} > 0 \tag{A.103}$$

$$D - C = 1 - \beta \tag{A.104}$$

As there is no explicit solution for the price, we use the total derivative of the equilibrium condition:

$$(1-\gamma)A\left[U + c\left(\bar{S} - U^*\right)\right] = (1-\beta+\beta\gamma)pQ_2 + \gamma pQ_2^* \tag{A.105}$$

with the logarithmic derivatives of the outputs:

$$Q_2 = KB^{\frac{1}{\beta}}\left[\frac{(1-\beta)p}{(1+c)A}\right]^{\frac{1}{\beta}-1} \Longrightarrow \frac{dQ_2}{Q_2} = \frac{dK}{K} + \left(\frac{1}{\beta} - 1\right)\frac{dp}{p} \tag{A.106}$$

$$Q_2^* = B\left(\bar{K}-K\right)^{\beta}(U^*)^{1-\beta} \Longrightarrow \frac{dQ_2^*}{Q_2^*} = -\beta\frac{K}{\bar{K}-K}\frac{dK}{K} + (1-\beta)\frac{dU^*}{U^*} \tag{A.107}$$

to get an expression of dp/p:

$$\begin{aligned}
-(1-\gamma)A(1+c)U^*\frac{dU^*}{U^*} &= (1-\beta+\beta\gamma)pQ_2\left(\frac{dp}{p} + \frac{dQ_2}{Q_2}\right) \\
&\quad + \gamma pQ_2^*\left(\frac{dp}{p} + \frac{dQ_2^*}{Q_2^*}\right) \\
&= (1-\beta+\beta\gamma)pQ_2\left(\frac{dK}{K} + \frac{1}{\beta}\frac{dp}{p}\right) \\
&\quad + \gamma pQ_2^*\left[\frac{dp}{p} - \beta\frac{K}{\bar{K}-K}\frac{dK}{K} + (1-\beta)\frac{dU^*}{U^*}\right] \\
&= \left(\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*\right)p\frac{dp}{p} \\
&\quad + \left[(1-\beta+\beta\gamma)Q_2 - \beta\gamma Q_2^*\frac{K}{\bar{K}-K}\right]p\frac{dK}{K} \\
&\quad + (1-\beta)\gamma pQ_2^*\frac{dU^*}{U^*} \qquad \text{(A.108)} \\
\Leftrightarrow \frac{dp}{p} &= -\frac{(1-\beta+\beta\gamma)Q_2 - \beta\gamma Q_2^*\frac{K}{\bar{K}-K}}{\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*}\frac{dK}{K} \\
&\quad - \frac{(1-\beta)\gamma pQ_2^* + (1-\gamma)A(1+c)U^*}{\left(\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*\right)p}\frac{dU^*}{U^*} \\
&= -E_K\frac{dK}{K} - E_U\frac{dU^*}{U^*} \qquad \text{(A.109)}
\end{aligned}$$

where:

$$E_K = \frac{(1-\beta+\beta\gamma)\,Q_2 - \beta\gamma Q_2^* \frac{K}{\bar{K}-K}}{\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*} = \frac{(1-\beta)\,Q_2 + \beta\gamma K\left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}\right)}{\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*} > 0 \tag{A.110}$$

$$E_U = \frac{(1-\beta)\,\gamma p Q_2^* + (1-\gamma)\,A\,(1+c)\,U^*}{\left(\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*\right)p} > 0 \tag{A.111}$$

the positive sign of E_K coming from the small investment condition (2.42).

Then:

$$\begin{aligned}\frac{d\tau}{\tau} &= -\left(1+\beta^{-1}D\right)\left(E_K\frac{dK}{K} + E_U\frac{dU^*}{U^*}\right) - C\left(\frac{dU^*}{U^*} + \frac{K}{\bar{K}-K}\frac{dK}{K}\right)\\ &= -\left[\left(1+\beta^{-1}D\right)E_K + C\frac{K}{\bar{K}-K}\right]\frac{dK}{K} - \left[\left(1+\beta^{-1}D\right)E_U + C\right]\frac{dU^*}{U^*} \qquad \text{(A.112)}\\ \frac{d\mu_u}{\mu_u+(1+c)\,A} &= -E_K\frac{dK}{K} - E_U\frac{dU^*}{U^*} - \beta\left(\frac{K}{\bar{K}-K}\frac{dK}{K} + \frac{dU^*}{U^*}\right)\\ &= -\left(E_K + \frac{\beta K}{\bar{K}-K}\right)\frac{dK}{K} - (E_U+\beta)\frac{dU^*}{U^*} \qquad \text{(A.113)}\end{aligned}$$

which may be written as:

$$M\begin{bmatrix}\frac{dK}{K}\\ \frac{dU^*}{U^*}\end{bmatrix} = -\begin{bmatrix}\frac{d\tau}{\tau}\\ \frac{d\mu_u}{\mu_u+(1+c)A}\end{bmatrix} \tag{A.114}$$

where:

$$M = \begin{bmatrix}\left(1+\beta^{-1}D\right)E_K + C\frac{K}{\bar{K}-K} & \left(1+\beta^{-1}D\right)E_U + C\\ E_K + \frac{\beta K}{\bar{K}-K} & E_U+\beta\end{bmatrix} \tag{A.115}$$

so that:

$$\begin{bmatrix}\frac{dK}{K}\\ \frac{dU^*}{U^*}\end{bmatrix} = -\frac{1}{\Delta}M^C\begin{bmatrix}\frac{d\tau}{\tau}\\ \frac{d\mu_u}{\mu_u+(1+c)A}\end{bmatrix} \tag{A.116}$$

where Δ is the determinant of M:

$$\begin{aligned}\Delta &= \left[\left(1+\beta^{-1}D\right)E_K + C\frac{K}{\bar{K}-K}\right](E_U+\beta)\\ &\quad - \left(E_K + \frac{\beta K}{\bar{K}-K}\right)\left[\left(1+\beta^{-1}D\right)E_U + C\right]\\ &= (\beta + D - C)\left(E_K - \frac{K}{\bar{K}-K}E_U\right) = E_K - \frac{K}{\bar{K}-K}E_U \qquad \text{(A.117)}\end{aligned}$$

and M^C is the co-factors matrix:

$$M^C = \begin{bmatrix}E_U+\beta & -\left(1+\beta^{-1}D\right)E_U - C\\ -\left(E_K + \frac{\beta K}{\bar{K}-K}\right) & \left(1+\beta^{-1}D\right)E_K + C\frac{K}{\bar{K}-K}\end{bmatrix} \tag{A.118}$$

Using the expressions of E_K and E_U, we get:

$$\Delta = E_K - \frac{K}{\bar{K}-K}E_U = \frac{(1-\beta+\beta\gamma)\,p\frac{Q_2}{K} - \gamma p\frac{Q_2^*}{\bar{K}-K} - (1-\gamma)\,A\,(1+c)\,\frac{U^*}{\bar{K}-K}}{\left(\frac{1-\beta+\beta\gamma}{\beta}Q_2 + \gamma Q_2^*\right)pK^{-1}} \tag{A.119}$$

The denominator of Δ is straightforwardly positive. As for the numerator, using the equilibrium conditions, we get:

$$\begin{aligned}
Num &= (1-\beta+\beta\gamma)\,p\frac{Q_2}{K} - \gamma p\frac{Q_2^*}{\bar{K}-K} - (1-\gamma)\,A\,(1+c)\,\frac{U^*}{\bar{K}-K} \\
&= (1-\beta+\beta\gamma)\,p\frac{Q_2}{K} - \gamma p\frac{Q_2^*}{\bar{K}-K} - (1-\gamma)\,\frac{U^*}{\bar{K}-K}\left[(1-\beta)\,p\frac{Q_2^*}{U^*} - \mu_u\right] \\
&= (1-\beta+\beta\gamma)\,p\frac{Q_2}{K} - [\gamma+(1-\gamma)\,(1-\beta)]\,p\frac{Q_2^*}{\bar{K}-K} + (1-\gamma)\,\frac{\mu_u U^*}{\bar{K}-K} \\
&= (1-\beta+\beta\gamma)\,p\left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}\right) + (1-\gamma)\,\frac{\mu_u U^*}{\bar{K}-K} \\
&= \frac{1-\beta+\beta\gamma}{\beta}\tau + \frac{(1-\gamma)\,K}{\bar{K}-K}\mu_u U^* > 0
\end{aligned} \tag{A.120}$$

so that $\Delta > 0$.

Then, the diagonal terms of M^C being unambiguously positive and the two non diagonal terms unambiguously negative, we get the following signs for the impacts of an increase in τ and μ_u:

	$\frac{d\tau}{\tau}$	$\frac{d\mu_u}{\mu_u+(1+c)A}$
$\frac{dK}{K}$	-	+
$\frac{dU^*}{U^*}$	+	-

A.7 Impact of a risk premium and migration costs variation on the factor allocation (large transfer case with abundant capital endowment)

At equilibrium, we look at the impact of a risk premium and migration costs variations on the factor allocation among countries, when capital is worldly abundant and is invested in both countries ($K > 0$ and $K^* > 0$), case initially developed in section 2.3.4.

Let us remind the equilibrium conditions:

$$\tau = \beta B p \left[\left(\frac{S}{K} \right)^{1-\beta} - \left(\frac{U^*}{\bar{K} - K} \right)^{1-\beta} \right] = \beta p \left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K} - K} \right) \tag{A.121}$$

$$\mu_s = (1-\beta) B p \left(\frac{K}{S} \right)^{\beta} - (1+c) A \tag{A.122}$$

$$\mu_u = (1-\beta) B p \left(\frac{\bar{K} - K}{U^*} \right)^{\beta} - (1+c) A \tag{A.123}$$

where the world price of the industrial good is:

$$p = \frac{1-\gamma}{\gamma} \frac{Q_1 + Q_1^*}{Q_2 + Q_2^*} = \frac{1-\gamma}{\gamma} \frac{A \left[\bar{U} + c\bar{S} - (1+c)(U^* + S) \right]}{B \left[K^{\beta} S^{1-\beta} + \left(\bar{K} - K \right)^{\beta} (U^*)^{1-\beta} \right]} \tag{A.124}$$

The logarithmic derivative of the price is:

$$\begin{aligned}
\frac{dp}{p} =& \frac{d(Q_1 + Q_1^*)}{Q_1 + Q_1^*} - \frac{d(Q_2 + Q_2^*)}{Q_2 + Q_2^*} \\
=& - \frac{A(1+c)(dS + dU^*)}{Q_1 + Q_1^*} - \frac{Q_2 \left[\beta \frac{dK}{K} + (1-\beta) \frac{dS}{S} \right] + Q_2^* \left[(1-\beta) \frac{dU^*}{U^*} - \beta \frac{dK}{\bar{K} - K} \right]}{Q_2 + Q_2^*} \\
=& - \frac{A(1+c)}{Q_1 + Q_1^*} (dS + dU^*) - \frac{\beta Q_2}{Q_2 + Q_2^*} \frac{dK}{K} - \frac{(1-\beta) Q_2}{Q_2 + Q_2^*} \frac{dS}{S} \\
& - \frac{(1-\beta) Q_2^*}{Q_2 + Q_2^*} \frac{dU^*}{U^*} + \frac{\beta Q_2^*}{Q_2 + Q_2^*} \frac{dK}{\bar{K} - K} \\
=& - \frac{A(1+c)}{Q_1 + Q_1^*} (dS + dU^*) + \frac{\beta}{Q_2 + Q_2^*} \left(\frac{K Q_2^*}{\bar{K} - K} - Q_2 \right) \frac{dK}{K} \\
& - \frac{(1-\beta) Q_2}{Q_2 + Q_2^*} \frac{dS}{S} - \frac{(1-\beta) Q_2^*}{Q_2 + Q_2^*} \frac{dU^*}{U^*} \\
=& B_K \frac{dK}{K} - B_S \frac{dS}{S} - B_U \frac{dU^*}{U^*}
\end{aligned} \tag{A.125}$$

with:

$$B_K = -\frac{\beta K}{Q_2 + Q_2^*}\left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K} - K}\right) = -\frac{\tau K/p}{Q_2 + Q_2^*} < 0 \tag{A.126}$$

$$B_S = \frac{A\,(1+c)}{Q_1 + Q_1^*} S + \frac{(1-\beta)\,Q_2}{Q_2 + Q_2^*} > 0 \tag{A.127}$$

$$B_U = \frac{A\,(1+c)}{Q_1 + Q_1^*} U^* + \frac{(1-\beta)\,Q_2^*}{Q_2 + Q_2^*} > 0 \tag{A.128}$$

and:

$$\begin{aligned} B_U + B_S &= \frac{A\,(1+c)\,(S+U^*)}{Q_1 + Q_1^*} + 1 - \beta \\ &= \frac{1}{\frac{\bar{U} + c\bar{S}}{(1+c)(U^*+S)} - 1} + 1 - \beta \\ &= \frac{1}{1 - (1+c)\,\frac{S+U^*}{\bar{U}+c\bar{S}}} - \beta \end{aligned} \tag{A.129}$$

The logarithmic derivatives of the equilibrium conditions are:

$$\begin{aligned} \frac{d\tau}{\tau} &= \frac{dp}{p} + (1-\beta)\,\frac{\frac{Q_2}{K}\left(\frac{dS}{S} - \frac{dK}{K}\right) - \frac{Q_2^*}{\bar{K}-K}\left(\frac{dU^*}{U^*} + \frac{dK}{\bar{K}-K}\right)}{\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}} \\ &= \frac{dp}{p} - A_K\frac{dK}{K} + A_S\frac{dS}{S} - A_U\frac{dU^*}{U^*} \end{aligned} \tag{A.130}$$

$$\frac{d\mu_s}{\mu_s + (1+c)\,A} = \frac{dp}{p} + \beta\left(\frac{dK}{K} - \frac{dS}{S}\right) \tag{A.131}$$

$$\frac{d\mu_u}{\mu_u + (1+c)\,A} = \frac{dp}{p} - \beta\left(\frac{dK}{\bar{K} - K} + \frac{dU^*}{U^*}\right) \tag{A.132}$$

where:

$$A_K = (1-\beta)\,\frac{\frac{Q_2}{K} + \frac{K}{\bar{K}-K}\frac{Q_2^*}{\bar{K}-K}}{\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}} = A_S + \frac{K}{\bar{K}-K}A_U > 0 \tag{A.133}$$

$$A_S = \frac{(1-\beta)\,\frac{Q_2}{K}}{\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}} = (1-\beta)\,\frac{\beta p}{\tau}\frac{Q_2}{K} > 0 \tag{A.134}$$

$$A_U = \frac{(1-\beta)\,\frac{Q_2^*}{\bar{K}-K}}{\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K}} = (1-\beta)\,\frac{\beta p}{\tau}\frac{Q_2^*}{\bar{K}-K} > 0 \tag{A.135}$$

Combining the last two equilibrium conditions, we find:

$$\frac{dK}{K} = \frac{\bar{K}-K}{\bar{K}}\left(\frac{dS}{S} - \frac{dU^*}{U^*}\right) + \frac{\bar{K}-K}{\beta\bar{K}}\left[\frac{d\mu_s}{\mu_s + (1+c)\,A} - \frac{d\mu_u}{\mu_u + (1+c)\,A}\right] \tag{A.136}$$

Then:

$$\begin{aligned}\frac{d\tau}{\tau} =& \frac{dp}{p} - \frac{\bar{K}-K}{\beta\bar{K}} A_K \left[\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{d\mu_u}{\mu_u+(1+c)\,A}\right] \\ &+ \left(A_S - \frac{\bar{K}-K}{\bar{K}} A_K\right)\frac{dS}{S} + \left(\frac{\bar{K}-K}{\bar{K}} A_K - A_U\right)\frac{dU^*}{U^*} \end{aligned} \tag{A.137}$$

$$\begin{aligned}\frac{d\mu_s}{\mu_s+(1+c)\,A} =& \frac{dp}{p} - \beta\left(\frac{K}{\bar{K}}\frac{dS}{S} + \frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*}\right) \\ &+ \frac{\bar{K}-K}{\bar{K}}\left[\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{d\mu_u}{\mu_u+(1+c)\,A}\right] \end{aligned} \tag{A.138}$$

$$\begin{aligned}\frac{d\mu_u}{\mu_u+(1+c)\,A} =& \frac{dp}{p} - \beta\left(\frac{K}{\bar{K}}\frac{dS}{S} + \frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*}\right) \\ &- \frac{K}{\bar{K}}\left[\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{d\mu_u}{\mu_u+(1+c)\,A}\right] \end{aligned} \tag{A.139}$$

where noting that $A_S - A_U = 1-\beta$:

$$\begin{aligned} A_S - \frac{\bar{K}-K}{\bar{K}} A_K &= A_S - \frac{\bar{K}-K}{\bar{K}}\left(A_S + \frac{K}{\bar{K}-K} A_U\right) \\ &= \frac{K}{\bar{K}}\left(A_S - A_U\right) = (1-\beta)\,\frac{K}{\bar{K}} \end{aligned} \tag{A.140}$$

$$\begin{aligned} \frac{\bar{K}-K}{\bar{K}} A_K - A_U &= \frac{\bar{K}-K}{\bar{K}}\left(A_S + \frac{K}{\bar{K}-K} A_U\right) - A_U \\ &= \frac{\bar{K}-K}{\bar{K}}\left(A_S - A_U\right) = (1-\beta)\,\frac{\bar{K}-K}{\bar{K}} \end{aligned} \tag{A.141}$$

Then, by reducing the last two equations to the same final equation, we find:

$$\begin{aligned}\frac{d\tau}{\tau} =& \frac{dp}{p} + (1-\beta)\,\frac{K}{\bar{K}}\frac{dS}{S} + (1-\beta)\,\frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*} \\ &- \frac{\bar{K}-K}{\beta\bar{K}} A_K\left[\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{d\mu_u}{\mu_u+(1+c)\,A}\right] \end{aligned} \tag{A.142}$$

$$\beta\left(\frac{K}{\bar{K}}\frac{dS}{S} + \frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*}\right) = \frac{dp}{p} - \frac{K}{\bar{K}}\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{\bar{K}-K}{\bar{K}}\frac{d\mu_u}{\mu_u+(1+c)\,A} \tag{A.143}$$

or equivalently:

$$\begin{aligned}(1-\beta)\left(\frac{K}{\bar{K}}\frac{dS}{S} + \frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*}\right) =& \frac{d\tau}{\tau} - \frac{dp}{p} \\ &+ \frac{\bar{K}-K}{\beta\bar{K}} A_K\left[\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{d\mu_u}{\mu_u+(1+c)\,A}\right] \end{aligned} \tag{A.144}$$

$$\beta\left(\frac{K}{\bar{K}}\frac{dS}{S} + \frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*}\right) = \frac{dp}{p} - \frac{K}{\bar{K}}\frac{d\mu_s}{\mu_s+(1+c)\,A} - \frac{\bar{K}-K}{\bar{K}}\frac{d\mu_u}{\mu_u+(1+c)\,A} \tag{A.145}$$

so that:

$$\begin{aligned}\frac{K}{\bar{K}}\frac{dS}{S}+\frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*} =&\frac{d\tau}{\tau}+\left(\frac{\bar{K}-K}{\beta\bar{K}}A_K-\frac{K}{\bar{K}}\right)\frac{d\mu_s}{\mu_s+(1+c)A}\\ &-\frac{\bar{K}-K}{\beta\bar{K}}(A_K+\beta)\frac{d\mu_u}{\mu_u+(1+c)A} \qquad \text{(A.146)}\\ \frac{dp}{p} =&\beta\frac{d\tau}{\tau}+\left[\frac{\bar{K}-K}{\bar{K}}A_K+(1-\beta)\frac{K}{\bar{K}}\right]\frac{d\mu_s}{\mu_s+(1+c)A}\\ &+(1-\beta-A_K)\frac{\bar{K}-K}{\bar{K}}\frac{d\mu_u}{\mu_u+(1+c)A}\\ =&\beta\frac{d\tau}{\tau}+A_S\frac{d\mu_s}{\mu_s+(1+c)A}-A_U\frac{d\mu_u}{\mu_u+(1+c)A} \qquad \text{(A.147)}\end{aligned}$$

Moreover:

$$\begin{aligned}\frac{dp}{p} =&B_K\frac{dK}{K}-B_S\frac{dS}{S}-B_U\frac{dU^*}{U^*}\\ =&B_K\left\{\frac{\bar{K}-K}{\bar{K}}\left(\frac{dS}{S}-\frac{dU^*}{U^*}\right)+\frac{\bar{K}-K}{\beta\bar{K}}\left[\frac{d\mu_s}{\mu_s+(1+c)A}-\frac{d\mu_u}{\mu_u+(1+c)A}\right]\right\}\\ &-B_S\frac{dS}{S}-B_U\frac{dU^*}{U^*}\\ =&\frac{\bar{K}-K}{\beta\bar{K}}B_K\left[\frac{d\mu_s}{\mu_s+(1+c)A}-\frac{d\mu_u}{\mu_u+(1+c)A}\right]+\left(\frac{\bar{K}-K}{\bar{K}}B_K-B_S\right)\frac{dS}{S}\\ &-\left(\frac{\bar{K}-K}{\bar{K}}B_K+B_U\right)\frac{dU^*}{U^*} \qquad \text{(A.148)}\end{aligned}$$

and then:

$$\begin{aligned}&\left(\frac{\bar{K}-K}{\bar{K}}B_K+B_U\right)\frac{dU^*}{U^*}-\left(\frac{\bar{K}-K}{\bar{K}}B_K-B_S\right)\frac{dS}{S}\\ =&\frac{\bar{K}-K}{\beta\bar{K}}B_K\left[\frac{d\mu_s}{\mu_s+(1+c)A}-\frac{d\mu_u}{\mu_u+(1+c)A}\right]-\frac{dp}{p}\\ =&\frac{\bar{K}-K}{\beta\bar{K}}B_K\left[\frac{d\mu_s}{\mu_s+(1+c)A}-\frac{d\mu_u}{\mu_u+(1+c)A}\right]\\ &-\beta\frac{d\tau}{\tau}-A_S\frac{d\mu_s}{\mu_s+(1+c)A}+A_U\frac{d\mu_u}{\mu_u+(1+c)A}\\ =&-\beta\frac{d\tau}{\tau}+\left(\frac{\bar{K}-K}{\beta\bar{K}}B_K-A_S\right)\frac{d\mu_s}{\mu_s+(1+c)A}\\ &+\left(A_U-\frac{\bar{K}-K}{\beta\bar{K}}B_K\right)\frac{d\mu_u}{\mu_u+(1+c)A} \qquad \text{(A.149)}\end{aligned}$$

so that:

$$\begin{aligned}\frac{K}{\bar{K}}\frac{dS}{S}+\frac{\bar{K}-K}{\bar{K}}\frac{dU^*}{U^*} =&\frac{d\tau}{\tau}+\left(\frac{\bar{K}-K}{\beta\bar{K}}A_K-\frac{K}{\bar{K}}\right)\frac{d\mu_s}{\mu_s+(1+c)A}\\ &-\frac{\bar{K}-K}{\beta\bar{K}}(A_K+\beta)\frac{d\mu_u}{\mu_u+(1+c)A} \qquad \text{(A.150)}\end{aligned}$$

$$\begin{aligned}\left(B_S-\frac{\bar{K}-K}{\bar{K}}B_K\right)\frac{dS}{S}+\left(\frac{\bar{K}-K}{\bar{K}}B_K+B_U\right)\frac{dU^*}{U^*} =&-\beta\frac{d\tau}{\tau}+\left(\frac{\bar{K}-K}{\beta\bar{K}}B_K-A_S\right)\frac{d\mu_s}{\mu_s+(1+c)A}\\ &+\left(A_U-\frac{\bar{K}-K}{\beta\bar{K}}B_K\right)\frac{d\mu_u}{\mu_u+(1+c)A} \qquad \text{(A.151)}\end{aligned}$$

or equivalently:

$$\Omega \begin{bmatrix} \frac{dS}{S} \\ \frac{dU^*}{U^*} \end{bmatrix} = \begin{bmatrix} 1 & \frac{\bar{K}-K}{\beta\bar{K}} A_K - \frac{K}{\bar{K}} & -\frac{\bar{K}-K}{\beta\bar{K}} (A_K + \beta) \\ -\beta & \frac{\bar{K}-K}{\beta\bar{K}} B_K - A_S & A_U - \frac{\bar{K}-K}{\beta\bar{K}} B_K \end{bmatrix} \begin{bmatrix} \frac{d\tau}{\tau} \\ \frac{d\mu_s}{\mu_s+(1+c)A} \\ \frac{d\mu_u}{\mu_u+(1+c)A} \end{bmatrix} \tag{A.152}$$

where:

$$\Omega = \begin{bmatrix} \frac{K}{\bar{K}} & \frac{\bar{K}-K}{\bar{K}} \\ B_S - \frac{\bar{K}-K}{\bar{K}} B_K & \frac{\bar{K}-K}{\bar{K}} B_K + B_U \end{bmatrix} \tag{A.153}$$

The determinant of Ω is

$$\begin{aligned} \nabla =& \frac{K}{\bar{K}} \left(\frac{\bar{K}-K}{\bar{K}} B_K + B_U \right) - \frac{\bar{K}-K}{\bar{K}} \left(B_S - \frac{\bar{K}-K}{\bar{K}} B_K \right) \\ & \frac{K}{\bar{K}} \left(\frac{\bar{K}-K}{\bar{K}} B_K + B_U \right) - \frac{\bar{K}-K}{\bar{K}} \left(B_S - \frac{\bar{K}-K}{\bar{K}} B_K \right) \\ =& \frac{\bar{K}-K}{\bar{K}} (B_K - B_S) + \frac{K}{\bar{K}} B_U \end{aligned} \tag{A.154}$$

Then:

$$\begin{aligned} \begin{bmatrix} \frac{dS}{S} \\ \frac{dU^*}{U^*} \end{bmatrix} =& \frac{1}{\nabla} \begin{bmatrix} \frac{\bar{K}-K}{\bar{K}} B_K + B_U & -\frac{\bar{K}-K}{\bar{K}} \\ \frac{\bar{K}-K}{\bar{K}} B_K - B_S & \frac{K}{\bar{K}} \end{bmatrix} \\ & \begin{bmatrix} 1 & \frac{\bar{K}-K}{\beta\bar{K}} A_K - \frac{K}{\bar{K}} & -\frac{\bar{K}-K}{\beta\bar{K}} (A_K + \beta) \\ -\beta & \frac{\bar{K}-K}{\beta\bar{K}} B_K - A_S & A_U - \frac{\bar{K}-K}{\beta\bar{K}} B_K \end{bmatrix} \begin{bmatrix} \frac{d\tau}{\tau} \\ \frac{d\mu_s}{\mu_s+(1+c)A} \\ \frac{d\mu_u}{\mu_u+(1+c)A} \end{bmatrix} \end{aligned} \tag{A.155}$$

and, after calculations:

$$\frac{dS}{S} = \frac{M_{S\tau}}{\nabla} \frac{d\tau}{\tau} + \frac{M_{SS}}{\nabla} \frac{d\mu_s}{\mu_s + (1+c)A} + \frac{M_{SU}}{\nabla} \frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.156}$$

$$\frac{dU^*}{U^*} = \frac{M_{U\tau}}{\nabla} \frac{d\tau}{\tau} + \frac{M_{US}}{\nabla} \frac{d\mu_s}{\mu_s + (1+c)A} + \frac{M_{UU}}{\nabla} \frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.157}$$

where, using the equalities $A_K = A_S + \frac{K}{\bar{K}-K} A_U$ and $A_S - A_U = 1 - \beta$:

$$M_{S\tau} = \frac{\bar{K}-K}{\bar{K}} B_K + B_U + \beta \frac{\bar{K}-K}{\bar{K}} = \frac{\bar{K}-K}{\bar{K}} (B_K + \beta) + B_U \tag{A.158}$$

$$\begin{aligned} M_{SS} =& \left(\frac{\bar{K}-K}{\bar{K}} B_K + B_U \right) \left(\frac{\bar{K}-K}{\beta\bar{K}} A_K - \frac{K}{\bar{K}} \right) - \frac{\bar{K}-K}{\bar{K}} \left(\frac{\bar{K}-K}{\beta\bar{K}} B_K - A_S \right) \\ =& \frac{\bar{K}-K}{\beta\bar{K}} \left[\left(\frac{\bar{K}-K}{\bar{K}} A_K + (1-\beta) \frac{K}{\bar{K}} - 1 \right) B_K + \beta A_S + \left(A_K - \frac{\beta K}{\bar{K}-K} \right) B_U \right] \\ =& \frac{\bar{K}-K}{\beta\bar{K}} \left[(A_S - 1) B_K + \beta A_S + \left(A_K - \frac{\beta K}{\bar{K}-K} \right) B_U \right] \end{aligned} \tag{A.159}$$

$$\begin{aligned} M_{SU} =& -\frac{\bar{K}-K}{\beta\bar{K}} (A_K + \beta) \left(\frac{\bar{K}-K}{\bar{K}} B_K + B_U \right) - \frac{\bar{K}-K}{\bar{K}} \left(A_U - \frac{\bar{K}-K}{\beta\bar{K}} B_K \right) \\ =& -\frac{\bar{K}-K}{\beta\bar{K}} \left[(A_K + \beta - 1) \frac{\bar{K}-K}{\bar{K}} B_K + (A_K + \beta) B_U + \beta A_U \right] \\ =& -\frac{\bar{K}-K}{\beta\bar{K}} \left[(B_K + \beta) A_U + (A_K + \beta) B_U \right] \end{aligned} \tag{A.160}$$

and:

$$M_{U\tau} = \frac{\bar{K}-K}{\bar{K}} B_K - B_S - \beta \frac{K}{\bar{K}} \tag{A.161}$$

$$\begin{aligned} M_{US} &= \left(\frac{\bar{K}-K}{\bar{K}} B_K - B_S\right)\left(\frac{\bar{K}-K}{\beta\bar{K}} A_K - \frac{K}{\bar{K}}\right) + \frac{K}{\bar{K}}\left(\frac{\bar{K}-K}{\beta\bar{K}} B_K - A_S\right) \\ &= \frac{\bar{K}-K}{\beta\bar{K}}\left[\left(\frac{\bar{K}-K}{\bar{K}} B_K - B_S\right)\left(A_K - \frac{\beta K}{\bar{K}-K}\right) + \frac{K}{\bar{K}}\left(B_K - \frac{\beta\bar{K}}{\bar{K}-K} A_S\right)\right] \\ &= \frac{\bar{K}-K}{\beta\bar{K}}\left[A_S B_K - A_K B_S + \frac{\beta K}{\bar{K}-K}\left(B_S - A_S\right)\right] \end{aligned} \tag{A.162}$$

$$\begin{aligned} M_{UU} &= -\frac{\bar{K}-K}{\beta\bar{K}}\left(A_K+\beta\right)\left(\frac{\bar{K}-K}{\bar{K}} B_K - B_S\right) + \frac{K}{\bar{K}}\left(A_U - \frac{\bar{K}-K}{\beta\bar{K}} B_K\right) \\ &= \frac{K}{\bar{K}} A_U - \frac{\bar{K}-K}{\beta\bar{K}}\left\{\left[\left(A_K+\beta\right)\frac{\bar{K}-K}{\bar{K}} + \frac{K}{\bar{K}}\right] B_K - \left(A_K+\beta\right) B_S\right\} \\ &= \frac{\bar{K}-K}{\beta\bar{K}}\left[\left(A_K+\beta\right) B_S - \left(A_U+1\right) B_K + \frac{\beta K}{\bar{K}-K} A_U\right] \end{aligned} \tag{A.163}$$

Combining the two expressions, we get:

$$\frac{dS}{S} - \frac{dU^*}{U^*} = \frac{D_\tau}{\nabla}\frac{d\tau}{\tau} + \frac{D_S}{\nabla}\frac{d\mu_s}{\mu_s + (1+c)A} + \frac{D_U}{\nabla}\frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.164}$$

where:

$$D_\tau = M_{S\tau} - M_{U\tau} = B_U + B_S + \beta \tag{A.165}$$

$$D_S = M_{SS} - M_{US} = \left(\frac{\bar{K}-K}{\beta\bar{K}} A_K - \frac{K}{\bar{K}}\right)\left(B_U + B_S\right) - \frac{\bar{K}-K}{\beta\bar{K}} B_K + A_S \tag{A.166}$$

$$D_U = M_{SU} - M_{UU} = -\frac{\bar{K}-K}{\beta\bar{K}}\left[\left(A_K+\beta\right)\left(B_U+B_S\right) - B_K\right] - A_U \tag{A.167}$$

hence:

$$\begin{aligned} \frac{dK}{K} =& \frac{\bar{K}-K}{\bar{K}}\left(\frac{dS}{S} - \frac{dU^*}{U^*}\right) + \frac{\bar{K}-K}{\beta\bar{K}}\left[\frac{d\mu_s}{\mu_s+(1+c)A} - \frac{d\mu_u}{\mu_u+(1+c)A}\right] \\ =& \frac{\bar{K}-K}{\bar{K}}\left[\frac{D_\tau}{\nabla}\frac{d\tau}{\tau} + \frac{D_S}{\nabla}\frac{d\mu_s}{\mu_s+(1+c)A} + \frac{D_U}{\nabla}\frac{d\mu_u}{\mu_u+(1+c)A}\right] \\ &+ \frac{\bar{K}-K}{\beta\bar{K}}\left[\frac{d\mu_s}{\mu_s+(1+c)A} - \frac{d\mu_u}{\mu_u+(1+c)A}\right] \\ =& \frac{\bar{K}-K}{\bar{K}\nabla} D_\tau \frac{d\tau}{\tau} + \frac{\bar{K}-K}{\beta\bar{K}}\left(1 + \frac{\beta D_S}{\nabla}\right)\frac{d\mu_s}{\mu_s+(1+c)A} \\ &+ \frac{\bar{K}-K}{\beta\bar{K}}\left(\frac{\beta D_U}{\nabla} - 1\right)\frac{d\mu_u}{\mu_u+(1+c)A} \end{aligned} \tag{A.168}$$

Knowing that $A_K = A_S + \frac{K}{\bar{K}-K} A_U$, $A_S - A_U = 1 - \beta$, $A_K > 0$, $A_S > 0$, $A_U > 0$, $B_K < 0$, $B_S > 0$, $B_U > 0$, and $\frac{U^*}{\bar{K}-K} < \frac{S}{K}$, we find the following signs:

$$\begin{aligned}
\nabla =& \frac{\bar{K}-K}{\bar{K}} (B_K - B_S) + \frac{K}{\bar{K}} B_U \\
=& \frac{\bar{K}-K}{\bar{K}} \left[-\frac{\tau K/p}{Q_2+Q_2^*} - \frac{A(1+c)}{Q_1+Q_1^*} S - \frac{(1-\beta) Q_2}{Q_2+Q_2^*} \right] \\
&+ \frac{K}{\bar{K}} \left[\frac{A(1+c)}{Q_1+Q_1^*} U^* + \frac{(1-\beta) Q_2^*}{Q_2+Q_2^*} \right] \\
=& - \frac{K\left(\bar{K}-K\right)}{\bar{K}} \\
& \left[\frac{\tau/p}{Q_2+Q_2^*} + \frac{A(1+c)}{Q_1+Q_1^*} \left(\frac{S}{K} - \frac{U^*}{\bar{K}-K} \right) + \frac{1-\beta}{Q_2+Q_2^*} \left(\frac{Q_2}{K} - \frac{Q_2^*}{\bar{K}-K} \right) \right] < 0
\end{aligned} \tag{A.169}$$

and:

$$B_K + \beta = \frac{\bar{K}}{\bar{K}-K} \frac{\beta Q_2^*}{Q_2+Q_2^*} > 0 \tag{A.170}$$

so that:

$$M_{S\tau} = \frac{\bar{K}-K}{\bar{K}} (B_K + \beta) + B_U = \frac{\beta Q_2^*}{Q_2+Q_2^*} + B_U > 0 \tag{A.171}$$

$$M_{U\tau} = \frac{\bar{K}-K}{\bar{K}} B_K - B_S - \beta \frac{K}{\bar{K}} < 0 \tag{A.172}$$

$$M_{SU} = -\frac{\bar{K}-K}{\beta \bar{K}} \left[(B_K + \beta) A_U + (A_K + \beta) B_U \right] < 0 \tag{A.173}$$

$$M_{UU} = \frac{\bar{K}-K}{\beta \bar{K}} \left[(A_K + \beta) B_S - (A_U + 1) B_K + \frac{\beta K}{\bar{K}-K} A_U \right] > 0 \tag{A.174}$$

$$D_\tau = B_U + B_S + \beta > 0 \tag{A.175}$$

and:

$$\begin{aligned}
\beta D_U - \nabla &= \frac{\bar{K}-K}{\bar{K}} \left[B_K - (A_K + \beta)(B_U + B_S) \right] - \beta A_U - \frac{\bar{K}-K}{\bar{K}} (B_K - B_S) - \frac{K}{\bar{K}} B_U \\
&= \frac{\bar{K}-K}{\bar{K}} B_S - \frac{K}{\bar{K}} B_U - \frac{\bar{K}-K}{\bar{K}} (A_K + \beta)(B_U + B_S) - \beta A_U \\
&= \frac{\bar{K}-K}{\bar{K}} (B_S + B_U) - B_U - \frac{\bar{K}-K}{\bar{K}} (A_K + \beta)(B_U + B_S) - \beta A_U \\
&= -\frac{\bar{K}-K}{\bar{K}} (A_K + \beta - 1)(B_U + B_S) - \beta A_U - B_U \\
&= -A_U (B_U + B_S + \beta) - B_U < 0
\end{aligned} \tag{A.176}$$

The signs of the following coefficients have not been determined yet:

$$M_{SS} = \frac{\bar{K}-K}{\beta\bar{K}}\left[(A_S-1)B_K + \beta A_S + \left(A_K - \frac{\beta K}{\bar{K}-K}\right)B_U\right] \tag{A.177}$$

$$M_{US} = \frac{\bar{K}-K}{\beta\bar{K}}\left[A_S B_K - A_K B_S + \frac{\beta K}{\bar{K}-K}(B_S - A_S)\right] \tag{A.178}$$

$$\begin{aligned}\beta D_S + \nabla &= \left(\frac{\bar{K}-K}{\bar{K}}A_K - \beta\frac{K}{\bar{K}}\right)(B_U + B_S) - \frac{\bar{K}-K}{\bar{K}}B_S + \frac{K}{\bar{K}}B_U + \beta A_S \\ &= \left[\frac{\bar{K}-K}{\bar{K}}A_K + (1-\beta)\frac{K}{\bar{K}}\right]B_U + \left(\frac{\bar{K}-K}{\bar{K}}A_K - \beta\frac{K}{\bar{K}} - \frac{\bar{K}-K}{\bar{K}}\right)B_S + \beta A_S \\ &= \left[\frac{\bar{K}-K}{\bar{K}}A_K + (1-\beta)\frac{K}{\bar{K}}\right]B_U + \left[\frac{\bar{K}-K}{\bar{K}}A_K + (1-\beta)\frac{K}{\bar{K}} - 1\right]B_S + \beta A_S \\ &= \left[\frac{\bar{K}-K}{\bar{K}}A_K + (1-\beta)\frac{K}{\bar{K}}\right]B_U + (A_S-1)B_S + \beta A_S \end{aligned} \tag{A.179}$$

To summarise, we get the following results:

$$\frac{dS}{S} = \frac{M_{S\tau}}{\nabla}\frac{d\tau}{\tau} + \frac{M_{SS}}{\nabla}\frac{d\mu_s}{\mu_s + (1+c)A} + \frac{M_{SU}}{\nabla}\frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.180}$$

$$\frac{dU^*}{U^*} = \frac{M_{U\tau}}{\nabla}\frac{d\tau}{\tau} + \frac{M_{US}}{\nabla}\frac{d\mu_s}{\mu_s + (1+c)A} + \frac{M_{UU}}{\nabla}\frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.181}$$

$$\frac{dK}{K} = \frac{\bar{K}-K}{\bar{K}\nabla}D_\tau\frac{d\tau}{\tau} + \frac{\bar{K}-K}{\beta\bar{K}}\left(1 + \frac{\beta D_S}{\nabla}\right)\frac{d\mu_s}{\mu_s + (1+c)A} \tag{A.182}$$

$$+ \frac{\bar{K}-K}{\beta\bar{K}}\left(\frac{\beta D_U}{\nabla} - 1\right)\frac{d\mu_u}{\mu_u + (1+c)A} \tag{A.183}$$

with $\nabla < 0$, $M_{S\tau} > 0$, $M_{U\tau} < 0$, $M_{SU} > 0$, $M_{UU} > 0$, $D_\tau > 0$, $\beta D_U - \nabla < 0$, so that:

	$\frac{d\tau}{\tau}$	$\frac{d\mu_u}{\mu_u+(1+c)A}$
$\frac{dK}{K}$	-	+
$\frac{dS}{S}$	-	+
$\frac{dU^*}{U^*}$	+	-

B Appendix to Chapter 3

B.1 Investors by operating country and origin region

	Eastern Asia (China excluded)	China	Eastern Europe & Central Asia	Western Europe	Latin America & Caribbean	North America	Middle East & North Africa	SSA countries (South Africa excluded)	South Africa	Oceania	Domestic firms
Burkina Faso	0	0	0	3	0	0	2	3	0	0	16
Burundi	1	0	0	12	0	0	1	3	0	0	44
Cameroon	4	4	1	74	1	3	9	4	1	1	88
Ethiopia	19	12	4	44	0	19	27	14	2	1	313
Ghana	32	16	4	47	0	10	26	5	3	0	159
Kenya	67	19	2	114	1	25	12	14	11	3	255
Lesotho	3	30	0	3	0	0	0	4	18	0	78
Madagascar	2	5	0	53	0	1	3	32	1	0	89
Malawi	3	0	0	12	0	0	0	4	6	0	51
Mali	0	7	0	37	0	3	11	12	6	1	182
Mozambique	6	1	1	53	3	2	1	5	33	1	117
Nigeria	11	8	5	22	0	6	17	5	1	0	288
Senegal	3	1	0	43	0	3	4	5	0	0	95
Tanzania	35	7	2	28	0	6	7	21	13	0	242
Uganda	107	14	1	74	0	20	13	97	20	1	354
Zambia	14	3	1	22	2	3	7	7	12	1	168
Total	307	127	21	641	7	101	140	235	127	9	2,539

Notice that the origin country of 1,02% of foreign firms is unknown.

Table B.1.: Number of investors by operating country and origin region

B.2 Variables description

Variable	Definition	Source	Expected sign
y_{nij}	Nr. of foreign workers (high skilled, low skilled)	Africa Investor Survey 2010	Dep. variable
$\ln K_{nij}$	log(value of fixed assets/ nr. of full-time employees)	Africa Investor Survey 2010	+
Skill_j	Endowment of skilled labour (5th pillar): level of higher education and training in 2009. Composite indicator assessed using: (a) Secondary enrolment, (b) Tertiary enrolment, (c) Quality of educational system, (d) internet access in schools, (e) availability of research and training, and (f) Extent of staff training etc.	The Global Competitiveness, Report 2009-2010, World Economic Forum (2009)	-
Skill2_j	Average of the gross enrolment ratios in the secondary and tertiary education in 2009	WDI, World Bank (2014)	-
Skill3_j	Secondary and tertiary education attainment for population aged 25 and over in 2005	Educational attainment dataset (2014), (Barro & Lee, 2013)	-
$\ln \text{Size}_{nij}$	log(nr. of full time employee)	Africa Investor Survey 2010	+
$\ln \text{Age}_{nij}$	log(nr. of years since the creation of the company)	Africa Investor Survey 2010	-
$\ln \text{Exp}_{nij}$	Export intensity: log(value of exports/nr. of full-time employees)	Africa Investor Survey 2010	+
MultiPr_{nij}	1 if the firm produces at least 4 different products	Africa Investor Survey 2010	+
Green_{nij}	1 if the investment is a greenfield investment	Africa Investor Survey 2010	+
Sub_{nij}	1 if the firm is a wholly owned subsidiary of a foreign firm	Africa Investor Survey 2010	+
JV_{nij}	1 if the firm is a joint-venture between a foreign firm and a local firm	Africa Investor Survey 2010	-
GDPcap_j	GDP per capita in PPP (constant international $ of 2011), in 2009	WDI, World Bank (2014)	+
$\ln \text{Pop}_j$	log(total population in 2009)	WDI, World Bank (2014)	+/-
Corruption_j	Extra payments/bribes/favouritism: based on the Global Competitiveness Report questions: "In your industry, how commonly would you estimate that firms make undocumented extra payments or bribes." Countries with a higher corruption degree are given lower rates.	Economic freedom of the World (2010)	+/-
$\ln \text{MigStock}_j$	International migration stock of the investment in 2005	WDI, World Bank (2014)	+
Open_j	Freedom of the foreigners to visit for tourist and business purposes: It is assessed as the % of countries for which a visa is required. Counties in which it is difficult to enter are given lower rating.	Economic freedom of the World (2010)	+
LabReg_j	Hiring regulation and minimum wage: based on the World Bank's Doing Business "Difficulty of Hiring Index". Counties with higher difficulty of hiring are given lower rating.	Economic freedom of the World (2010)	+/-
$\ln \text{Dist}_{ij}$	Distance in kilometres between the most populated city of the origin country of the investor and the firm's operating country	CEPII (Mayer & Zignago, 2011)	+/-
Lang_{ij}	1 if the origin country of the investor and the firm's operating country share the same official language	CEPII (Mayer & Zignago, 2011)	+/-

Table B.2.: Variables description

B.3 Correlation matrices

	Skill_j	$\ln K_{nij}$	$\ln \text{Size}_{nij}$	$\ln \text{Age}_{nij}$	$\ln \text{Exp}_{nij}$	MultiPr_{nij}	$\ln \text{MigStock}_j$	$\ln \text{Pop}_j$	GDPcap_j	Open_j	Corruption_j	LabReg_j
Skill_j	1.0000											
$\ln K_{nij}$	0.0708	1.0000										
$\ln \text{Size}_{nij}$	0.0455	0.1654	1.0000									
$\ln \text{Age}_{nij}$	0.1552	0.1060	0.3077	1.0000								
$\ln \text{Exp}_{nij}$	0.0708	0.0641	0.1833	0.0505	1.0000							
MultiPr_{nij}	-0.0031	0.0170	0.1156	0.0792	0.0033	1.0000						
$\ln \text{MigStock}_j$	0.2187	-0.0149	-0.0608	-0.0049	-0.0065	-0.0318	1.0000					
$\ln \text{Pop}_j$	-0.0677	0.1371	0.2137	0.0590	-0.0151	0.0642	-0.2206	1.0000				
GDPcap_j	0.4031	0.0896	0.0217	0.1370	-0.0246	-0.0919	-0.0506	0.3449	1.0000			
Open_j	0.2429	-0.0489	-0.1943	-0.0017	-0.0116	-0.0339	0.3347	-0.5507	-0.2550	1.0000		
Corruption_j	0.2897	-0.0048	-0.0113	0.0968	-0.0510	0.0197	0.1081	0.1271	0.4269	-0.2029	1.0000	
LabReg_j	-0.1822	-0.0291	0.0852	0.0104	-0.0375	0.0358	0.1125	-0.0556	-0.1365	0.0409	-0.2624	1.0000

Table B.3.: Correlation matrix, sub-sample of domestic firms (2608 observations)

	Skill_j	$\ln K_{nij}$	$\ln \text{Size}_{nij}$	$\ln \text{Age}_{nij}$	$\ln \text{Exp}_{nij}$	MultiPr_{nij}	Sub_{nij}	JV_{nij}	Green_{nij}	$\ln \text{MigStock}_j$	$\ln \text{Pop}_j$	GDPcap_j	Open_j	Corruption_j	LabReg_j	$\ln \text{Dist}_{ij}$	Lang_{ij}
Skill_j	1.000																
$\ln K_{nij}$	0.141	1.000															
$\ln \text{Size}_{nij}$	0.121	0.050	1.000														
$\ln \text{Age}_{nij}$	0.113	0.168	0.237	1.000													
$\ln \text{Exp}_{nij}$	0.187	-0.029	0.308	-0.020	1.000												
MultiPr_{nij}	0.136	0.086	0.093	0.064	0.043	1.000											
Sub_{nij}	0.012	0.064	0.197	0.065	0.123	0.069	1.000										
JV_{nij}	0.159	0.098	0.115	0.072	-0.024	0.033	-0.281	1.000									
Green_{nij}	0.037	-0.045	-0.133	0.053	-0.040	-0.032	-0.090	-0.033	1.000								
$\ln \text{MigStock}_j$	0.216	0.069	-0.146	0.017	-0.089	-0.015	-0.094	-0.009	0.018	1.000							
$\ln \text{Pop}_j$	-0.028	0.191	0.008	0.018	-0.121	0.028	-0.100	0.163	0.024	0.019	1.000						
GDPcap_j	0.403	0.052	0.074	0.107	-0.023	-0.000	-0.024	0.061	-0.009	0.114	0.180	1.000					
Open_j	0.311	-0.014	-0.019	0.000	0.090	-0.012	-0.005	0.007	-0.038	0.217	-0.388	-0.173	1.000				
Corruption_j	0.224	0.031	-0.085	0.053	0.000	-0.010	-0.092	-0.022	0.064	0.300	0.105	0.315	0.031	1.000			
LabReg_j	-0.259	-0.110	-0.031	-0.129	-0.110	-0.091	-0.051	-0.080	-0.017	0.144	-0.161	-0.022	-0.040	-0.312	1.000		
$\ln \text{Dist}_{ij}$	0.175	0.046	0.076	0.030	0.033	-0.009	-0.067	0.020	0.010	0.062	0.012	0.145	-0.016	-0.027	0.020	1.000	
Lang_{ij}	0.006	0.002	-0.025	0.088	-0.012	0.052	0.018	0.015	-0.044	-0.047	-0.036	-0.101	0.110	-0.009	-0.165	-0.154	1.000

Table B.4.: Correlation matrix, sub-sample of foreign firms (1646 observations)

B.4 Demand for foreign low skilled workers

In order to control that the complementarity is stronger between the firm's capital intensity and its use of foreign high skilled workers, than between the firm's capital intensity and its use of foreign low skilled workers, we use the number of low skilled workers in the firm as our dependent variable (Table B.5, specification 1). Interestingly, we also find a relation of complementarity between the firm's capital intensity and its use of foreign low skilled workers. We find that a marginal increase of the capital intensity by 1% entails an increase in the use of foreign low skilled workers by 0.0719 unit (Table B.5, specification 1'). However, the degree of complementarity is higher between the capital intensity and the use of foreign high skilled workers; to every increase in the capital intensity by 1% corresponds an increase in the use of foreign high skilled workers by 0.222 unit (Table 3.3, specification 2'). One may think that this important complementarity between the capital intensity and the use of foreign low skilled workers may be related to MNEs coming from developing countries such as India or China. Those firms show little local integration and few linkages to domestic firms. Morrissey and Zgovu (2011) underlines that Chinese firms settling in Africa import all necessary equipment, skilled and unskilled labour from China, taking low benefits for the local economies. However, our result should not be related to the origin country of the foreign firm as we include origin region dummies in our specifications.

	(1)	(1')
ln K_{nij}	0.0786^{b}	0.0719^{b}
	(0.0334)	(0.0309)
Skill$_{j}$	-1.624^{a}	-1.486^{a}
	(0.226)	(0.220)
ln Size$_{nij}$	0.703^{a}	0.643^{a}
	(0.0668)	(0.0709)
ln Age$_{nij}$	-0.166	-0.152
	(0.108)	(0.0993)
ln Exp$_{nij}$	0.149	0.136
	(0.389)	(0.356)
MultiPr$_{nij}$	-0.0637	-0.0583
	(0.265)	(0.243)
Sub$_{nij}$	0.00429	0.00392
	(0.184)	(0.168)
JV$_{nij}$	-0.497^{b}	-0.455^{b}
	(0.222)	(0.204)
Green$_{nij}$	0.518^{b}	0.474^{b}
	(0.209)	(0.193)
ln MigStock$_{j}$	0.202	0.184
	(0.188)	(0.172)
Observations	1,691	1,691
ln α	1.829^{a}	
	(0.0660)	
Sector dummies	yes	yes
Origin region dummies	yes	yes
Origin country dummies	no	no
Country dummies	no	no

Standard errors in parentheses. Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.
Column 1' presents the marginal effects at the mean values of the predictors based on specification 1.

Table B.5.: Demand for foreign unskilled workers, sub-sample of foreign firms

B.5 Interpretation of the interaction effect

We follow Berry et al. (2012) and Brambor et al. (2006) to interpret the interaction effect we add to our specification. The figure below indicates how the marginal effect of the age of the firm $\left(\ln \text{Age}_{nij}\right)$ on our dependent variable, changes with the skilled labour endowment of the firm's operating country (Skill_j).

Any point on the solid line is given by $\frac{\partial(\ln \lambda_{nij})}{\partial\left(\ln \text{Age}_{nij}\right)} = \beta_a + \beta_b \text{Skill}_j$, where β_a is the coefficient of the variable $\ln \text{Age}_{nij}$, and β_b is the coefficient of the interaction $\ln \text{Age}_{nij} * \text{Skill}_j$. The dotted lines represent a 95% confidence interval. The variable $\ln \text{Age}_{nij}$ has a statistically significant effect on the employment of foreign high skilled workers (conditional on the variable Skill_j), when the upper and lower bounds of the confidence interval are both above or below the zero line. Note that the vertical axe on the right is for the histogram which depicts the distribution of observations for the variable Skill_j.

Here, the variable $\ln \text{Age}_{nij}$ has a significant and positive effect on the employment of foreign high skilled workers, when the endowment in skilled labour is below 2.7 units. This positive effect declines when the variable Skill_j gets higher. The variable $\ln \text{Age}_{nij}$ has a significant and negative effect on the employment of foreign high skilled workers, when the variable Skill_j is at least equal to 3.3 units. This negative effect increases when the endowment in skilled labour gets higher.

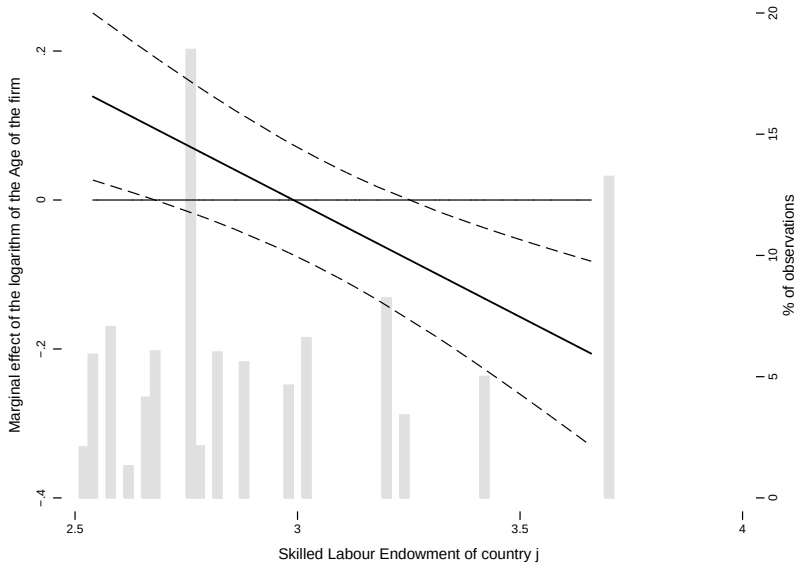

Figure B.1.: Marginal effect of the age $\left(\ln \text{Age}_{nij}\right)$ on the number of foreign high skilled workers employed, conditional on the level of skilled labour endowment of the country (Skill_j)

B.6 Robustness tests

We realise different robustness checks using alternative specifications and alternative empirical models. The following table presents our results.

	(1) NB2	(2) NB2	(3) PPML	(4) TOBIT
ln K_{nij}	0.108^a	0.0713^a	0.0944^a	0.00386^a
	(0.0156)	(0.0154)	(0.0239)	(0.00123)
Skill$_j$			-0.445^a	-0.0367^a
			(0.123)	(0.00636)
Skill2$_j$	-0.0150^a			
	(0.00180)			
Skill3$_j$		-0.0202^a		
		(0.00634)		
ln Size$_{nij}$	0.571^a	0.591^a	0.588^a	
	(0.0241)	(0.0252)	(0.0346)	
ln Age$_{nij}$	-0.0673^c	-0.0534	-0.156^a	-0.00561^c
	(0.0389)	(0.0415)	(0.0500)	(0.00292)
ln Exp$_{nij}$	0.249^c	0.316^b	0.330^c	0.0153
	(0.141)	(0.145)	(0.179)	(0.0111)
MultiPr$_{nij}$	0.146	0.0619	0.130	0.00365
	(0.0923)	(0.100)	(0.142)	(0.00790)
Sub$_{nij}$	0.0301	-0.109	0.0276	-0.0101^c
	(0.0655)	(0.0675)	(0.0868)	(0.00518)
JV$_{nij}$	-0.443^a	-0.591^a	-0.484^a	-0.0239^a
	(0.0840)	(0.0895)	(0.133)	(0.00653)
Green$_{nij}$	0.0615	0.0477	0.129	0.00937
	(0.0782)	(0.0811)	(0.117)	(0.00621)
ln MigStock$_j$	0.578^a	0.224^b	0.323^a	0.0334^a
	(0.0730)	(0.0886)	(0.0931)	(0.00505)
ln Dist$_{ij}$			0.128^a	
			(0.0461)	
Lang$_{ij}$			0.0710	
			(0.0763)	
Observations	1,600	1,433	1,646	1,690
ln α	-0.385^a	-0.411^a		
	(0.0599)	(0.0611)		
R-squared			0.371	-0.154
Sector dummies	yes	yes	yes	yes
Origin region dummies	yes	yes	no	yes
Origin country dummies	no	no	no	no
Country dummies	no	no	no	no

Standard errors in parentheses. Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.
The dependent variable used in the Tobit model
is the share of foreign skilled workers with respect to the full workforce.

Table B.6.: Robustness tests: Demand for foreign skilled workers, subsample of foreign firms

B.7 Endogeneity tests

We perform a two-step exponential GMM to control for a possible endogeneity bias between our dependent variable and the size of the firm measured as the total number of full-time employees. We present the results in Table B.7. In specification 1, we instrument the size by the number of full-time low skilled workers employed by the firm, and its operating costs during the last financial year such as rent and telecommunication[1]. In specification 2, we use the number of full-time mid-skilled workers employed by the firm and its operating costs during the last financial year.

	(1)	(2)
ln K_{nij}	0.0989^a	0.0987^a
	(0.0258)	(0.0252)
Skill$_j$	-0.442^a	-0.411^a
	(0.122)	(0.128)
ln Size$_{nij}$	0.561^a	0.506^a
	(0.0448)	(0.0551)
ln Age$_{nij}$	-0.108^c	-0.0908
	(0.0619)	(0.0607)
ln Exp$_{nij}$	0.351^c	0.422^b
	(0.182)	(0.199)
MultiPr$_{nij}$	0.0961	0.117
	(0.148)	(0.146)
Sub$_{nij}$	0.0529	0.102
	(0.0915)	(0.0987)
JV$_{nij}$	-0.499^a	-0.459^a
	(0.116)	(0.118)
Green$_{nij}$	0.117	0.0899
	(0.115)	(0.111)
ln MigStock$_j$	0.314^a	0.308^a
	(0.0881)	(0.0887)
Observations	1,591	1,591
Hansen J test	0.1685	0.2697
Sector dummies	yes	yes
Origin region dummies	yes	yes
Origin country dummies	no	no
Country dummies	no	no

Standard errors in parentheses. Intercept not reported. ^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table B.7.: Endogeneity tests: Demand for foreign skilled workers, sub-sample of foreign firms

[1] The latter variable comes from the UNIDO Africa Investor Survey 2010.

The following table shows the correlation between the chosen instruments, the dependent variable and the initial proxy for the size of the firm.

	dep. variable: nr. of foreign skilled workers	initial proxy: log(nr. of total workers)	operating costs	log(nr. of low skilled workers)	log(nr. of mid-skilled workers)
dep. variable: nr. of foreign skilled workers	1.0000				
initial proxy: log(nr. of total workers)	0.4188	1.0000			
operating costs	0.0799	0.1969	1.0000		
log(nr. of low skilled workers)	0.3517	0.8597	0.1605	1.0000	
log(nr. of mid-skilled workers)	0.2832	0.7149	0.1841	0.4926	1.0000

Table B.8.: Correlation test for the two-step exponential GMM

C

Appendix to Chapter 4

C.1 Cultural diversity measures

We use a Herfindahl index to measure the cultural concentration among workers of type e within firm i such that:

$$\text{Herf}_i = \sum_{z=1}^{Z} (\lambda_i^{ez})^2 \ \forall e$$

where Z is the number of regions of birth represented within the studied group of workers (e), and λ_i^{ez} is the share of workers born in country z within the group. This index ranges from $\frac{1}{Z}$ to one, and can be normalised such that:

$$\text{Herf}_i^{\text{norm}} = \begin{cases} \frac{\text{Herf}_i - \frac{1}{Z}}{1 - \frac{1}{Z}} & \text{if Z>1} \\ 1 & \text{if Z=1} \end{cases}$$

Alternatively, we can measure the cultural diversity using the Theil index:

$$\text{Theil}_i = \frac{1}{\eta} \sum_{z=1}^{n+1} \left(\frac{l_i^{ez}}{\Lambda_i^{ez}} \ln \frac{l_i^{ez}}{\Lambda_i^{ez}} \right)$$

where $n+1$ denotes the number of birth regions that can potentially be represented within the group of workers e, l_i^{ez} represents the number of individuals born in country z, and Λ_i^{ez} represents the average number of individuals within each sub-group. This index ranges from zero to $\ln(n+1)$ and can be normalised such that:

$$\text{Theil}_i^{\text{norm}} = \frac{\text{Theil}_i}{\ln(n+1)}$$

C.2 Additional stylised facts

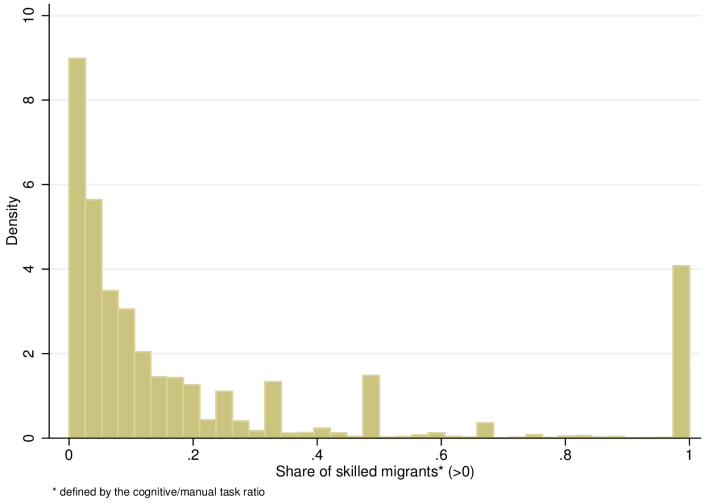

Figure C.1.: Distribution of the shares of foreign skilled workers (defined by their cognitive skills) (2008)

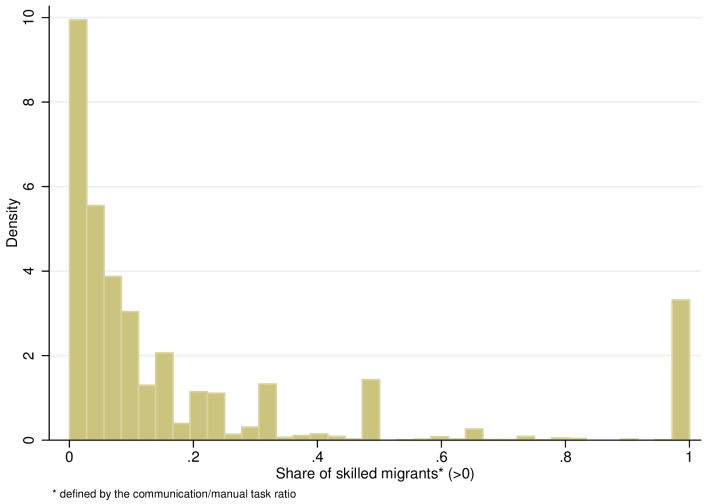

Figure C.2.: Distribution of the shares of foreign skilled workers (defined by their communication skills) (2008)

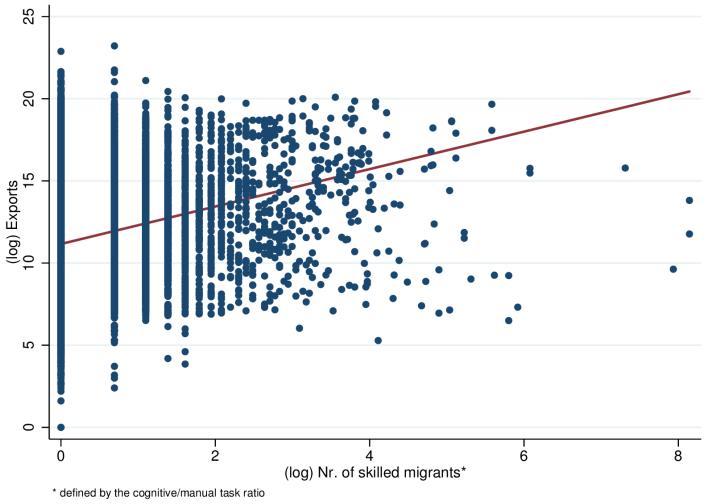

Figure C.3.: Exported quantities and employment of foreign skilled workers (defined by their cognitive skills) (2008)

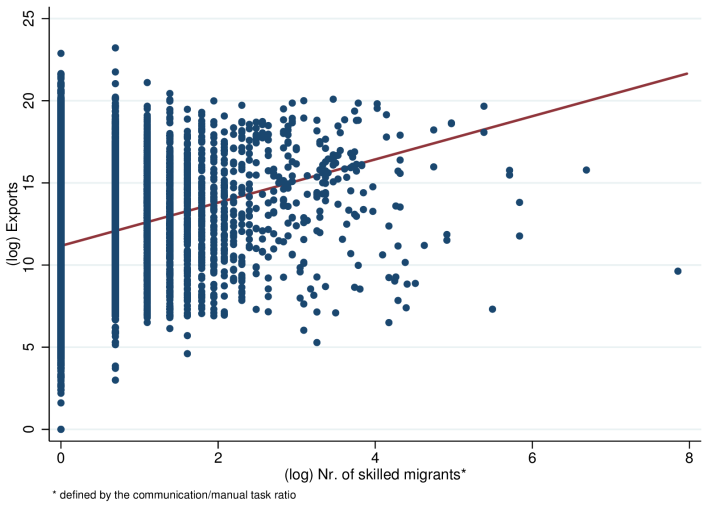

Figure C.4.: Exported quantities and employment of foreign skilled workers (defined by their communication skills) (2008)

C.3 Additional results

Dep. variable: ln(nr. of destinations)				
Sample (x)	whole	whole	whole	whole
	(1)	(2)	(3)	(4)
$\text{CapInt}_{i,\,t-1}$	0.041^{a}	0.041^{a}	0.041^{a}	0.041^{a}
	(0.003)	(0.003)	(0.003)	(0.003)
$\text{Employ}_{i,\,t-1}$	0.298^{a}	0.298^{a}	0.298^{a}	0.298^{a}
	(0.004)	(0.004)	(0.004)	(0.004)
$\text{Age}_{i,\,t}$	-0.014^{b}	-0.014^{b}	-0.014^{b}	-0.014^{b}
	(0.005)	(0.005)	(0.005)	(0.005)
$\text{Herfindahl index}_{i,\,t-1}$	-0.188^{a}			
	(0.020)			
$\text{Normalised Herfindahl index}_{i,\,t-1}$		-0.095^{a}		
		(0.010)		
$\text{Theil index}_{i,\,t-1}$			-0.102^{a}	
			(0.013)	
$\text{Normalised Theil index}_{i,\,t-1}$				-0.112^{a}
				(0.014)
Observations	603,319	603,319	603,319	603,319
R^2	0.173	0.173	0.173	0.173
Zone-year fixed effects	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes

Standard errors in parentheses.

Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table C.1.: Extensive margin and diversity

Dep. variable: $\ln\left(q^{x}_{i,t}\right)$			
Sample (x)	whole	nonEU	EU
	(1)	(2)	(3)
$\text{Mig}^{nb}_{i,t-1}$	0.058^{a}	0.094^{a}	0.034^{a}
	(0.009)	(0.006)	(0.009)
$\text{CapInt}_{i,t-1}$	0.232^{a}	0.310^{a}	0.185^{a}
	(0.014)	(0.013)	(0.009)
$\text{Employ}_{i,t-1}$	0.708^{a}	0.811^{a}	0.647^{a}
	(0.020)	(0.009)	(0.015)
$\text{Age}_{i,t}$	-0.193^{a}	-0.284^{a}	-0.133^{a}
	(0.018)	(0.015)	(0.012)
Observations	895,386	335,893	559,493
R^2	0.226	0.267	0.215
Zone-year fixed effects	yes	yes	yes
Sector dummies	yes	yes	yes
Cluster - sector level	yes	yes	yes

Standard errors in parentheses.

Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table C.2.: Intensive margin: complementary results

Dep. variable: $\ln\left(q_{i,t}^{x}\right)$				
Sample (x)	whole	whole	whole	whole
	(1)	(2)	(3)	(4)
$\text{CapInt}_{i,t-1}$	0.260^{a}	0.260^{a}	0.260^{a}	0.260^{a}
	(0.013)	(0.013)	(0.013)	(0.013)
$\text{Employ}_{i,t-1}$	0.724^{a}	0.724^{a}	0.723^{a}	0.723^{a}
	(0.019)	(0.019)	(0.019)	(0.019)
$\text{Age}_{i,t}$	-0.220^{a}	-0.220^{a}	-0.220^{a}	-0.220^{a}
	(0.019)	(0.019)	(0.019)	(0.019)
Herfindahl $\text{index}_{i,t-1}$	-0.616^{a}			
	(0.031)			
Normalised Herfindahl $\text{index}_{i,t-1}$		-0.312^{a}		
		(0.015)		
Theil $\text{index}_{i,t-1}$			-0.368^{a}	
			(0.021)	
Normalised Theil $\text{index}_{i,t-1}$				-0.404^{a}
				(0.023)
Observations	616,542	616,542	616,542	616,542
R^2	0.248	0.248	0.248	0.248
Zone-year fixed effects	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes

Standard errors in parentheses.

Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table C.3.: Intensive margin and diversity

Dep. variable:	ln(nr. of destinations)					ln(nr. of products)				
Sample (x)	whole (1)	whole (2)	whole (3)	whole (4)	whole (5)	whole (6)	whole (7)	whole (8)	whole (9)	whole (10)
$\text{Mig}_{i,t-1}$	0.132^a					0.174^a				
	(0.017)					(0.025)				
$\text{SkilledMig}_{i,t-1}$ (25%)		0.192^a	0.159^a				0.236^a	0.187^a		
		(0.022)	(0.022)				(0.025)	(0.024)		
$\text{SkilledMig}_{i,t-1}$ (5%)				0.011	0.042				0.247	0.204
				(0.271)	(0.272)				(0.508)	(0.512)
$\text{Skilled}_{i,t-1}$ (25%)			0.264^a					0.394^a		
			(0.012)					(0.026)		
$\text{Skilled}_{i,t-1}$ (5%)				-0.215				-0.443^a		
					(0.146)					(0.131)
$\text{CapInt}_{i,t-1}$	0.059^a	0.056^a	0.054^a	0.057^a	0.057^a	0.087^a	0.082^a	0.079^a	0.083^a	0.083^a
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.009)	(0.008)	(0.009)	(0.009)
$\text{Employ}_{i,t-1}$	0.309^a	0.305^a	0.317^a	0.305^a	0.305^a	0.452^a	0.449^a	0.467^a	0.449^a	0.449^a
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
$\text{Age}_{i,t}$	0.010	0.003	0.006	0.002	0.002	0.013	0.007	0.011	0.006	0.006
	(0.006)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Observations	237,029	237,029	237,029	237,029	237,029	244,989	244,989	244,989	244,989	244,989
R^2	0.180	0.178	0.179	0.178	0.178	0.269	0.274	0.276	0.273	0.273
Zone-year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Standard errors in parentheses.
Intercept not reported.
^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table C.4.: Extensive margin and communication skills

Dep. variable: $\ln\left(q^{x}_{i,t}\right)$					
Sample (x)	whole	whole	whole	whole	whole
	(1)	(2)	(3)	(4)	(5)
$\text{Mig}_{i,t-1}$	0.473^{a}				
	(0.051)				
$\text{SkilledMig}_{i,t-1}$ (25%)		0.547^{a}	0.447^{a}		
		(0.067)	(0.066)		
$\text{SkilledMig}_{i,t-1}$ (5%)				-0.349	-0.346
				(0.612)	(0.617)
$\text{Skilled}_{i,t-1}$ (25%)			0.807^{a}		
			(0.031)		
$\text{Skilled}_{i,t-1}$ (5%)					-0.025
					(0.357)
$\text{CapInt}_{i,t-1}$	0.287^{a}	0.314^{a}	0.307^{a}	0.316^{a}	0.316^{a}
	(0.017)	(0.016)	(0.016)	(0.016)	(0.016)
$\text{Employ}_{i,t-1}$	0.743^{a}	0.743^{a}	0.780^{a}	0.743^{a}	0.743^{a}
	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)
$\text{Age}_{i,t}$	-0.180^{a}	-0.202^{a}	-0.195^{a}	-0.205^{a}	-0.205^{a}
	(0.018)	(0.017)	(0.018)	(0.018)	(0.018)
Observations	244,989	244,989	244,989	244,989	244,989
R^2	0.268	0.269	0.272	0.268	0.268
Zone-year fixed effects	yes	yes	yes	yes	yes
Sector dummies	yes	yes	yes	yes	yes
Cluster - sector level	yes	yes	yes	yes	yes

Standard errors in parentheses.

Intercept not reported.

^{a}, ^{b} and ^{c} respectively denote significance at the 1%, 5% and 10% level.

Table C.5.: Intensive margin and communication skills

	Mean		T-test	
Variable	Treated	Non-treated	T-value	P-value
Employment (t-1)	0.633	0.627	0.52	0.602
Labour productivity (t-1)	3.869	3.877	0.38	0.701
Profit growth (t-1)	-0.102	-0.095	-0.88	0.379
Capital Intensity (t-1)	3.517	3.527	1.35	0.176
Age (t-1)	2.771	2.768	0.62	0.538

Table C.6.: Groups comparison, $T_i = 1$ if $\text{Mig}_{i,t-1} > \text{Mig}_{i,t-2}$

	(1)
Dep. variable	$T_i = 1$
Employment (t-1)	-0.077^a
	(0.006)
Labour productivity (t-1)	-0.063^a
	(0.003)
Profit growth (t-1)	-0.002^a
	(0.001)
[1em] Capital Intensity (t-1)	0.089^a
	(0.002)
Age (t-1)	-0.016^b
	(0.008)
Observations	1,132,880
R^2	0.0085

Standard errors in parentheses.
Intercept not reported.
^{a} and ^{b} respectively denote significance at the 1% and 5% level.

Table C.7.: Results from logit regression, $T_i = 1$ if $\text{Mig}_{i,\,t-1} > \text{Mig}_{i,\,t-2}$

Sample (x): whole		
	(1)	(2)
Treatment	$\text{SkilledMig}_{t-1} > \text{SkilledMig}_{t-2}$	$\text{SkilledMig}_{t-4} > \text{SkilledMig}_{t-5}$
ln(nr. of destinations)	0.216^a	0.353^a
	(0.010)	(0.013)
ln(nr. of products)	0.334^a	0.479^a
	(0.011)	(0.016)
$\ln\left(q^x_{i,\,t}\right)$	0.279^a	0.623 ^{a}
	(0.021)	(0.027)

Standard errors in parentheses. Intercept not reported.
^{a} denotes significance at the 1% level.

Table C.8.: Exports and communication skills – PSM (one-to-one matching algorithm)

Sample (x): whole		
	(1)	(2)
Treatment	$\text{SkilledMig}_{t-1} > \text{SkilledMig}_{t-2}$	$\text{SkilledMig}_{t-4} > \text{SkilledMig}_{t-5}$
ln(nr. of destinations)	0.099^a	0.212^a
	(0.007)	(0.009)
ln(nr. of products)	0.015^a	0.277^a
	(0.008)	(0.011)
$\ln\left(q^x_{i,\,t}\right)$	0.194^a	0.439^a
	(0.014)	(0.019)

Standard errors in parentheses. Intercept not reported.
^{a} denotes significance at the 1% level.

Table C.9.: Exports and cognitive skills – PSM (5-neighbour matching algorithm)

Sample (x): whole		
	(1)	(2)
Treatment	$\text{SkilledMig}_{t-1} > \text{SkilledMig}_{t-2}$	$\text{SkilledMig}_{t-4} > \text{SkilledMig}_{t-5}$
ln(nr. of destinations)	0.074^a	0.199^a
	(0.007)	(0.009)
ln(nr. of products)	0.0119^a	0.269^a
	(0.008)	(0.011)
$\ln\left(q^x_{i,\,t}\right)$	0.150^a	0.448^a
	(0.015)	(0.019)

Standard errors in parentheses. Intercept not reported.

^{a} denotes significance at the 1% level.

Table C.10.: Exports and communication skills – PSM (5-neighbour matching algorithm)

Sample (x)	nonEU	EU
	(1)	(2)
Treatment	$\left(\text{Mig}^{EU}_{t-1} - \text{Mig}^{EU}_{t-2}\right) < \left(\text{Mig}^{nonEU}_{t-1} - \text{Mig}^{nonEU}_{t-2}\right)$	$\left(\text{Mig}^{EU}_{t-1} - \text{Mig}^{EU}_{t-2}\right) < \left(\text{Mig}^{nonEU}_{t-1} - \text{Mig}^{nonEU}_{t-2}\right)$
ln(nr. of destinations)	0.492^a	0.307^a
	(0.007)	(0.008)
ln(nr. of products)	0.605^a	0.316^a
	(0.008)	(0.009)
$\ln\left(q^x_{i,\,t}\right)$	0.845^a	0.587^a
	(0.012)	(0.016)

Standard errors in parentheses. Intercept not reported.

^{a} denotes significance at the 1% level.

Table C.11.: Exports and foreign employment by zone of birth (I) – PSM (5-neighbour matching algorithm)

Sample (x)	nonEU	EU
	(1)	(2)
Treatment	$\left(\text{Mig}^{EU}_{t-4} - \text{Mig}^{EU}_{t-5}\right) < \left(\text{Mig}^{nonEU}_{t-4} - \text{Mig}^{nonEU}_{t-5}\right)$	$\left(\text{Mig}^{EU}_{t-4} - \text{Mig}^{EU}_{t-5}\right) < \left(\text{Mig}^{nonEU}_{t-4} - \text{Mig}^{nonEU}_{t-5}\right)$
ln(nr. of destinations)	0.484^a	0.396^a
	(0.009)	(0.011)
ln(nr. of products)	0.661^a	0.365^a
	(0.011)	(0.011)
$\ln\left(q^x_{i,\,t}\right)$	0.842^a	0.746^a
	(0.017)	(0.021)

Standard errors in parentheses. Intercept not reported.

^{a} denotes significance at the 1% level.

Table C.12.: Exports and foreign employment by zone of birth (II) – PSM (5-neighbour matching algorithm)

D

Appendix to Chapter 5

D.1 Probability to migrate to country k', conditional on the capacity to pay for the migration cost

To find the probability to migrate to country k' conditional on the capacity of the individual to afford his migration, we use the most straightforward reasoning: individual i first identifies affordable destinations and then chooses among this set of countries the one that maximises his utility.

We defined $\theta(k,k')$ as the rank of country k' when destinations are ranked in increasing order of migration cost from country k, and $\kappa(k,l)$ as the inverse permutation of $\theta(k,k')$: $\theta(k,k') = l \iff \kappa(k,l) = k'$.

To find the set of affordable destinations, individual i first considers a potential destination country k'. With probability $\Phi\left(C^{k,k'}\right)$, $w_i^k < C^{k,k'}$ and country k' cannot be a destination country. Conversely, with probability $1 - \Phi\left(C^{k,k'}\right)$, k' is an affordable destination. For any $l \geq \theta(k,k')$, we know that $C^{k,k'} \leq C^{k,\kappa(k,l)} \leq C^{k,\kappa(k,l+1)}$. Thus, with probability $\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]$, the double inequality $C^{k,\kappa(k,l)} < w_i^k < C^{k,\kappa(k,l+1)}$ holds: country l is affordable but not country $l+1$. Then, the choice set generated by the budget constraint is the set of all the countries ranked from 1 to l (including k'), $\mathcal{A}_{kl} = \{\kappa(k,1), \ldots, \kappa(k,l)\}$.

Following the results of McFadden (1974) and McFadden (1984), the probability of a migrant to choose country k' is:

$$\Pr\left[U_i^{k,k'} = \max_{q \in \mathcal{A}_{kl}} U_i^{k,q} \,|\, C^{k,\kappa(k,l)} < w_i^k < C^{k,\kappa(k,l+1)}\right] = \frac{e^{W^{k,k'} - C^{k,k'}}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \quad \text{(D.1)}$$

Then, summing for every $l \geq \theta(k,k')$, we get the unconditional probability of k' to be a destination country from k:

$$\begin{aligned} p_{BC}^{k,k'} &= \sum_{l=\theta(k,k')}^{P} \Pr\left[C^{k,\kappa(k,l)} < w_i^k < C^{k,\kappa(k,l+1)}\right] \Pr\left[U_i^{kk'} = \max_{q \in A_{kl}} U_i^{kq} \,|\, C^{k,\kappa(k,l)} < w_i^k < C^{k,\kappa(k,l+1)}\right] \\ &= \sum_{l=\theta(k,k')}^{P} \left\{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]\right\} \frac{e^{W^{k,k'} - C^{k,k'}}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \\ &= A^{k,k'} e^{W^{k,k'} - C^{k,k'}} \end{aligned} \tag{D.2}$$

where:

$$A^{k,k'} = \sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \tag{D.3}$$

using the convention $C^{k,\kappa(k,P+1)} = \infty$ so that $\Phi\left[C^{k,\kappa(k,P+1)}\right] = 1$.

This formula implies that the probability of the agent not to migrate out of country k is:

$$p_{BC}^{k,k} = e^{W^{k,k}} \sum_{l=1}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} = A^{k,k} e^{W^{k,k}} \tag{D.4}$$

Then, the bilateral migration rate equals:

$$M_{BC}^{k,k'} = \frac{p_{BC}^{k,k'}}{p_{BC}^{k,k}} = f^{k,k'} \frac{e^{W^{k,k'} - W^{k,k}}}{e^{C^{k,k'}}} = f^{k,k'} M^{k,k'} \tag{D.5}$$

where:

$$f^{k,k'} = \frac{A^{k,k'}}{A^{k,k}} = \frac{\sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}}{\sum_{l=1}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}} < 1 \tag{D.6}$$

More generally, if $\theta(k,k') < \theta(k,k'')$, then the ratio of migration rates equals:

$$\frac{M_{BC}^{k,k''}}{M_{BC}^{k,k'}} = \frac{p_{BC}^{k,k''}}{p_{BC}^{k,k'}} = \frac{f^{k,k''}}{f^{k,k'}} \frac{M^{k,k''}}{M^{k,k'}} \tag{D.7}$$

with:

$$\begin{aligned} \frac{f^{k,k''}}{f^{k,k'}} &= \frac{A^{k,k''}}{A^{k,k'}} \\ &= \frac{\sum_{l=\theta(k,k'')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}}{\sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}}} < 1 \end{aligned} \tag{D.8}$$

Thus, the budget constraint decreases relatively more the attractiveness of the most costly destinations compared to the less costly ones.

D.2 Derivatives of the bilateral migration rate with budget constraint with respect to bilateral migration costs

D.2.1 Derivatives of the individual probabilities

We know that the probability to migrate from country k toward country k' is:

$$p_{BC}^{k,k'} = A^{k,k'} e^{W^{k,k'} - C^{k,k'}} \tag{D.9}$$

where:

$$A^{k,k'} = \sum_{l=\theta(k,k')}^{P} \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} = \sum_{l=\theta(k,k')}^{P} \Psi^{k,l} \tag{D.10}$$

with:

$$\Psi^{k,l} = \frac{\Phi\left[C^{k,\kappa(k,l+1)}\right] - \Phi\left[C^{k,\kappa(k,l)}\right]}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \tag{D.11}$$

We first need to calculate the derivative of $A^{k,k'}$ with respect to any cost $C^{k,j}$. Differentiating $\Psi^{k,l}$, we get:

- If $l < \theta(k,j) - 1$, then $\forall q \leq l,\ \kappa(k,q) \neq j$ and:

$$\frac{1}{\Psi^{k,l}} \frac{\partial \Psi^{k,l}}{\partial C^{k,j}} = 0 \tag{D.12}$$

- If $l = \theta(k,j) - 1$ (or, equivalently, $\kappa(k,l+1) = j$), then:

$$\frac{1}{\Psi^{k,l}} \frac{\partial \Psi^{k,l}}{\partial C^{k,j}} = \frac{1}{\Psi^{k,\theta(k,j)-1}} \frac{\partial \Psi^{k,\theta(k,j)-1}}{\partial C^{k,j}} = \frac{\Phi'\left(C^{k,j}\right)}{\Phi\left(C^{k,j}\right) - \Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} \tag{D.13}$$

- If $l = \theta(k,j)$ (or, equivalently, $\kappa(k,l) = j$), then:

$$\begin{aligned}\frac{1}{\Psi^{k,l}} \frac{\partial \Psi^{k,l}}{\partial C^{k,j}} = & \frac{1}{\Psi^{k,\theta(k,j)}} \frac{\partial \Psi^{k,\theta(k,j)}}{\partial C^{k,j}} = \frac{e^{W^{k,j} - C^{k,j}}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \\ & - \frac{\Phi'\left(C^{k,j}\right)}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\} - \Phi\left(C^{k,j}\right)}\end{aligned} \tag{D.14}$$

- If $l > \theta(k,j)$, then $\exists\, q < l \; s.t. \; \kappa(k,q) = j$ and:

$$\frac{1}{\Psi^{k,l}} \frac{\partial \Psi^{k,l}}{\partial C^{k,j}} = \frac{e^{W^{k,j} - C^{k,j}}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \tag{D.15}$$

Then, knowing that:

$$\frac{\partial A^{k,k'}}{\partial C^{k,j}} = \sum_{l=\theta(k,k')}^{P} \frac{\partial \Psi^{k,l}}{\partial C^{k,j}} \tag{D.16}$$

we get:

- If $j = k'$, then:

$$\begin{aligned} \frac{\partial A^{k,k'}}{\partial C^{k,k'}} = & \sum_{l=\theta(k,k')}^{P} \frac{e^{W^{k,k'} - C^{k,k'}} \Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \\ & - \frac{\Phi'\left(C^{k,k'}\right) \Psi^{k,\theta\left(k,k'\right)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,k')+1]}\right\} - \Phi\left(C^{k,k'}\right)} \end{aligned} \tag{D.17}$$

- If $\theta(k,j) < \theta(k,k')$, then:

$$\frac{\partial A^{k,k'}}{\partial C^{k,j}} = \sum_{l=\theta(k,k')}^{P} \frac{e^{W^{k,j} - C^{k,j}} \Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} > 0 \tag{D.18}$$

- If $\theta(k,j) > \theta(k,k')$, then:

$$\begin{aligned} \frac{\partial A^{k,k'}}{\partial C^{k,j}} = & \frac{\Phi'\left(C^{k,j}\right) \Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right) - \Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} \\ & - \frac{\Phi'\left(C^{k,j}\right) \Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\} - \Phi\left(C^{k,j}\right)} \\ & + \sum_{l=\theta(k,j)}^{P} \frac{e^{W^{k,j} - C^{k,j}} \Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} > 0 \end{aligned} \tag{D.19}$$

the positive sign coming from the following equality:

$$\begin{aligned} & \frac{\Phi'\left(C^{k,j}\right) \Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right) - \Phi\left(C^{k,\kappa(k,\theta(k,j)-1)}\right)} - \frac{\Phi'\left(C^{k,j}\right) \Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\} - \Phi\left(C^{k,j}\right)} \\ & = \Phi'\left(C^{k,j}\right) \left[\frac{1}{\sum_{l=1}^{\theta(k,j)-1} e^{W^{k,\kappa(k,t)} - C^{k,\kappa(k,t)}}} - \frac{1}{\sum_{l=1}^{\theta(k,j)} e^{W^{k,\kappa(k,t)} - C^{k,\kappa(k,t)}}} \right] > 0 \end{aligned} \tag{D.20}$$

Since $p_{BC}^{k,k'} = A^{k,k'} e^{W^{k,k'} - C^{k,k'}}$, we get:

$$\frac{\partial p_{BC}^{k,k'}}{\partial C^{k,j}} = \frac{\partial A^{k,k'}}{\partial C^{k,j}} e^{\left(W^{k,k'} - C^{k,k'}\right)} > 0 \, \forall j \neq k' \tag{D.21}$$

$$\frac{\partial p_{BC}^{k,k'}}{\partial C^{k,k'}} = \left(\frac{\partial A^{k,k'}}{\partial C^{k,k'}} - A^{k,k'} \right) e^{\left(W^{k,k'} - C^{k,k'}\right)} < 0 \tag{D.22}$$

because:

$$\begin{aligned} \frac{\partial A^{k,k'}}{\partial C^{k,k'}} - A^{k,k'} = & - \sum_{l=\theta(k,k')}^{P} \left[1 - \frac{e^{W^{k,k'} - C^{k,k'}}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)} - C^{k,\kappa(k,q)}}} \right] \Psi^{k,l} \\ & - \frac{\Phi'\left(C^{k,k'}\right) \Psi^{k,\theta\left(k,k'\right)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,k')+1]}\right\} - \Phi\left(C^{k,k'}\right)} < 0 \end{aligned} \tag{D.23}$$

D.2.2 Derivatives of the bilateral migration rate

The bilateral migration rate between country k and country k' is given by:

$$M_{BC}^{k,k'} = \frac{p_{BC}^{k,k'}}{p_{BC}^{k,k}} \tag{D.24}$$

Thus:

$$\frac{1}{M_{BC}^{k,k'}} \frac{\partial M_{BC}^{k,k'}}{\partial C^{k,j}} = \frac{1}{p_{BC}^{k,k'}} \frac{\partial p_{BC}^{k,k'}}{\partial C^{k,j}} - \frac{1}{p_{BC}^{k,k}} \frac{\partial p_{BC}^{k,k}}{\partial C^{k,j}} \tag{D.25}$$

For $j = k'$, we know that $\frac{\partial p_{BC}^{k,k'}}{\partial C^{k,k'}} < 0$ and $\frac{\partial p_{BC}^{k,k}}{\partial C^{k,k'}} > 0$, so that:

$$\frac{1}{M_{BC}^{k,k'}} \frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} = \frac{1}{p_{BC}^{k,k'}} \frac{\partial p_{BC}^{k,k'}}{\partial C^{k,k'}} - \frac{1}{p_{BC}^{k,k}} \frac{\partial p_{BC}^{k,k}}{\partial C^{k,k'}} < 0 \tag{D.26}$$

and thus $\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,k'}} < 0$. Increasing the migration cost $C^{k,k'}$ decreases the probability to move from country k to country k' and increases the probability to stay in country k, in turn decreasing the migration rate from country k to country k'.

For $j \neq k'$, knowing that $p_{BC}^{k,k'} = A^{k,k'} e^{W^{k,k'} - C^{k,k'}}$, we get:

$$\frac{1}{M_{BC}^{k,k'}} \frac{\partial M_{BC}^{k,k'}}{\partial C^{k,j}} = \frac{1}{A^{k,k'}} \frac{\partial A^{k,k'}}{\partial C^{k,j}} - \frac{1}{A^{k,k}} \frac{\partial A^{k,k}}{\partial C^{k,j}} \tag{D.27}$$

- If $\theta(k,j) > \theta(k,k')$, which means that $C^{k,j} > C^{k,k'}$, then from equation (D.19) we get:

$$\begin{aligned}\frac{\partial A^{k,k}}{\partial C^{k,j}} = \frac{\partial A^{k,k'}}{\partial C^{k,j}} =& \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right) - \Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} \\ &- \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\} - \Phi\left(C^{k,j}\right)} \\ &+ \sum_{l=\theta(k,j)}^{P} \frac{e^{W^{k,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} > 0 \end{aligned} \tag{D.28}$$

so that:

$$\frac{1}{M_{BC}^{k,k'}}\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,j}} = \left(\frac{1}{A^{k,k'}} - \frac{1}{A^{k,k}}\right)\frac{\partial A^{k,k}}{\partial C^{k,j}} > 0 \tag{D.29}$$

because:

$$0 < A^{k,k'} = \sum_{l=\theta(k,k')}^{P} \Psi^{k,l} < \sum_{l=1}^{P} \Psi^{k,l} = A^{k,k} \tag{D.30}$$

- If $\theta(k,j) < \theta(k,k')$, which means that $C^{k,j} < C^{k,k'}$, then from equations D.18 and D.19, we get:

$$\frac{\partial A^{k,k'}}{\partial C^{k,j}} = \sum_{l=\theta(k,k')}^{P} \frac{e^{W^{k,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} \tag{D.31}$$

and:

$$\begin{aligned}\frac{\partial A^{k,k}}{\partial C^{k,j}} =& \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right) - \Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} \\ &- \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\} - \Phi\left(C^{k,j}\right)} \\ &+ \sum_{l=\theta(k,j)}^{P} \frac{e^{W^{kj}-C^{kj}}\Psi^{k,l}}{\sum_{q=1}^{l} e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} \end{aligned} \tag{D.32}$$

so that:

$$\begin{aligned}\frac{1}{M_{BC}^{k,k'}}\frac{\partial M_{BC}^{k,k'}}{\partial C^{k,j}} =& \frac{1}{A^{k,k'}}\sum_{l=\theta\left(k,k'\right)}^{P}\frac{e^{W^{k,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l}e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} - \frac{1}{A^{kk}}\sum_{l=\theta(k,j)}^{P}\frac{e^{W^{k,,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l}e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} \\ &- \frac{1}{A^{k,k}}\left(\frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right)-\Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} - \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\}-\Phi\left(C^{k,j}\right)}\right) \\ =& \left(\frac{1}{A^{k,k'}}-\frac{1}{A^{k,k}}\right)\sum_{l=\theta\left(k,k'\right)}^{P}\frac{e^{W^{k,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l}e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} \\ &- \frac{1}{A^{k,k}}\sum_{l=\theta(k,j)}^{\theta\left(k,k'\right)-1}\frac{e^{W^{k,j}-C^{k,j}}\Psi^{k,l}}{\sum_{q=1}^{l}e^{W^{k,\kappa(k,q)}-C^{k,\kappa(k,q)}}} - \frac{1}{A^{kk}} \\ &\left(\frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)-1}}{\Phi\left(C^{k,j}\right)-\Phi\left\{C^{k,\kappa[k,\theta(k,j)-1]}\right\}} - \frac{\Phi'\left(C^{k,j}\right)\Psi^{k,\theta(k,j)}}{\Phi\left\{C^{k,\kappa[k,\theta(k,j)+1]}\right\}-\Phi\left(C^{k,j}\right)}\right) \end{aligned} \tag{D.33}$$

which is uncertain in sign, as the first term is positive while the second and third terms are both negative.

D.3 European migration policies in 2007 for the 25 studied countries

	Schengen members (a)	**Restrictions implemented toward new member states**
Old EU member states		
Austria	x	x
Belgium	x	x
Denmark	x	x
Finland	x	
France	x	x
Germany	x	x
Greece	x	
Ireland		
Italy	x	
the Netherlands	x	
Portugal	x	
Spain	x	
Sweden	x	
the United Kingdom		
Other European countries (not in the EU)		
Norway	x	x
Switzerland		
New EU member states (b)		
Cyprus		
Czech Republic		
Estonia		
Hungary		
Latvia		
Lithuania		
Poland		
Slovakia		
Slovenia		

(a) Schengen agreement implemented before December 2007.
(b) Enlargement wave of 2004.

Table D.1.: European agreements and restrictions implemented toward new member states in 2007

D.4 Availability of immigration data for 2008

Reporting country	Data source	Residency criterion	Available origin countries	Note
Austria	UNPD	more than 3 months	Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	(a)
Belgium	no data available			
Cyprus	UNPD	more than 1 year	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
Czech Republic	UNPD	permanent	Austria, Belgium, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
Denmark	UNPD	more than 6 months	Austria, Belgium, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	(a)
Estonia	UNPD	more than 1 year	Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland	
Finland	UNPD	more than 1 year	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	(a)
France	UNPD	more than 1 year	Switzerland	
Germany	UNPD	no minimum duration	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
Greece	no data available			
Hungary	UNPD	more than 3 months	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland	
Ireland	OECD	no minimum duration	the United Kingdom	
Italy	UNPD	more than 1 year	France, Germany, Poland, Switzerland	
Latvia	UNPD	more than 1 year	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
Lithuania	UNPD	more than 6 months	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
The Netherlands	UNPD	other criterion	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	
Norway	UNPD	more than 6 months	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland	(a)
Poland	UNPD	permanent	Austria, Belgium, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Slovakia, Spain, Sweden, Switzerland	(a)

Portugal	UNPD	permanent	France, Germany, Spain	
Slovakia	UNPD	permanent	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland	
Slovenia	UNPD	more than 1 year	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland	
Spain	UNPD	no minimum duration	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Sweden, Switzerland	
Sweden	UNPD	more than 1 year	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Switzerland	(a)
Switzerland	UNPD	more than 1 year	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden	(a)
The United Kingdom	OECD	more than 1 year	Germany, Italy, Poland	

(a) A zero indicates that the value is zero, not available or not applicable. Therefore, we replaced zeros by missing values.

Table D.2.: Availability of immigration flows of foreign citizens by reporting country in 2008

D.5 Robustness checks

source	destination	Baseline simulation		Scenario 2			Scenario 3		
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
country k	country k'	$C_0^{k,k'}$	$M_0^{k,k'}$	$C_2^{k,k'}$	$M_2^{k,k'}$	$\frac{M_2^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$	$C_3^{k,k'}$	$M_3^{k,k'}$	$\frac{M_3^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$
FRA	FRA	0	1	0	1	0	0	1	0
BEL	FRA	36,402	1.77e-02	36,402	1.77e-02	0	36,402	1.77e-02	0
DEU	FRA	138,579	6.81e-07	138,579	6.81e-07	0	138,579	6.81e-07	0
GBR	FRA	141,758	6.55e-07	141,758	6.55e-07	0	141,758	6.55e-07	0
CHE	FRA	149,379	7.10e-08	149,379	7.10e-08	0	149,379	7.10e-08	0
ESP	FRA	150,984	3.77e-07	150,984	3.77e-07	0	150,984	3.77e-07	0
NLD	FRA	159,110	5.58e-08	159,110	5.58e-08	0	159,110	5.58e-08	0
PRT	FRA	166,008	1.75e-07	166,008	1.75e-07	0	166,008	1.75e-07	0
IRL	FRA	176,486	6.68e-09	176,486	6.68e-09	0	176,486	6.68e-09	0
DNK	FRA	177,074	9.61e-09	177,074	9.61e-09	0	177,074	9.61e-09	0
SWE	FRA	195,706	1.87e-09	195,706	1.87e-09	0	195,706	1.87e-09	0
NOR	FRA	207,874	5.41e-11	207,874	5.41e-11	0	207,874	5.41e-11	0
ITA	FRA	239,009	4.24e-11	239,009	4.24e-11	0	239,009	4.24e-11	0
AUT	FRA	240,583	1.86e-11	240,583	1.86e-11	0	240,583	1.86e-11	0
FIN	FRA	249,173	9.28e-12	249,173	9.28e-12	0	249,173	9.28e-12	0
CZE	**FRA**	**256,150**	**1.89e-11**	**225,531**	**4.05e-10**	**2.04e+01**	**225,531**	**4.05e-10**	**2.04e+01**
CYP	FRA	270,716	2.50e-12	270,716	2.50e-12	0	270,716	2.50e-12	0
HUN	**FRA**	**276,832**	**4.00e-12**	**246,214**	**8.54e-11**	**2.04e+01**	**246,214**	**8.54e-11**	**2.04e+01**
SVN	**FRA**	**279,330**	**1.36e-12**	**248,712**	**2.90e-11**	**2.04e+01**	**248,712**	**2.90e-11**	**2.04e+01**
POL	**FRA**	**280,951**	**3.52e-12**	**250,333**	**7.53e-11**	**2.04e+01**	**250,333**	**7.53e-11**	**2.04e+01**
SVK	**FRA**	**288,745**	**9.27e-13**	**258,126**	**1.98e-11**	**2.04e+01**	**258,126**	**1.98e-11**	**2.04e+01**
EST	**FRA**	**290,754**	**6.76e-13**	**260,135**	**1.44e-11**	**2.04e+01**	**260,135**	**1.44e-11**	**2.04e+01**
GRC	FRA	297,080	2.04e-13	297,080	2.04e-13	0	297,080	2.04e-13	0
LVA	**FRA**	**297,695**	**4.04e-13**	**267,077**	**8.63e-12**	**2.04e+01**	**267,077**	**8.63e-12**	**2.04e+01**
LTU	**FRA**	**300,622**	**3.09e-13**	**270,004**	**6.61e-12**	**2.04e+01**	**270,004**	**6.61e-12**	**2.04e+01**

Table D.3.: Migration rates toward France derived from the standard RUM model – robustness tests

source country k	destination country k'	Baseline simulation (1) $C_0^{k,k'}$	(2) $M_0^{k,k'}$	Scenario 2 (3) $C_2^{k,k'}$	(4) $M_2^{k,k'}$	(5) $\frac{M_2^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$	Scenario 3 (6) $C_3^{k,k'}$	(7) $M_3^{k,k'}$	(8) $\frac{M_3^{k,k'}-M_0^{k,k'}}{M_0^{k,k'}}$
SVK	SVK	0	1	0	1	0	0	1	0
SVK	CZE	136,588	1.49e-06	136,588	1.49e-06	0	136,588	1.49e-06	0
SVK	AUT	193,479	2.43e-08	193,479	2.43e-08	0	158,325	8.18e-07	3.26e+01
SVK	HUN	218,495	2.47e-10	218,495	2.47e-10	0	218,495	2.47e-10	0
SVK	DEU	220,322	1.22e-09	220,322	1.22e-09	0	193,780	1.74e-08	1.32e+01
SVK	SVN	227,952	2.20e-10	227,952	2.20e-10	0	227,952	2.20e-10	0
SVK	NLD	234,592	4.59e-10	234,592	4.59e-10	0	234,592	4.59e-10	0
SVK	ITA	252,752	3.33e-11	252,752	3.33e-11	0	252,752	3.33e-11	0
SVK	POL	254,800	4.93e-12	254,800	4.93e-12	0	254,800	4.93e-12	0
SVK	CHE	257,163	1.00e-10	257,163	1.00e-10	0	257,163	1.00e-10	0
SVK	SWE	259,812	2.83e-11	259,812	2.83e-11	0	259,812	2.83e-11	0
SVK	DNK	261,493	3.00e-11	261,493	3.00e-11	0	231,327	6.13e-10	1.94e+01
SVK	GBR	265,160	1.04e-11	265,160	1.04e-11	0	265,160	1.04e-11	0
SVK	BEL	271,756	7.50e-12	271,756	7.50e-12	0	249,652	6.84e-11	8.12e+00
SVK	LTU	272,805	1.30e-12	272,805	1.30e-12	0	272,805	1.30e-12	0
SVK	GRC	277,652	1.73e-12	277,652	1.73e-12	0	277,652	1.73e-12	0
SVK	FIN	281,950	2.97e-12	281,950	2.97e-12	0	281,950	2.97e-12	0
SVK	LVA	283,333	4.65e-13	283,333	4.65e-13	0	283,333	4.65e-13	0
SVK	FRA	288,745	9.27e-13	258,126	1.98e-11	2.04e+01	258,126	1.98e-11	2.04e+01
SVK	IRL	291,614	2.25e-12	291,614	2.25e-12	0	291,614	2.25e-12	0
SVK	EST	293,215	2.07e-13	293,215	2.07e-13	0	293,215	2.07e-13	0
SVK	NOR	297,716	6.55e-12	297,716	6.55e-12	0	275,671	5.94e-11	8.07e+00
SVK	CYP	311,281	6.80e-14	311,281	6.80e-14	0	311,281	6.80e-14	0
SVK	ESP	320,315	2.90e-14	320,315	2.90e-14	0	320,315	2.90e-14	0
SVK	PRT	344,185	1.28e-15	344,185	1.28e-15	0	344,185	1.28e-15	0

Table D.4.: Migration rates from Slovakia derived from the standard RUM model – robustness tests

source country k	destination country k'	Baseline simulation (1) $C_0^{k,k'}$	(2) $\theta_0(k,k')$	(3) $M_{0,BC}^{k,k'}$	Scenario 2 (4) $C_2^{k,k'}$	(5) $\theta_2(k,k')$	(6) $M_{2,BC}^{k,k'}$	(7) $\frac{M_{2,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$	Scenario 3 (8) $C_3^{k,k'}$	(9) $\theta_3(k,k')$	(10) $M_{3,BC}^{k,k'}$	(11) $\frac{M_{3,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$
FRA	FRA	0	1	1	0	1	1	0	0	1	1	0
ESP	FRA	134,367	2	7.38e-12	134,367	2	7.38e-12	0	134,367	2	7.38e-12	0
PRT	FRA	148,252	2	5.88e-13	148,252	2	5.88e-13	0	148,252	2	5.88e-13	0
BEL	FRA	32,340	3	2.00e-02	32,340	3	2.00e-02	0	32,340	3	2.00e-02	0
CHE	FRA	139,237	3	5.63e-11	139,237	3	5.63e-11	0	139,237	3	5.63e-11	0
DEU	FRA	125,968	5	8.87e-11	125,968	5	8.87e-11	0	125,968	5	8.87e-11	0
GBR	FRA	131,584	5	4.52e-11	131,584	5	4.52e-11	0	131,584	5	4.52e-11	0
ITA	FRA	218,228	5	2.23e-18	218,228	5	2.23e-18	0	218,228	5	2.23e-18	0
CZE	**FRA**	**235,749**	**7**	**3.24e-26**	**205,130**	**4**	**3.46e-25**	**9.68e+00**	**205,130**	**5**	**3.46e-25**	**9.68e+00**
IRL	FRA	163,497	7	6.14e-13	163,497	7	6.14e-13	0	163,497	7	6.14e-13	0
NLD	FRA	148,383	7	4.08e-13	148,383	7	4.08e-13	0	148,383	7	4.08e-13	0
DNK	FRA	160,442	8	4.62e-15	160,442	8	4.62e-15	0	160,442	8	4.62e-15	0
NOR	FRA	189,027	9	6.65e-16	189,027	9	6.65e-16	0	189,027	9	6.65e-16	0
SWE	FRA	176,304	9	2.01e-18	176,304	9	2.01e-18	0	176,304	9	2.01e-18	0
CYP	FRA	246,192	11	6.43e-23	246,192	11	6.43e-23	0	246,192	11	6.43e-23	0
AUT	FRA	221,310	14	8.40e-21	221,310	14	8.40e-21	0	221,310	15	8.40e-21	-1.92e-07
FIN	FRA	226,979	14	7.56e-22	226,979	14	7.56e-22	0	226,979	14	7.56e-22	0
HUN	**FRA**	**254,228**	**14**	**8.51e-27**	**223,610**	**5**	**1.82e-25**	**2.04e+01**	**223,610**	**5**	**1.82e-25**	**2.04e+01**
SVN	**FRA**	**259,029**	**16**	**2.30e-27**	**228,410**	**9**	**4.90e-26**	**2.04e+01**	**228,410**	**11**	**4.90e-26**	**2.04e+01**
GRC	FRA	271,862	17	1.44e-22	271,862	17	1.44e-22	0	271,862	17	1.44e-22	0
EST	**FRA**	**267,882**	**18**	**1.16e-24**	**237,263**	**12**	**3.43e-22**	**2.95e+02**	**237,263**	**14**	**3.43e-22**	**2.95e+02**
POL	**FRA**	**258,835**	**19**	**3.57e-27**	**228,216**	**7**	**9.92e-25**	**2.77e+02**	**228,216**	**9**	**9.92e-25**	**2.77e+02**
SVK	**FRA**	**267,167**	**19**	**1.78e-27**	**236,548**	**9**	**3.81e-26**	**2.04e+01**	**236,548**	**11**	**3.81e-26**	**2.04e+01**
LVA	**FRA**	**274,849**	**22**	**9.97e-25**	**244,231**	**12**	**2.35e-22**	**2.35e+02**	**244,231**	**14**	**2.35e-22**	**2.35e+02**
LTU	**FRA**	**277,533**	**23**	**4.08e-26**	**246,915**	**14**	**1.19e-23**	**2.91e+02**	**246,915**	**16**	**1.19e-23**	**2.91e+02**

Table D.5.: Migration rates toward France derived from the RUM model with BC – robustness tests

source country k	destination country k'	Baseline simulation (1) $C_0^{k,k'}$	(2) $\theta_0(k,k')$	(3) $M_{0,BC}^{k,k'}$	Scenario 2 (4) $C_2^{k,k'}$	(5) $\theta_2(k,k')$	(6) $M_{2,BC}^{k,k'}$	(7) $\frac{M_{2,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$	Scenario 3 (8) $C_3^{k,k'}$	(9) $\theta_3(k,k')$	(10) $M_{3,BC}^{k,k'}$	(11) $\frac{M_{3,BC}^{k,k'}-M_{0,BC}^{k,k'}}{M_{0,BC}^{k,k'}}$
SVK	SVK	0	1	1	0	1	1	0	0	1	1	0
SVK	CZE	125,374	2	6.59e-18	125,374	2	6.59e-18	0	125,374	2	6.59e-18	0
SVK	AUT	184,378	3	1.34e-23	184,378	3	1.34e-23	0	149,224	3	1.44e-20	1.08e+03
SVK	DEU	204,343	4	1.34e-24	204,343	4	1.34e-24	0	177,800	4	1.91e-23	1.32e+01
SVK	HUN	206,700	5	1.79e-25	206,700	5	1.79e-25	0	206,700	5	1.79e-25	-2.07e-06
SVK	SVN	214,759	6	1.83e-25	214,759	6	1.83e-25	0	214,759	7	1.83e-25	-2.02e-06
SVK	NLD	216,776	7	6.05e-25	216,776	7	6.05e-25	0	216,776	8	6.05e-25	-2.12e-06
SVK	ITA	233,148	8	5.26e-26	233,148	8	5.26e-26	0	233,148	10	5.26e-26	-1.99e-06
SVK	POL	238,833	9	5.40e-27	238,833	10	5.40e-27	0	238,833	12	5.40e-27	-2.07e-06
SVK	SWE	239,077	10	5.00e-26	239,077	11	5.00e-26	0	239,077	13	5.00e-26	-2.09e-06
SVK	CHE	240,749	11	1.15e-25	240,749	12	1.15e-25	0	240,749	14	1.15e-25	-2.04e-06
SVK	GBR	243,884	12	1.94e-26	243,884	13	1.94e-26	0	243,884	15	1.94e-26	-2.06e-06
SVK	DNK	244,096	13	3.80e-26	244,096	14	3.80e-26	0	213,930	6	7.75e-25	1.94e+01
SVK	BEL	252,368	14	1.16e-26	252,368	15	1.16e-26	0	230,264	9	1.06e-25	8.12e+00
SVK	LTU	254,766	15	1.75e-27	254,766	16	1.75e-27	0	254,766	17	1.75e-27	-2.09e-06
SVK	GRC	255,103	16	3.65e-27	255,103	17	3.65e-27	0	255,103	18	3.65e-27	-2.00e-06
SVK	FIN	258,818	17	6.68e-27	258,818	18	6.68e-27	0	258,818	19	6.68e-27	-2.08e-06
SVK	LVA	264,502	18	6.78e-28	264,502	19	6.78e-28	0	264,502	20	6.78e-28	-2.06e-06
SVK	FRA	267,167	19	1.78e-27	236,548	9	3.81e-26	2.04e+01	236,548	11	3.81e-26	2.04e+01
SVK	IRL	267,235	20	5.73e-27	267,235	20	5.73e-27	0	267,235	21	5.73e-27	-2.02e-06
SVK	EST	272,350	21	3.70e-28	272,350	21	3.70e-28	0	272,350	22	3.70e-28	-2.08e-06
SVK	NOR	275,280	22	1.37e-26	275,280	22	1.37e-26	0	253,236	16	1.24e-25	8.07e+00
SVK	CYP	284,689	23	2.16e-28	284,689	23	2.16e-28	0	284,689	23	2.16e-28	-2.12e-06
SVK	ESP	292,829	24	1.01e-28	292,829	24	1.01e-28	0	292,829	24	1.01e-28	-2.09e-06
SVK	PRT	313,901	25	5.86e-30	313,901	25	5.86e-30	0	313,901	25	5.86e-30	-2.05e-06

Table D.6.: Migration rates from Slovakia derived from the RUM model with BC – robustness tests

E Appendix to Chapter 6

E.1 Wage data

	2003	2004	2005
EU15 $(i\ ,\ j)$	39,776.1	40,765.9	41,501.5
low and middle income country group (k)	4,984.9	5,319.4	5,632.2

Table E.1.: Average GDP per capita in ppp (constant 2011 international dollars), World Bank (2015)

E.2 Initial parameter set

Environmental parameters

Space characteristics

space dimension in number of cells (width*height)		150*100
non-toric discrete space (the sides of the area are impervious walls)		

Characteristics of the developed area (country i and country j)

number of native individuals in the country		1,000
mean of the wage distribution at time $t-1$	μ^i_{t-1},μ^j_{t-1}	$\ln(41,501.5)$
mean of the wage distribution at time $t-2$	μ^i_{t-2},μ^j_{t-2}	0
persistence of wage variations over time	b^i,b^j	0
variance of the wage distribution	σ^i,σ^j	0.2
quota of visas		63
probability to reach the destination economy for an illegal migrant	p	0.9

Characteristics of the developing economy (country k)

number of native individuals in the country		1,000
mean of the wage distribution at time $t-1$	μ^k_{t-1}	$\ln(5,632.2)$
mean of the wage distribution at time $t-2$	μ^k_{t-2}	0
persistence of wage variations over time	b^k	0
variance of the wage distribution	σ^k	0.2
quota of visas		no quota
probability to reach the destination economy for an illegal migrant	p	0.9

Individual parameters

Migration decision

preference for the present*	α_n	0^+
fixed migration cost	c	0.1
weighting parameter for the informational cost	β	0.1
fixed illegal migration cost	c_i	0.1

Network patterns

range of the Moore neighbourhood		3
weight of a relationship at its creation	$\Omega_{nq,\,t}$	1
variation of a relationship over time	$\triangle_\Omega$	0.2

*We assume that individuals have a very low preference for the present because they anticipate a permanent migration. Thereby, when α_n approaches zero the limit of $\alpha_n \mathrm{C}^{ijm}_{n,\,t}$ approaches zero ($\lim_{\alpha_n \to 0^+} \alpha_n \mathrm{C}^{ijm}_{n,\,t} = 0^+$).

Table E.2.: Parameter set

E.3 Robustness test

As a robustness test, we perform a sensitivity analysis to look at what happens when the probability to succeed in crossing a border unlawfully changes. The probability is initially set to 90%. We analyse the changes induced by a gradual increase (decrease) to 95% (80%). Figure E.1 shows that the model is robust to a change in this parameter.

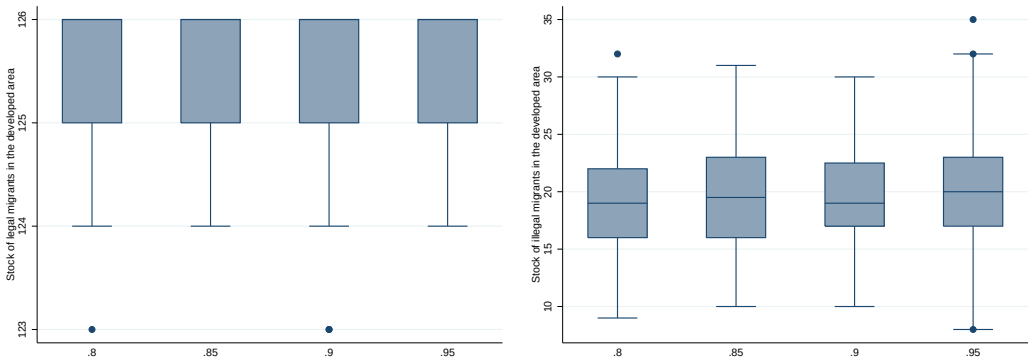

Figure E.1.: Illegal migration stocks in the developed area at the 50th period for different probabilities to succeed (100 simulations plotted for each scenario)

In addition to this visual control, we use a two-group mean-comparison t-test on the two extreme sub-samples of simulated data to determine whether or not there is a statistically significant difference between the two scenarios. We find a $p-$value higher than 0.05, thus we cannot conclude that there is a statistically significant difference between the two sub-samples ($p-$value $= 0.1413$).

E.4 Change in the immigration policy of country j when countries are in a row

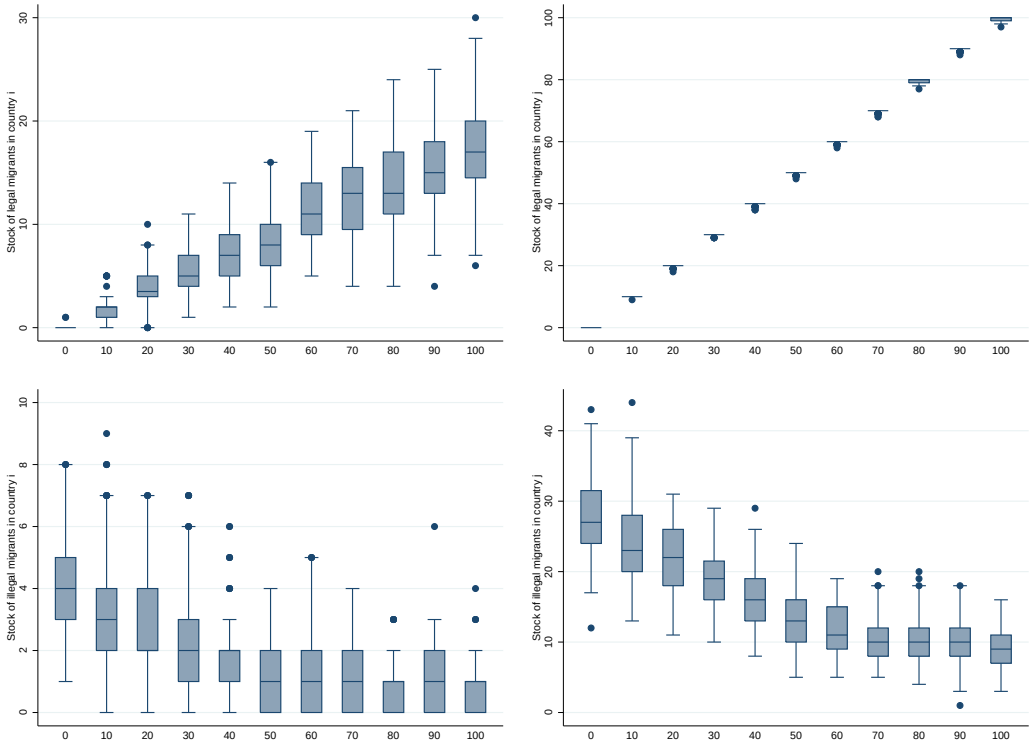

Figure E.2.: Migration stocks in the developed countries after 50 time periods, for different quotas implemented by country j (100 simulations plotted for each scenario)