UNIVERSITÉ LILLE 1
Lille, Economie et Management, UMR CNRS 8179
École Doctorale SESAM

Thèse en vue de l'obtention du Doctorat en Sciences de Gestion

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THE RELATION BETWEEN TECHNICAL EFFICIENCY AND STOCK RETURNS: EVIDENCE FROM THE US AIRLINE INDUSTRY

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soutenue le 6 décembre 2013

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Remerciements

Ce travail de recherche est le fruit d'une réflexion nourrie de l'échange et du soutien de personnes auxquelles je souhaite témoigner ma reconnaissance.

Je tiens en premier lieu à remercier mes Directeurs de Thèse Olivier Brandouy et Kristiaan Kerstens pour leurs conseils et leur confiance.

Je remercie tout particulièrement Stéphane Vanovermeir, Coordinateur du Pôle Revenue Management d'Air France, qui a permis d'enrichir l'analyse du secteur du transport aérien et de conforter les conclusions de la thèse.

Je remercie Albane, Benoit, David et Maxime, doctorants à l'IESEG, pour leurs encouragements.

Je remercie enfin ma femme, Valérie, qui a permis cet aboutissement. Le travail de recherche est parfois douloureux. Il nous confronte à nos propres limites et nous impose sans cesse de les surmonter. Son amour a été un moteur essentiel pour progresser. Sa présence m'a donné la confiance nécessaire pour avancer et surmonter les étapes les plus éprouvantes de cet exercice. Je lui en suis profondément reconnaissant.

J'ai bien entendu une pensée pour ma fille Eve qui a eu la patiente de laisser son papa travailler.

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Thèse de Matthieu Belarouci, Lille 1, 2013

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Résumé

Ce travail de recherche vise à explorer la relation entre deux mesures de performance: l'efficience technique et les rentabilités financières. Toutes deux relèvent de modélisations distinctes de l'entreprise et de son environnement.

L'efficience technique appréhende l'organisation comme une collection de facteurs de production physiques. Elle mesure la capacité de l'entreprise à maximiser son potentiel de production compte tenu de sa dotation factorielle. Ce potentiel est évalué par comparaison de l'entreprise à ses pairs les plus productifs dans son industrie. Ce processus d'évaluation est réalisé par les méthodes frontières. Ces dernières consistent à inférer, sur la base des observations, un référentiel des combinaisons les plus productives pour chaque niveau de production. Ce référentiel, qui représente la productivité maximale, peut être construit suivant le paradigme stochastique, fondé sur l'analyse de régression en éliminant l'effet du bruit blanc dans les mesures, ou suivant le paradigme déterministe notamment par la méthode d'enveloppement des données (DEA). Dans les deux cas, la distance entre la productivité de l'entreprise et celle spécifiée par le référentiel quantifie l'inefficience. Cette inefficience est une mesure de la qualité de la décision de production.

La rentabilité financière approche quant à elle l'organisation comme une collection d'actifs dont la productivité est mesurée par la magnitude et la régularité des flux monétaires qu'ils génèrent dans le temps. La théorie financière s'attache donc à maximiser et à fiabiliser le potentiel de valeur des entreprises. Là encore, aux mesures des rentabilités financières sont jointes des méthodologies permettant de quantifier le niveau de performance relativement à un référentiel qu'est la rentabilité moyenne espérée.

Alors que la finance mesure la performance du point de vue de la sélection des investissements, l'efficience technique focalise sur la capacité à mettre en oeuvre ces mêmes investissements. En revanche, les approches s'accordent sur la typologie des facteurs susceptibles d'affecter la performance. Chacune propose un cadre d'analyse permettant leurs différenciations en facteurs déterministes exogènes d'une part et en facteurs endogènes relevant de la volonté stratégique de la firme ou d'attributs spécifiques d'autre part.

Par le biais d'une application au secteur du transport civil aérien américain sur la période 1990-2012, la thèse met en évidence l'existence d'une relation statistique entre efficience technique, mesurée par la méthode DEA, et rentabilités. Nous observons que l'efficience technique, calculée sur la base des rapports officiels du Département du Transport Américain (US DOT), complète l'information comptable dans la valorisation des entreprises. En outre, la décomposition Hicks-Moorsteen et Färe-Primont de la productivité totale indique que les changements d'efficience technique sont associées aux rentabilités spécifiques. En revanche, les variations de la productivité issues de facteurs technologiques sont associés aux facteurs de risque systématique spécifiés par le modèle Fama-French-Carhart. La persistence de l'efficience technique au cours des cinq périodes consécutives suggère que l'amélioration de l'efficience entraine une réduction du risque systématique refletée par la réduction du coût des fonds propres exigés.

Mots clefs: performance, efficience technique, envelopment des donnés, DEA, aviation, aérien, majors, transporteurs, USA, rentabilités, spécifique, systématique, MEDAF, value relevance, productivité, Malmquist, Hicks-Moorsteen, Färe-Primont

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Abstract

This investigation explores the relation between two performance measures: technical efficiency and stock returns. Both rely on distinct modeling of the firms and of their environment. Technical efficiency approaches the firm as a collection of input and output. It measures the extent to which the firm is able to maximize its production potential with respect to the technical constraints. Regarding its construction, technical efficiency contains information about the productive performance of the firm and its competitors. In addition, the modeling of the firm implied by technical efficiency is joined with its computational methods. The formalization of the technical constraints and the nature of the score depend on the specification of the Data Envelopment Analysis (DEA) model. Based on a deterministic paradigm, DEA models do not maintain any strong assumptions about the environment of the firm nor on the structure of the production technology.

By contrast, the expected stock return approaches the firm as a collection of assets producing a stream of cash-flows to shareholders. It measures the ability of the firm at maximizing the value potential of assets. The hurdle potential is generally inferred from the expected relation between the returns of the firm and the changes in industry and common market factors. These common factors represent measures of risks that cannot be diversified by investors. The realized performance of the firm is assessed by the amount of cash-flows per unit of risk incurred by the activity. The greater these cash-flows per unit of risk are, the greater the ability of the firm is at outperforming despite adverse market conditions. Again, the modeling of the firm and its environment implied by the measurement of the expected return is joined with the estimation method and with the Efficient Market Hypothesis.

Technical efficiency and stock returns are complementary measures. While the abnormal returns - that is to say, the difference between the expected and the realized returns - measures the ability of the management at picking investment projects efficiently, technical efficiency focuses on the managerial ability at implementing these investment projects. In addition, both recognize that the performance of the firm ensues from the exposure to common exogenous factors and from the management strategy specific to each firm. They propose in both cases a decomposition of the performance in pure managerial effects and exogenous effects.

Through an application on the US airline industry over the period 1990-2012, the study reveals the value relevance of technical efficiency in stock valuation. In addition, the analysis of the Total Factor Productivity (TFP) decompositions based on Hicks-Moorsteen and Färe-Primont indicates that the effect of efficiency information on returns is twofold. First, the changes in pure technical efficiency are related to the firms-specific returns. Next, technological change is associated with the variance of returns explained by systematic risks estimated with the Fama-French-Carhart model. Moreover, technological changes are positively related to stock returns, while technical efficiency is negatively related. Given technical efficiency is persistent over the five consecutive years, results suggest that improvements in technical efficiency imply the reduction in the firm's exposure to systematic risk. It results a reduction in the firms' required rate of returns.

Keywords: technical efficiency, data envelopment analysis, DEA, US airline, stock returns, valuation, value relevance, specific risk, systematic risk, total factor productivity, TFP, Malmquist, Hicks-Moorsteen, Färe-Primont

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Résumé de la Thèse

L'efficience est un facteur clef de la pérennité et de la rentabilité des entreprises. Supposée immanente par les sciences économiques, la recherche de l'efficience technique devient de plus en plus pressante. L'évolution démographique mondiale combinée à la raréfaction des ressources et à la nécessité de réduction des externalités négatives de l'activité humaine sur l'environnement, fait de l'amélioration qualitative des processus productifs un impératif. Du point de vue des entreprises, ces modifications se traduisent mécaniquement par l'augmentation de la valeur des intrants et la nécessité de réduire les gaspillages pour demeurer pérennes.

Pourtant, les mesures traditionnelles de la productivité restent insuffisantes pour orienter les décisions compte tenu des enjeux actuels. A cet égard, la recherche opérationnelle a développé des méthodes d'évaluation de la performance à même d'intégrer les enjeux et contraintes auxquelles sont soumises les organisations. Ces méthodes, telles que l'enveloppement des données, permettent la mesure de l'efficience technique. L'efficience technique permet d'apprécier la productivité d'une entreprise relativement à la productivité des meilleures entreprises de son secteur. En outre, elles intègrent dans l'évaluation les différences de taille des organisations, leur structure de coûts, la production d'outputs négatifs (e.g. les émissions de polluants) et permettent la décomposition des sources de la performance en facteurs endogènes et exogènes.

Au regard de leur capacité à rendre compte des spécificités des conditions de production, il nous paraît intéressant de tester si leur usage constitue un avantage pour l'évaluation financière. De plus, la démonstration de la capacité de ces outils à prévoir les rentabilités financières est un vecteur de leur diffusion. Si affirmer l'existence d'un lien fort entre productivité et création de valeur peut sembler relever du truisme, il est étonnant de constater que la relation entre les décisions de production et les décisions d'investissement, en particulier de portefeuille, est relativement peu abordée en théorie financière. Cette relation, telle qu'elle est décrite dans les modèles d'équilibre des actifs financiers, n'autorise pas l'existence d'inefficiences productives si elles ne sont issues d'externalités de l'incertitude. Cette modélisation, certes accommodante sur le plan de la résolution des optima, est cependant inappropriée pour rendre compte d'une réalité où l'inefficience productive est le modèle dominant de l'économie (Leibenstein, 1966).

Pourtant, de ces modèles d'équilibre ont été dérivés des outils prescriptifs pour l'aide à la décision d'investissement productif dans l'entreprise. Ces outils financiers ont pour objectif l'orientation des décisions vers la maximisation de la valeur de la firme. Force est de constater, néanmoins, que la décision de l'investissement productif est d'ordre technique et aurait dû être traitée dans le cadre d'analyse de la recherche opérationnelle plutôt que dans celui de la finance. Aussi, rien n'indique que les décisions prises suivant l'une et l'autre approche convergent. Par conséquent, il n'est pas non plus permis d'affirmer qu'en dehors des modèles d'équilibre, la recherche de l'efficience technique contribue

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systématiquement à la maximisation de la valeur de la firme. Analyser le lien entre efficience technique et rentabilités financières consiste donc à tester si la recherche de l'efficience technique converge bien vers la maximisation de la valeur de la firme.

L'efficience technique appréhende l'organisation comme une collection de facteurs de production physiques. Elle mesure la capacité de l'entreprise à maximiser son potentiel de production compte tenu de sa dotation factorielle. Ce potentiel est évalué par comparaison de l'entreprise à ses pairs les plus productifs dans son industrie. Ce processus d'évaluation est réalisé par les méthodes frontières. Ces dernières consistent à inférer, sur la base des observations, un référentiel des combinaisons les plus productives pour chaque niveau de production. Ce référentiel, qui représente la productivité maximale, peut être construit suivant le paradigme stochastique, fondé sur l'analyse de régression en éliminant l'effet du bruit blanc dans les mesures, ou suivant le paradigme déterministe notamment par la méthode d'enveloppement des données (DEA). Dans les deux cas, la distance entre la productivité de l'entreprise et celle spécifiée par le référentiel quantifie l'inefficience. Cette inefficience est une mesure de la qualité de la décision de production.

La rentabilité financière approche quant à elle l'organisation comme une collection d'actifs dont la productivité est mesurée par la magnitude et la régularité des flux monétaires qu'ils génèrent dans le temps. La théorie financière s'attache donc à maximiser et à fiabiliser le potentiel de valeur des entreprises. Là encore, aux mesures des rentabilités financières sont jointes des méthodologies permettant de quantifier le niveau de performance relativement à un référentiel qu'est la rentabilité moyenne espérée.

Efficience technique et rentabilités financières sont deux mesures de performance qui relèvent de modélisations distinctes de l'activité des entreprises et de leur environnement. Alors que la finance mesure la performance du point de vue de la sélection des investissements, l'efficience technique focalise sur la capacité à mettre en oeuvre ces mêmes investissements. En revanche, les approches s'accordent sur la typologie des facteurs susceptibles d'affecter la performance. Chacune propose un cadre d'analyse permettant leurs différenciations en facteurs déterministes exogènes d'une part et en facteurs endogènes relevant de la volonté stratégique de la firme ou d'attributs spécifiques d'autre part.

Si certaines études empiriques ont déjà démontrées un lien entre les deux mesures de performance, notamment le lien entre rentabilité et profitabilité qui intègre implicitement le niveau d'efficience technique, la nature de leur relation reste obscure. La thèse porte sur la nature de cette relation, les conditions qui induisent son changement et les méthodologies les mieux appropriées pour en rendre compte. Elle présente et compare la production d'indicateurs d'efficience à destination de l'analyse financière. Elle démontre notamment l'utilité pratique des indicateurs issus des méthodes frontières pour l'analyse financière.

Ce travail présente des intérêts théoriques, méthodologiques et empiriques. D'un point de vue théorique, l'analyse de la relation entre efficience technique et valorisation boursière s'inscrit dans le débat sur la déconnexion des valeurs de marché aux réalités internes des firmes. Ce débat se traduit sur le plan empirique par la dichotomie entre l'analyse fondamentale et l'analyse technique. L'analyse fondamentale a pour objectif la détermination de la valeur intrinsèque de la firme à moyen et long terme. Elle repose essentiellement sur l'examen des états financiers, de la structure de l'industrie et des informations diffusées par l'entreprise sur ses opportunités d'investissements. L'analyse technique focalise quant à elle sur l'étude des comportements statistiques des séries de rentabilités passées. Elle

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consiste en la détermination des lois de probabilité qui gouvernent les rentabilités pour en déduire l'évolution future. Cette approche, orientée vers le court terme, est en opposition avec l'approche académique. En analysant la pertinence de l'efficience technique et de ses composants dans l'évaluation financière, nous nous inscrivons dans le cadre de l'analyse fondamentale.

Cette étude s'attache dans le même temps à démontrer le contenu informationnel des indicateurs issus des méthodes frontières. Roll (1988) a mis en évidence que les informations publiques et privées ont des effets différents sur les modèles de rentabilités. Les informations publiques sont associées à la synchronicité des rentabilités alors que les informations privées correspondent à la part des rentabilités spécifiques. Par construction, l'efficience technique est vectrice de ces deux types d'information. Par le biais des techniques de décomposition de la productivité, nous précisons la relation entre efficience technique et rentabilités financières.

Enfin, la comparaison des indicateurs d'efficience aux informations comptables permet de nous conforter dans leur apport à l'analyse financière. L'étude de la relation dans un secteur marqué par l'occurrence d'évènements adverses et de fortes irrégularités dans les résultats d'exploitations permet de démontrer que l'efficience et les informations non-financières associées sont des compléments utiles lorsque les conditions d'analyse comptable de la performance opérationnelle ne sont pas rencontrées. En ce sens, ma thèse contribue à la recherche en comptabilité orientée vers la production d'information à destination du marché financier.

D'un point de vue méthodologique ce travail met en évidence les designs de recherche les mieux appropriés pour la prévision des rentabilités. Par une réflexion sur la manière dont l'efficience doit être calculée pour correspondre aux problématiques financières ainsi que le test de spécifications alternatives. La signification du score d'efficience diffère selon les données utilisées, le traitement du panel, l'horizon temporel choisi, le paradigme méthodologique employé et la spécification des contraintes auxquelles sont soumises les firmes. Le choix de ces paramètres dépend de l'objectif de l'utilisateur. De plus, la confrontation des paradigmes méthodologiques de l'analyse frontière renforce la validité des résultats et fournit une vision plus complète de la performance.

Enfin, deux méthodes de décomposition de l'efficience technique par les indices de productivité sont introduites : le Hicks-Moorsteen et le Färe-Primont. Contrairement aux méthodes de décomposition plus populaires telles que le Malmquist, ces mesures fournissent une évaluation complète de la productivité et échappent aux biais associés aux rendements d'échelle. La décomposition qu'ils proposent est en outre claire et non-ambiguë. Hicks-Moorsteen et Färe-Primont diffèrent dans la sélection du référentiel pour mesurer l'efficience. Le Hicks-Moorstens mesure l'efficience en référence à l'entreprise la plus productive du secteur. En revanche, le Färe-Primont analyse et décompose l'efficience relativement à une entreprise sélectionnée arbitrairement. L'intérêt de cette dernière approche et de permettre de différencier la performance relative de deux entreprises dont les configurations diffèrent fortement mais ayant une équifinalité.

D'un point de vue empirique, la thèse a un intérêt à la fois pour l'analyse du secteur du transport aérien américain mais aussi pour le gain potentiel associé à la mise en oeuvre des méthodes frontières dans l'analyse financière. La détermination de l'efficience technique requiert la connaissance des quantités physiques utilisées par les entreprises pour effectuer leur activité de production. Force est de constater que cette information n'est généralement pas diffusée par les entreprises. L'efficience technique est donc généralement approchée par la décomposition des valeurs comptables en quantités physiques à l'aide

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d'indices des prix sectoriels. En travaillant sur les rapports officiels du Ministère du Transport Américain, les données sur les quantités physiques réellement employées par les transporteurs ont pu être collectées. Les mesures d'efficience technique proposées dans cette étude sont en conséquence plus précises que dans la plupart des contributions.

En outre, l'analyse de l'efficience des transporteurs aériens américains mérite un renouvellement. Les études sur ce terrain portent sur des échantillons dont les plus récent s'arrêtent en 1991. L'échantillon des majors proposé ici couvre la période 1990-2012.

Par ailleurs, l'étude de la relation entre l'efficience par les méthodes d'enveloppement des données et les rentabilités financières permet un gain de productivité significatif dans le processus d'évaluation. Alors que l'évaluation financière implique de traiter une grande quantité d'information sur l'entreprise et son environnement, la méthode DEA les synthétise en un seul indicateur et fournit un classement des entreprises au regard de leur performance reflétant des écarts de valorisation. En ce sens, la méthode DEA est analogue à la méthode des comparables en finance mais implique une grande économie de moyen. En tant que méthode des comparables, une analyse DEA permet de faciliter la valorisation des firmes non-cotées.

Les premiers résultats ont été apportés par la revue de littérature des contributions empiriques sur le thème de la relation entre efficience technique et création de valeur actionnariale. Cette analyse contribue à caractériser cette relation. Cette étude fait état d'une relation plus complexe que celle établie par les modèles d'équilibre des actifs financiers :

- En premier lieu, les études empiriques confirment la relation bidirectionnelle établie par la théorie de l'équilibre. En outre, le changement comme le niveau d'efficience, qui quantifie le déficit potentiel ou existant de productivité, sont fortement corrélés aux valorisations et rentabilités boursières.

- Les tests sur la relation entre l'efficience mesurée sur les périodes antérieures et les rentabilités présentes observées indiquent l'existence d'un effet persistent de l'efficience sur les rentabilités. L'effet peut persister sur plusieurs années consécutives et concerne les niveaux et changements d'efficience. L'analyse des séries temporelles des scores d'efficience indiquent une autocorrélation des scores d'efficience dans le temps. L'information fournie par les indicateurs est donc récurrente.

- Les contributions mettent aussi en évidence l'instabilité du signe de la relation mesurée par régression. La relation peut être négative ou positive suivant le pays, l'industrie ou la série temporelle étudiés. Cinq articles mettent d'ailleurs en évidence une relation négative entre efficience et rentabilités boursières.

- Les analyses mettent en évidence la supériorité des indicateurs d'efficience sur les ratios comptables pour expliquer la valorisation et les rentabilités des titres. Cette supériorité relative s'explique d'abord par le contenu informationnel plus important de l'efficience lié au nombre de variables synthétisées. Ensuite, dans la mesure où l'efficience est une information récurrente, elle est susceptible d'être mieux appréciée par les investisseurs.

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- Certaines études comparatives soulignent que les entreprises cotées sont plus efficientes que leurs pairs privés. Ces résultats semblent soutenir le rôle de mécanisme de contrôle du marché financier.

- La méthode DEA est la plus employée pour mesurer l'efficience dans cette littérature. Les quelques études comparatives mettent, en outre, en évidence que la méthode DEA est la mieux appropriée pour expliquer les rentabilités financières.

Ces résultats préliminaires ont orienté le choix des problématiques développées dans les chapitres empiriques. Trois types de résultats peuvent être dégagés des analyses empiriques réalisées. Les premiers résultats empiriques concernent le cadre théorique de l'analyse comptable à destination des marchés financiers. Ces résultats confirment que l'efficience technique et les informations associées, telles que les caractéristiques des moteurs, les distances et les altitudes des vols, complètent l'information comptable pour la valorisation des actifs financiers. Bien que l'information comptable utilisée explique la majeure partie de la valorisation, l'information technique comporte des éléments pertinents non véhiculés par la comptabilité. Néanmoins, l'efficience technique est, sur le plan incrémental, plus pertinente que l'information comptable. Ces résultats confirment Amir et Lev (1996) et Riley, Pearson et Trompeter (2003). Les résultats obtenus valent pour la méthode DEA convexe à rendements d'échelle constants et pour l'estimation stochastique de Battese et Coelli (1992) suivant la forme fonctionnelle log-linéaire avec effets fixes.

La deuxième catégorie de résultats contribuent au développement de l'analyse frontière et portent essentiellement sur la décomposition de la productivité totale par l'application des indices Hicks-Moorsteen et Färe-Primon aux modèles DEA. Ces indices comportent des propriétés particulièrement intéressantes. En premier lieu, ces indices sont complets puisqu'ils mesurent la productivité totale en intégrant simultanément la maximisation des outputs et la minimisation des inputs. En ce sens, ils diffèrent de l'indice Malmquist, le plus utilisé dans la décomposition de la productivité, qui ne focalise que sur la minimisation des inputs ou la maximisation des outputs. De plus, le Hicks-Moorsteen et le Färe-Primont fournissent une décomposition non ambiguë des sources de la productivité, là où la signification des composants du Malmquist diffère sensiblement suivant la spécification du rendement d'échelle. L'apport de cette analyse de la décomposition est multiple :

- Notre étude renouvelle l'analyse du secteur du transport civil aérien américain. Les analyses antérieures basées sur les méthodes frontières focalisaient sur des échantillons dont le le plus récent se termine en 1991.

- Notre étude introduit aussi la première décomposition par Hicks-Moorsteen de la productivité totale du secteur étudié.

- A notre connaissance, nous fournissons aussi la première décomposition en Färe-Primont dans le cadre de la méthode DEA.

- Les déterminants de la productivité, isolés par la décomposition des indices, confirment la littérature empirique et le diagnostic des acteurs de l'industrie. En conséquence, la fiabilité des décompositions du Hicks-Moorsteen et du Färe-Primont pour décrire les déterminants de la productivité des entreprises est confirmée. Les décompositions rendent compte des éléments suivant :

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- Les résultats confirment la présence de chocs exogènes importants ayant contribués à dégrader la situation financière des transporteurs. Les principaux relevés sont l'effet des Guerres du Golfe, du 11 septembre 2001, de l'épidémie de SRAS et des récessions de 1993 et 2008. De plus, nous observons que le changement technologique a été le principal moteur de l'évolution de la productivité des transporteurs.
- Conformément aux analystes du secteur, l'efficience d'échelle, qui intègrent l'effet des rendements associés à l'intensité d'utilisation du réseau, a été le principal déterminant de l'efficience technique des transporteurs. D'autres composantes de l'efficience capturent l'effet de l'excès des capacités telles que l'efficience mix.
- Les résultats confirment l'utilité du Färe-Primont en base fixe pour différencier le mode d'organisation des réseaux et de développement des transporteurs. Par exemple, les transporteurs low-costs organisés suivant un réseau point-to-point ont une productivité essentiellement déterminée par l'efficience technique pure et l'efficience mix. En revanche, les autres transporteurs, dit legacy, ont leur performance productive essentiellement dirigée par l'efficience d'échelle associée à la maximisation de l'utilisation des réseaux hub and spoke.
- Nous notons aussi que les transporteurs low-costs, tels que Southwest Airlines, sont en moyenne moins productifs que les legacy. Ce résultat, cohérent avec les avantages des configurations de réseaux des legacy, indique que la performance financière supérieure des low-costs n'est pas associée à leur productivité. Il apparaît que, bien que les low-costs bénéficient moins des rendements de densité, leurs configurations de réseaux point-to-point leur assure une structure de coûts plus flexible leur permettant d'atteindre plus rapidement leur seuil de rentabilité.

Enfin, la troisième catégorie de résultats contribue à la théorie financière. Ces résultats découlent des tests de la relation entre les composants de l'efficience technique et les rentabilités attendues. A l'instar du paradigme du Modèle d'Evaluation des Actifs Financiers (MEDAF), l'analyse frontière dissocie la performance issue des attributs spécifiques à la firme et de sa volonté stratégique de celle issue de facteurs systématiques exogènes. Le test vise à confirmer ou infirmer si la décomposition proposée par les indices de productivité correspond à celle du MEDAF. Le test de la relation est réalisé suivant le modèle Fama-French-Carhart. Les résultats reportés ci-dessous valent pour le Hicks-Moorsteen et le Färe-Primont :

- La mesure de productivité totale est positivement corrélée aux rentabilités attendues.
- Les principales sources de la productivité diagnostiquées dans l'analyse frontière, c'est-à-dire le changement technologique et l'efficience d'échelle, sont aussi les plus pertinents pour expliquer les rentabilités. En outre, nous notons que la productivité totale est moins explicative des rentabilités que ses constituants.
- Comme attendu, le changement technologique et le changement en efficience technique reflétant respectivement l'effet des facteurs exogènes et la modification des

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pratiques managériales sur la productivité, ont une relation différente avec les rentabilités attendues. Le changement technologique est positivement corrélé aux rentabilités alors que la variation d'efficience l'est négativement. Ces résultats sont observés même après la prise en compte dans le modèle de régression de l'évolution des parts de marché et de la concentration du secteur par l'indice de Herfindahl-Hirschman.

- Une analyse plus détaillée vise à mesurer la relation entre le niveau de la technologie et de l'efficience technique d'une part et les facteurs de risques systématiques et spécifiques d'autre part. Les résultats indiquent que la productivité totale expliquée par le niveau de la technologie est négativement corrélée aux facteurs de risque spécifique, et positivement corrélée aux facteurs de risque systématique. La relation inverse est observée pour le niveau d'efficience technique. Cette dernière est positivement corrélée à la mesure de risque spécifique et négativement corrélée à celle de risque systématique. Ce résultat tend à confirmer que la décomposition de la performance fournie par les indices de productivité est cohérente avec celle proposée par le paradigme du MEDAF.

- Enfin, l'analyse indique la persistance de l'efficience technique dans le temps. L'observation de l'évolution de l'efficience des 30% des entreprises les plus efficientes et des 30% les moins efficientes révèle un effet d'inertie dans les changements d'efficience sur 5 années consécutives. Les 30% des observations les plus efficientes techniquement voient leurs scores décroitre alors que les 30% les moins efficientes ont des scores qui augmentent de manière tendancielle.

- Cet effet de persistance est observé aussi pour les modèles de rentabilité. Au regard de la relation négative entre efficience technique et rentabilités et de la persistance des scores d'efficience; nous supposons que les investisseurs développent des stratégies contrariées sur la base de l'information analogue à l'efficience technique. Cette stratégie d'investissement consiste à vendre les winners et acheter à découvert les loosers.

Cette dernière catégorie de résultats confirme et démontre les points suivants. En premier lieu, les mesures d'efficience produites par les méthodes frontières contiennent de l'information publique et privée associée respectivement à l'exposition de la firme aux facteurs de risques systématiques et à ses attributs spécifiques (Roll, 1988). Les tests de la relation entre chaque facteur de risque, décomposés par le MEDAF, et les niveaux de productivité liés à l'état de la technologie et à l'efficience technique renforcent cette interprétation. De plus, ces résultats confirment la cohérence de la décomposition des sources de la productivité avec la décomposition des facteurs de risques définie par le paradigme du MEDAF.

La deuxième conclusion concerne la relation entre efficience technique zet rentabilité financière. Au regard de la persistance de l'efficience technique dans le temps et de sa relation avec les mesures du risque du MEDAF, nous concluons que la relation négative entre l'efficience technique et les rentabilités reflète la réduction du coût des fonds propres. Cette interprétation est cohérente avec les travaux de Nguyen and Swanson (2009).

Ce travail comporte des limites qui constistuent de futures pistes de recherche. Premièrement, l'analyse de l'efficience technique nécessite de se focaliser sur un secteur spécifique.

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Il est probable que la relation estimée ait différé dans d'autres secteurs ou d'autres pays. C'est d'ailleurs le résultat mis en évidence par Lin (2010) au travers de l'estimation de la relation entre les composants du Malmquist et les rentabilités financières du secteur bancaire de 9 pays d'Asie de l'est. La relation que nous établissons ici est donc difficilement généralisable.

Deuxièmement, la relation entre l'efficience technique et les rentabilités financières est étudiée suivant l'hypothèse de maximisation de la valeur actionnariale. En conséquence, nous prenons pour hypothèse que les surplus de valeur issus des gains de productivité sont distribués aux actionnaires. Néanmoins, la maximisation de la valeur actionnariale n'est pas nécessairement vérifiée dans notre application. Au regard de l'importance des déficits liés à l'augmentation considérable des principaux coûts, la valeur créée par les transporteurs a été essentiellement captée par les parties prenantes. Aussi, rien ne permet d'affirmer que la relation ne diffère pas dans un contexte où les décisions des entreprises ne sont pas orientées vers la maximisation de la valeur actionnariale. Dès lors, il paraît important d'analyser cette relation à la lumière des flux de répartition de la valeur créée par la firme. Une analyse de l'évolution de la productivité et du partage de la valeur par la méthode des comptes de surplus fait l'objet d'une recherche en cours.

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Troisièmement, l'analyse du contenu informationnel de l'efficience technique et la relation de ses déterminants aux facteurs de risques systématiques et spécifiques nécessite d'être approfondie au regard du débat dichotomique sur la capacité des modèles multifactoriels à refléter l'exposition aux risques de marché. Fama et French (1992, 1993, 1995) défendent l'idée que les facteurs de leur modèle fondamental précisent l'exposition aux risques systématiques. En revanche, Daniel et Titman (1998, 2001) suggèrent que les primes associées aux portefeuilles de Fama et French reflètent les caractéristiques des portefeuilles et non l'exposition aux facteurs de risques systématiques. Cette approche permettra d'améliorer notre compréhension de la relation entre efficience par les méthodes frontières et les rentabilités. Néanmoins, cette approche focalise généralement au niveau des indices de marché et non au niveau de l'industrie.

Quatrièmement, la méthode DEA fournit une description statique de l'efficience technique. Etant donnée la présence de rigidité dans les processus de production, les entreprises ne peuvent être évaluées techniquement efficientes sur le plan dynamique. La question du cycle de vie du produit illustre cette limite intrinsèque. Les performances d'une entreprise mesurées à deux moments du cycle de vie de son produit différeraient sensiblement. Lors des premières phases du cycle de vie du produit, l'entreprise serait évaluée inefficiente. Dans les phases suivantes où le volume des ventes atteint sa maturité, le degré d'efficience achevé serait bien meilleur. Pourtant, les différences d'efficience ne

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signifient pas que les décisions prisent par le gestionnaire ont été sous-optimales. La prise en compte de la temporalité est un élément nécessaire pour l'évaluation des performances de la firme. Idéalement, l'évaluation de la performance doit être adaptée aux cycles d'investissements et des produits/services. Il est certain que les investisseurs tiennent compte de la diversification temporelle du portefeuille de produits des entreprises.

Cinquièmement, l'interprétation que nous faisons de la relation entre efficience technique et rentabilités est fondée sur l'analyse en moyenne-variance. Du point de vue de la théorie financière, la rentabilité supposée orienter les décisions d'investissement et de production résulte de l'équilibre des décisions des investisseurs fondées sur la combinaison de leurs préférences pour le risque et le temps aux informations disponibles. Par souci de modélisation, l'univers moyenne-variance suppose l'aversion généralisée des investisseurs caractérisés par une fonction d'utilité quadratique et le partage du même horizon temporel. Ce corps d'hypothèses rend nos mesures et notre interprétation biaisées par la structure sous-jacente des préférences des investisseurs. Néanmoins, Hirschleifer (1965a, 1965b) et Myers (1968) ont développé un cadre théorique et empirique, permettant d'intégrer les préférences pour le temps et l'état de la nature. De plus, des études empiriques récentes en théorie du portefeuille permettent la dérivation des préférences des investisseurs pour le risque à l'instar des contributions de Briec, Kerstens, et Jokung (2007) et Brandouy, Kerstens, et Van De Woestyne (2010).

La thèse s'organise en deux parties. La première partie se concentre sur la relation théorique entre efficience technique et rentabilités. La seconde partie consiste en l'analyse empirique de cette relation dans le cadre d'une application au secteur du transport civil aérien américain. Le premier chapitre décrit la relation telle qu'elle est spécifiée dans les modèles d'équilibre des actifs financiers. Ce chapitre met en évidence que l'efficience technique est une condition nécessaire à l'achèvement du rôle d'allocation optimale des ressources par le marché financier. La relation spécifiée est bidirectionnelle. La rentabilité exigée entre dans le calcul des quantités marginales des facteurs de production. Par ce biais, la rentabilité oriente la décision d'allocation des ressources internes à la firme. D'autre part, le niveau d'efficience technique se traduit par des flux de profits valorisés sur le marché. Ce chapitre révèle cependant l'existence d'un conflit entre les décisions de production et l'équilibre des investisseurs sur le marché financier.

Les chapitres 2 et 3 se concentrent sur les outils dérivés de ces modèles d'équilibre pour mesurer la performance productive d'une part et financière d'autre part. Le chapitre 2 introduit la méthode DEA. Il détaille son cadre d'analyse, c'est-à-dire la modélisation de l'activité de la firme, et les principales mesures de performance qui peuvent être développées. Il apparaît que la définition de l'efficience technique est conforme au paradigme des modèles d'équilibre des actifs financiers.

Le chapitre 3 présente les différentes mesures de performance financières dérivées du modèle d'évaluation des actifs financiers. Il rappelle les analyses de l'information financière proposées par King (1966) et Roll (1988) pour interpréter le contenu informationnel de l'efficience technique. L'incidence de ces informations sur le modèle des rentabilités, c'est-à-dire les covariances et le degré de synchronicité aux facteurs de risque systématiques, y est développée.

Le chapitre 4 enfin est une revue des contributions empiriques focalisant sur la relation entre l'efficience mesurée par les méthodes frontières et les rentabilités ou les valorisations financières. Ce chapitre fournit une présentation exhaustive des 67 contributions

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recueillies et propose une typologie de leurs designs de recherche. Il met en évidence les caractéristiques des relations testées jusqu'à présent dans la littérature. Enfin, il propose des designs de recherche en cohérence avec l'analyse financière.

La seconde partie de la thèse présente l'analyse empirique. Elle vise à tester les conclusions tirées de l'état de l'art de la littérature. Le chapitres 5 se concentre sur la présentation du secteur du transport aérien qui sera étudié pour l'analyse de la relation. Il présente l'évolution historique du secteur depuis la dérégulation de 1978 et décrit les conditions d'exploitation et les contraintes auxquelles sont soumises les entreprises de ce secteur. Il présente aussi l'échantillon et sa collecte. L'échantillon est constitué de 28 majors, c'est-à-dire de tous les transporteurs dont les revenus ont excédé 20 millions, au cours de la période 1990-2012. Les données sont issues des rapports sur les quantités physiques et les états financiers non consolidés divulgués par le Ministère du Transport des Etats-Unis. Les données financières, qui consistent en des séries temporelles de prix d'action et les états financiers consolidés, ont été collectés via Bloomberg.

Les chapitres 6 et 7 concernent l'analyse statistique de la relation étudiée. Le chapitre 6 teste la relation entre niveau d'efficience technique et valorisation boursière. Ce chapitre met en évidence que l'efficience technique est une information non-financière qui complète celle véhiculée par la comptabilité pour l'évaluation de l'entreprise. Ce résultat est validé pour l'efficience technique mesurée par la méthode DEA et estimée par l'analyse des frontières stochastiques.

Le chapitre 7 focalise sur la détermination de la productivité totale et la décomposition de l'efficience par les indices Hicks-Moorstens et Färe-Primont. Après la présentation de la méthodologie des indices, une analyse des facteurs de la productivité du secteur du transport aérien est pratiquée. Dans un second temps, l'analyse de la relation entre efficience technique et rentabilité confirme, que dans les deux cas, l'efficience technique intègre bien des informations publiques et privées.

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List of Abbreviations

ADA	Airline Deregulation Act
APM	Arbitrage Pricing Model
ASM	Available seat miles
ATM	Available ton miles
BCC	Banker, Charnes and Cooper (1984)
BTS	Bureau of Transportation Statistics
C	Changes
CAB	Civil Aeronautic Board
CAPM	Capital Asset Pricing Model
CCD	Caves, Christensen and Diewert
CCR	Charnes, Cooper and Rhodes (1978)
CRS	Constant returns to scale
CSS	Cornwell, Schmidt and Sickles (1990)
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
dPTE	Pure technical efficiency change
dPTECH	Pure technological change
dRTS	Returns to scale change
dSE	Scale efficiency change
dSTC	Scale of technological change
dTE	Technical efficiency change
dTECH	Technological change
EMH	Efficient Market Hypothesis
EVA	Economic Value Added
FDH	Free Disposal Hull
FFP	Frequent flyer programm
FNGZ	Färe, Norris, Grosskopf and Zhang (1994)
FPTFP	Färe-Primont Total Factor Productivity
GDP	Gross Domestic Product
HHI	Herfindhal-Hirschman index
MIOS	Mix invariant optimal scale
Mkt.Rf	Market premium
MM	Malmquist
MMD	Modigliani-Miller-Diamond
MOM	Momentum effect
MPSS	Most productive scale size
NHHI	Normalized Herfindhal-Hirschman index
NI	Net income
OLS	Ordinary Least Squares
OME	Output oriented mix efficiency
OSE	Mix restricted output oriented scale efficiency
OTE	Mix restricted output oriented technical efficiency
PCF	Passenger facility charges
PTE	Pure technical efficiency
Rf	Risk free rate
RISE	Input oriented residual scale efficiency
RME	Residual mix efficiency
ROCE	Return on capital employed
ROSE	Output oriented residual scale efficiency
RTD	Returns to density
RTM	Revenue ton miles
RTS	Returns to scale
SARS	Severe Accurate Respiratory Syndrom
SBM	Slack Based Model
SE	Book Value of Stockholder Equity
SEC	Securities and Exchange Commission
SFA	Stochastic Frontier Analysis
SIC-codes	Standard Industrial Classification codes
SIFL	Standard Industry Fare Level
SMB	Small Minus Big premium

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HML	High Minus Low premium	SW	Simar and Wilson (1998)
HMTFP	Hicks-Moorsteen total factor productivity	TE	Technical efficiency
IATA	International Air Transportation Association	TFP	Total factor productivity
IME	Input oriented mix efficiency	TFP*	Total factor productivity at the most productive scale size
ISE	Mix restricted input oriented scale efficiency	TFPE	Total Factor Productivity Efficiency
ITE	Mix restricted input oriented technical efficiency	US DOT	United States Department of Transportation
JLMS	Jondrow, Lovell, Materov and Schmidt (1982)	VRS	Variable returns to scale
L	Level	X	Input set
LCC	Low-costs carriers	Y	Output set

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General Introduction

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Thèse de Matthieu Belarouci, Lille 1, 2013

General Introduction

The search for the achievement of efficiency of the productive organizations is generally perceived as a key factor for their survival in a competitive environment and for their evolution and selection. Supposedly immanent in economics, the search for efficiency is becoming crucial. The worldwide demographic evolution combined with the increasing scarcity of natural resources and the necessary reduction of the negative production externalities on the global environment requires to qualitatively improve all production processes. From the firms' point of view, these evolutions reduce their access to the production factors and require the limitation of waste in their production processes. Nevertheless, the standard measures of productivity are incomplete to account for the increasing technical constraints faced by firms. However, the framework of frontier analysis from operations research provides tractable tools and measures, such as technical efficiency, that permit to quantify complete measures of productivity taking into account the main constraints and to understand the main drivers of the productivity of the firms. This dissertation contributes to the extensions of these methods through their application in financial analysis. The purpose of our study is to analyze the relation of two performance measures: technical efficiency and stock returns. We believe that a clearer understanding of the relation between the frontier methods and the stockholder value creation will enhance their diffusion in productive organizations.

Technical efficiency approaches the firm as a collection of input and output. It measures the extent to which the firm is able to maximize its production potential with respect to the technical constraints. If the analysis of the technical constraints is the work of the engineers, then Data Envelopment Analysis (DEA) models permit their formalizations and the derivation of the production potential of the firm from the observed practices of comparables Decision Making Units (DMU). Regarding its construction, technical efficiency contains information about the productive performance of the firm and its competitors. In addition, the modeling of the firm implied by technical efficiency is joined with its computational methods. The formalization of the technical constraints and the nature of the technical efficiency evaluated (e.g. pure technical efficiency, scale efficiency or input/output mix efficiency) depend on the specification of the DEA model. Based on a deterministic paradigm, DEA models do not maintain any strong assumptions about the environment of the firm nor on the structure of the production technology.

By contrast, the expected stock return approaches the firm as a collection of assets producing a stream of cash-flows to shareholders. It measures the ability of the firm at maximizing the value potential of assets. The hurdle potential is generally inferred from the expected relation between the return of the firm and the changes in industry and common market factors. These common factors represent measures of risks that cannot be diversified by investors. The realized performance of the firm is assessed by the amount of cash-flows per unit of risk incurred by the activity. The greater these cash-flows per

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unit of risk are, the greater the ability of the firm is at outperforming despite adverse market conditions. Again, the modeling of the firm and its environment implied by the measurement of the expected return is joined with the estimation method and with the Efficient Market Hypothesis. The factors analysis, investigated in this dissertation, considers that the firm evolves in an environment dominated by stochastic processes. Hence, the decision of the firm is always, to a certain extent, assumed to be contingent.

Despite differences in the level of analysis and the paradigms involved, technical efficiency and stock returns are complementary measures. While the abnormal returns - that is to say, the difference between the expected and the realized returns - measure the ability of the management at picking investment projects efficiently, technical efficiency focuses on the management ability at implementing these investment projects. In addition, both recognize that the performance of the firm ensues from the exposure to common exogenous factors and from the management strategy specific to each firm. They propose in both cases a decomposition of the performance in pure managerial effects and exogenous effects.

Even though empirical contributions demonstrate the link between technical efficiency and stock returns, the characteristics of the relation remain - relatively speaking - unexplored. The purpose of this dissertation is to explore the nature of this relation. It implies first to describe the relation, but also to analyze the factors that condition this relation and to investigate the convergence between the production frontier and the financial methodologies. The understanding of the underlying sources of technical efficiency also requires to investigate the productivity indices methodology. We aim to assess the value relevance of the productivity components and their ability at reporting the effects of systematic risks on the operating performance of the firm. Likewise, this study highlights the practical usefulness of performance evaluation based on frontier methods for the purpose of financial analysis.

Theoretically, the analysis of the relation between firms' technical performance and stock valuation contributes to the debate about the financial market's connection or disconnection with the real sphere. This debate is developed into financial theory as the dichotomy between fundamental and technical analyses. The fundamental analysis seeks to determine the intrinsic value of the firms. It focuses mainly on the analysis of financial statements of the firms, on their environments and on the corporate disclosure of information about their future outcomes. The purpose of the analysis is to forecast the magnitude, the timing and the riskiness of the firms' cash-flows (Kothari, 2001). In contrast, the technical analysis relies on past market data. Its purpose is to infer from the observation of past stock returns' behavior the formation of future patterns of returns. By linking technical information with stock returns, this dissertation defends the fundamental analysis.

In addition, a clear understanding of the effect of technical efficiency information on the stock returns implies to analyze the nature of the information conveyed. The observed returns balance between systematic and specific determinants. Roll (1988) claims that the portion of variance explained by firms-specific attributes corresponds to trades on private information, while the variance explained by systematic pervasive factors is associated with public information. Given the intensity of trades on each information, the patterns of returns, especially their synchronicity may differ. Regarding the computational methods of technical efficiency, it is likely that it encompasses both kinds of information. This is one potential explanation of the contradictory results observed in the empirical literature on the relation of interest. The test of this hypothesis requires to decompose technical

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efficiency to determine whether each type of information can be isolated.

Finally, the dissertation demonstrates the complementary role of technical efficiency in accounting based valuation of stocks. Financial accounting analysis relies on the observation of the exploitation and investment cycles. Then it requires regularities to provide a fair comparison of the operating performance over time. When the industry of interest is characterized by important changes, the accounting based analysis is incomplete. The investigation of the value relevance of technical efficiency and associated technical information in tandem with accounting demonstrates the usefulness of frontier based efficiency measures for the production of financial information.

Regarding the methodology, we test alternative specifications of technical efficiency and we provide a survey of all of contributions about the relation between efficiency and stockholder value creation. The outcome of this analysis is the proposition of the designs which are most in line with financial concerns. In addition, the cross-checks of our results based on SFA and DEA strengthen our conclusions. Finally, the main methodological contribution of our study is the application of the multiplicatively complete total factor productivity indices: the Hicks-Moorsteen and the Färe-Primont. The present study is the first contribution to test the value relevance of each index. In addition, this is the first contribution that provides a Färe-Primont decomposition under the non-parametric paradigm.

The empirical contribution of this dissertation is twofold. On the one hand, it contributes to the analysis of the US airline industry. A core issue in the evaluation of technical efficiency is the availability of the data. Fair computation of technical efficiency requires the use of quantities consumed and produced usually not disclosed in official reports. The interest of the US airline industry is the existence of strict compulsory fillings about the activity of the firm that satisfy the data requirements for a fair computation of technical efficiency. Indeed, the official reports, released by the US Department of Transportation (DOT), include non-consolidated information about the physical quantities and the characteristics of the production possibility set. Hence, the measure of technical efficiency provided here is more accurate than in most other studies. In addition, we renew the frontier based analysis of the US airline industry. Previous contributions focus on a sample that end at the latest in 1991. Our sample extends the analysis for the period 1990-2012.

On the other hand, the study demonstrates the potential productivity gains achievable in financial analysis. Indeed, DEA models handle simultaneously a large number of value relevant variables and summarize them in a unique indicator. In addition, it provides a ranking of firms with respect to their potential or existing productivity shortfalls. Consequently, the measurement of efficiency based on DEA is akin to the method of *comparables* mainly based on accounting information, but requires less treatments and permits to avoid intrinsic pitfalls. Consequently, DEA is a potential tool for the valuation of private companies.

The results have implications for frontier analysis and financial theory. The analysis of the productivity of the US airline industry is in line with the literature and the diagnostic of the main actors in this sector. The Hicks-Moorsteen and the Färe-Primont decompositions provide a detailed evolution of the performance. We observe the ability of technological change components at reflecting the effect of adverse events such as the 11^{th} September, the economic recessions or the Severe Acute Respiratory Syndrome (SARS) epidemic on carriers' productivity. Next, the decomposition of total factor productivity efficiency confirms that the performance of carriers has mainly been driven by the scale efficiency effects associated with the exploitation of returns to density favored by the

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hub and spoke networks configurations. Finally, the results demonstrate the usefulness of the Hicks-Moorsteen and the Färe-Primont decompositions for the differentiation of the business models of carriers as well as for the distinction between low-costs and legacy carriers. Low-costs and legacy carriers are characterized by different network organizations captured in the efficiency components.

The second set of results focuses on the relation between technical efficiency and stock returns. First, the results confirm the complementary role of technical efficiency information in the accounting based analysis of the intrinsic value of the firm. We note that technical efficiency conveys information not integrated into accounting. In addition, technical efficiency is incrementally and relatively more value relevant than other non-financial information.

Finally, the main result of our research is the demonstration of a negative relation between the measures of efficiency and stock returns. In addition, we observe that the effect of efficiency on returns is persistent over time. Indeed, the most ones become less efficient over the five consecutive years, while the least efficient improve. This phenomenon, explained by underlying production conditions, suggests that the negative relation between efficiency and stock returns reflects the reduction in the required rate of return. This explanation is confirmed by further tests on the relation between the pure efficiency components and the technological component that drive technical efficiency. Pure technical efficiency is positively associated with the specific components of returns and negatively with the factors of systematic risks. This pattern reverses for the analysis of technological change. This contribution is twofold. On the one hand, the ability of indices at decomposing productivity into exogenous and endogenous sources in line with the financial approach is confirmed. On the other hand, in line with Roll (1988), technical efficiency carries both public and private information, that is to say mirrors exposition to systematic factors of risks, associated with economic and industry events, and purely specific performances. We suggest that, given the proportion of each kind of information conveyed, the relation between technical efficiency and stock returns may differ.

The dissertation is divided in two parts. The first part contains four chapters which focus on the theoretical aspects of the relation between technical efficiency and stock returns. The first chapter describes the relation as stated by the model of financial markets equilibrium. This chapter develops that the equilibrium of the production decisions, implying the achievement of technical efficiency, is a necessary condition for the stock market to perform its role of allocation of resources and risks optimally. In addition, the described relation between stock returns and technical efficiency is bidirectional. On the one hand, the market plays its allocation role of resources through the stock returns. The stock returns guide production decisions since it is included in the marginal calculations of the producers. On the other hand, the potential or existing profit shortfall associated with the inefficiencies is integrated into stock prices by a proportional reduction in the firms' value. However, this chapter describes the existing conflictual relation between the equilibrium of the production decisions and the investors' equilibrium. Indeed, the maximization of the production potential is in line with the value maximization in very restrictive settings that do not allow for the existence of technical efficiency, except if it arises from uncertainty.

The second and the third chapters introduce the tools derived from the equilibrium models. The second chapter develops the frontier framework and the data envelopment analysis. We make explicit the modeling of the firm implied by the framework and the main DEA models. The third chapter focuses on the main financial measures of the

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performance of the firm derived from the capital asset pricing paradigm. It details the main typologies of financial information by Fama (1970), King (1966) and Roll (1988) for the investigation of the information content of technical efficiency. The theoretical link between the nature of the information set and the pattern of returns, especially the synchronicity, is discussed.

The fourth chapter provides a survey of 67 contributions about the relation between frontier analysis based efficiency measures and stockholder value creation. The taxonomy, based on the methodologies and the results of the contributions reviewed, enables the ranking of the contributions for the characterization of the relation between efficiency and stock returns.

The second part concerns the empirical investigation of the relation of interest. The fifth chapter describes the empirical framework of our investigation: the US airline industry. We describe the historical evolution of the sector since the deregulation of 1978 and we analyze the main production constraints, that will drive the specification of the DEA model for the evaluation of technical efficiency. We also report the characteristics of the sample composed of 28 major air carriers over the period 1990-2012. The data set is composed of non-consolidated technical reports and financial statements released by the US DOT and of consolidated statements downloaded from Bloomberg.

The chapters 6 and 7 provide the statistical analysis of the relation between technical efficiency and stock prices and returns. The chapter 6 tests the value relevance of technical efficiency, computed with a constant returns to scale and strongly disposable DEA model, in tandem with related technical items and accounting. Cross-checking of the results is performed with a stochastic frontier analysis.

The last chapter, focuses on the relation between productivity components and expected stock returns. After reviewing the main Malmquist decompositions and their applications in the analysis of the relation between technical efficiency and stock returns, we introduce two alternative indices: the variable basis Hicks-Moorsteen and the fixed basis Färe-Primont. The analysis is performed in two stages. The first stage focuses on the interpretation of the total factor productivity provided by the indices for the evaluation of the operating performance of the carriers. The second stage concerns the tests of the relation between technical efficiency components, obtained by each index under different bases, and the stock returns.

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Part I

Literature Review

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Thèse de Matthieu Belarouci, Lille 1, 2013

Introduction

The relation between technical efficiency and stock returns is inherited from the theory of optimal capital accumulation. This theory bridges the microeconomic of production and the financial microeconomics. Microeconomic states that technical efficiency and stock returns reflect two interdependent equilibria.

On the one hand, technical efficiency corresponds with the state of equilibrium of the production. At this equilibrium, the firm reaches its maximal productivity with respect to the state of the technology. This equilibrium ensues from the optimal decisions about the allocation of production factors driven by prices and by the target of value maximization. The firm's expected return, that is to say, its unlevered cost of capital, contributes to this equilibrium through the amount of capital goods indicated by the marginal calculations.

On the other hand, stock returns result from the equilibrium of investors decisions based on the combination of preferences for risk and time with the information set about the future performance of the firm. Given the price mechanism, any information about a production disequilibrium implies trades that adjust the market value of the firm for the discounted value of the existing or potential profit shortfall associated with the inefficiencies. Hence, the theory of optimal capital accumulation relies on a strong dependence between producers and investors' decisions. The specified interaction implies that a production disequilibrium is immediately compensated by a new equilibrium of the stock market such that the general equilibrium remains unchanged. However, this interaction, based on a harmonistic hypothesis of the economy, has not been deeply investigated by empirical research (Hirshleifer, 1965b).

This lack of research is surprising when we consider the separate streams of empirical literature triggered by production and financial microeconomics. These evolutions are depicted in Figure 1. The red upward frame bounds the microeconomic theory that link the technical efficiency with stock return. The low blue frame is concerned with the streams of research that focus on the derivation of tools for performance analysis based on respective microeconomic paradigms. Nevertheless, it is important to remind that the frontier framework and empirical finance distinguish themselves somehow from microeconomic theory in the sense that they are not occupied with modeling of general equilibrium and social welfare maximization. Both streams of research are oriented towards the production of tractable and realistic tools for decision making.

Microeconomic of production has given rise to production frontier analysis that belongs to the field of operations research. Frontier analysis consists of developing tractable methods based on linear programming or on stochastic frontier analysis for the computation of marginal quantities and for performance evaluation in line with microeconomic concepts as well as technical efficiency. This theoretical and methodological framework has been developed by the Mathematical School of organization theory in the University of Carnegie Melon. This research has been mainly oriented towards the development of

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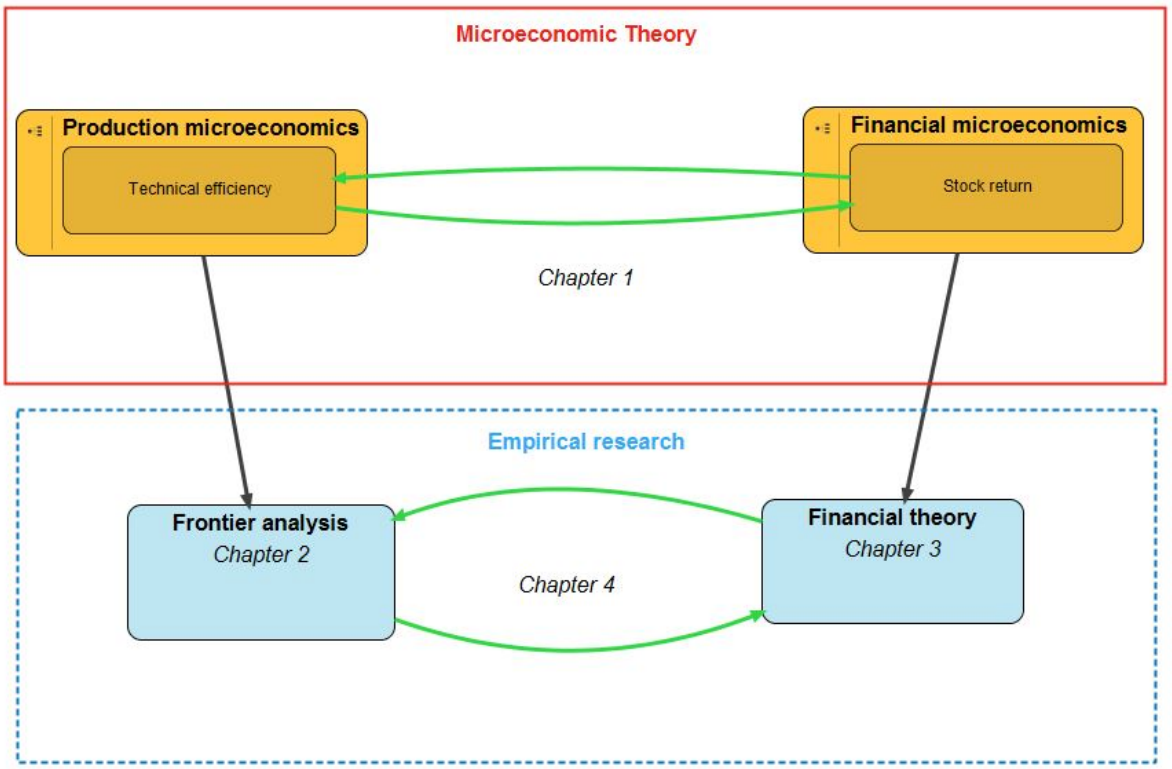

Figure 1: Relation between Technical Efficiency and Stock Returns given Theoretical Field

new tools for performance evaluation that take into account operational constraints of the firm. Applications of frontier analaysis in finance are recent and focus mainly on the portfolio theory.

In contrast, empirical finance - the left blue square in Figure 1 - has retained the relation specified by the theory of optimal capital accumulation in the capital budgeting. Financial theory provides descriptive and normative statements to guide the decisions of investment under uncertainty and assess their efficiency. A management is said efficient, that is to say maximize the productivity of capital, when it picks every project whose expected return adjusted for the uncertainty is equal or above the required rate of return. This efficiency of the capital budgeting process has been recently investigated empirically by Durnev, Morck, Yeung, and Zarowin (2003), Durnev, Morck, and Yeung (2004) and Wurgler (2000). Nevertheless, the efficiency of capital budgeting does not cover the same dimensions like technical efficiency. Capital budgeting efficiency evaluates the quality of investment decisions that is to say the ability of the manager at selecting and valuing projects. Technical efficiency is concerned with the ability of the management at implementing projects. Even though capital budgeting efficiency encompasses technical efficiency to a certain extent, financial methods do not allow to disentangle them accurately. In addition, literature in finance is not that concerned with production and technological decisions and employs frequently production and investment interchangeably.

The interest for bridging empirical measures of efficiency from frontier analysis with stock returns emerged in the middle of the nineties with the analysis of cost efficiency of the computer industry by Thore (1993). This contribution is the starting point of a small, but increasing body of literature that deals mainly with proxy of cost efficiency, revenue

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efficiency and profit efficiency. This literature provides statistical tests on the relation between frontier based performance and stock performance with no or few references to the initial theoretical link developed by microeconomic. In addition, technical efficiency is rarely investigated because of the data requirements for its computation.

This theoretical part aims at describing the theoretical and empirical link between technical efficiency and stock returns provided by the literature. Following Figure 1, the first chapter focuses on the relation between technical efficiency and stock returns rooted in models of financial equilibrium. This first chapter describes the extent to which technical inefficiencies are compatible with equilibrium models of financial evaluation. Its purpose is to make explicit the paradigms that underlie the tools derived from microeconomy developed in Chapter 2 and 3.

The second chapter introduces the production frontier framework. It is important to note that the main advantages of technical efficiency for evaluation are related to the computation techniques. Methodological developments in frontier analysis permits now to overcome fundamental limits of economic modeling. For instance, the non-parametric and deterministic frontier free disposal hull relaxes the convexity assumption and then is able to account for the fixity of charges in the producer activity. In addition, recent developments in index methodologies enable to disentangle accurately the exogenous from the endogenous sources of technical efficiency.

The third chapter introduces tools for the evaluation of financial performance based on multi-factors based models. This chapter emphasizes the importance of the information content of technical efficiency and its relation to private and public information flows in the stock market. Preliminary empirical evidence of the relation between firms' efficiency and stock performance are presented.

The last theoretical chapter is a survey that encompasses and classifies the empirical evidence of the link between frontier based measures of efficiency and financial market data based performance. This critical compilation of empirical works is concluded by a discussion of the limit of the current research.

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Thèse de Matthieu Belarouci, Lille 1, 2013

Chapter 1

Relation between Production Efficiency and Stock Returns in Models of Financial Equilibrium

In a world characterized by uncertainty, knowledge is substituted by opinion and investment may be defined as a certain sacrifice for an uncertain benefit (Hirshleifer, 1965b). Regarding production decisions, the producer may not know the amount of the future outcome resulting from its production. This means he does not know whether the conditions to achieve the planned production will be met or whether he will be able to value its production as expected. The models of financial market equilibrium are concerned with the fair pricing of uncertainty. The purpose is to price securities for the risk they incur in a way that provides a Pareto optimal repartition of wealth (Stiglitz, 1981). This topic deals with the allocation of investment for the maximization of the value potential of the assets per unit of risk. The process of allocation of financial resources is performed on the one hand by investors through the allocation of capital between securities and on the other hand by firms with the allocation of investment within the projects.

Despite the issue of internal allocation of capital, financial theory developed with little connection with the field of production. This disconnection is surprising when we consider the intrinsic link between financial and production purposes. Production equilibrium focuses on the issue of internal allocation of resources for the maximization of the profitability of the firm. It deals with the maximization of the production potential with respect to the quantity and the price of factors employed. Nevertheless, the modeling of complex mechanisms that underlie the general equilibrium requires the separability in sub-issues and the maintain of assumptions about partial equilibria. Likewise, production and financial theories evolved separately under the assumption that these specialized optima can be solved without affecting the optimum of the global solution. Fundamental contributions in finance attest this disconnection. Fama and Miller (1972, p.108) write about the analysis of capital budgeting of the firm:

...we consider the investment decision of the firms whose shares are traded in perfect capital markets... Strictly speaking, such decisions are technological rather than financial problems and so belong to the field of production. For a variety of reasons, however, the general subject of capital budgeting has come to be taught in finance courses...

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As a matter of fact, financial theory takes into account production inefficiencies in a very restrictive setting. The harmonistic functioning of the market, which states that a disequilibrium in production is compensated by the modification of the financial equilibrium, is only possible if the production inefficiencies are an externality of uncertainty.

The purpose of this chapter is to present the extent to which the models of financial equilibrium are compatible with the different sources of technical inefficiencies. This question raises several issues:

- How the cost of equity based on the mean expected stream of profits and investors' average preferences can carry production to its maximal potential?
- Does the market provide the appropriate signal for firms to drive production decisions?
- Is the market value maximization the right corporate objective function in a world featured by technical inefficiencies?

To answer these questions, this chapter is organized as follows:

- The first section develops the conditions of market equilibrium. It implies to satisfy three partial equilibria. This section defines each equilibrium and the related concepts employed in next sections.
- The second section is dedicated to the Modigliani-Miller-Diamond Model that bridges the gap between optimal production decisions and stock price equilibrium based on the concept of risk class. This section provides the demonstration that the existence of inefficiency is not allowed by the theoretical model of stock valuation.
- The third section is dedicated to the CAPM framework based on portfolio theory that provides an interpretation of inefficiencies consistent with the Modigliani-Miller-Diamond Model.
- The fourth section provides theoretical evidence that technical efficiency is positively related to stock returns in very restrictive settings. The presence of inefficiency that arises from something else than uncertainty prevent the perfect correlation property that is a necessary condition for the market to achieve the optimal allocation of capital within firms.
- Finally, a third equilibrium model is introduced. Dow and Gorton (1997) Model the relation through the informative role instead of the allocation role of the stock market. The relation detailed hold in a weaker set of assumption consistent with the interpretation provided in the next chapters.

1.1 Conditions of Financial Equilibrium

A clear understanding of the relation between the production modeling and the financial modeling of the firm requires to take a short detour to the theoretical link initially

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developed in financial equilibrium models. The purpose is to describe how equilibria of stock market related to traders' decisions enable the achievement of production equilibrium. The analysis of the relation implies to present 3 specialized optima described by Stiglitz (1981):

1. Exchange efficiency. Given the set of assets which are available, and the information (beliefs) of the various participants, are the available assets traded in such a way that there is no rearrangement of ownership claims which would increase the expected utility of one individual without decreasing that of some other?

2. Production efficiency. In exchange efficiency, the set of assets (securities) which are available is assumed to be given. Here, the concern is with the determination of the supply of various assets, given the available technology, resources and information. The analysis of production efficiency turns on three questions: (i) If firms maximize their market value, will the resource allocation be Pareto optimal? (ii) Would all shareholders wish firms to maximize their market value? If not, will there be unanimity in the actions they wish the firm to pursue? If there is unanimity, will the actions which are unanimously preferred be Pareto optimal? If not, what can we say about the equilibrium? (iii) Are there any control mechanisms which ensure that the managers of firms will in fact pursue the policies which are in the interests of shareholders?

The concept of production efficiency is akin to the concept of functional efficiency of Tobin (1982). This means an efficient market must allocate resources to their highest value use between firms and within firms. This concept covers the ability of the firm at selecting and implementing the investment opportunity optimally. Selecting and implementing investment refers to the capital budgeting efficiency and the technical efficiency respectively.

3. Information efficiency. In the economists' conventional analysis of efficiency (as typified, say, by the Arrow-Debreu Model), the beliefs about the probability distributions of various events (states) are given exogenously. Financial economists have rightly emphasized the importance of markets in conveying information. Information efficiency requires that: (i) the market must provide the correct incentives for gathering the right amount and kind of information; (ii) the market prices must reflect the information available to the various traders; and (iii) firms must be able to convey efficiently information about their prospects to potential investors.

Literature about the equilibrium of financial markets deals mainly with the optima 1 and 3. They are concerned with the determination of the cost of equity adjusted for uncertainty to drive internal decisions about investment and resources allocation. This literature may be divided into two separate streams. The first one is a demand based theory. It consists of deriving the value of the firm and its cost of capital from the value of identical peers traded on the market given the law of one price. This contribution results from the seminal work of Modigliani and Miller (1958) about the neutrality of financial structure on cost of capital. This Model is concerned with the market value instead of returns and with the decisions of the firm. It also provides a particular definition of uncertainty in term of negative deviation of stock performance from observed peers.

The second stream of literature is more concerned with the decision of the individual

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investor even though propositions have been derived to rule firms' behavior. This literature relies on Markowitz (1952) portfolio theory and defines uncertainty in terms of the variance of returns. The cost of capital employed for investment and production decisions is estimated as proportional to the contribution of risk the firm adds to the investors' portfolio. This theoretical path attempts to offset the complexity faced by agents in investment decisions with the reduction of firm's performance to their fundamental common factors.

A third approach provided by Dow and Gorton (1997) will be introduced. It differs from the previous two approaches by considering stock price has essentially an informative role. The internal allocation of resources is superseded to the coordination role of the manager. The Model is of interest because it does not require the perfect correlation assumption not compatible with the presence of inefficiencies. In this case, the firm does not derive the maximal production potential from the weighted average cost of capital, but from the information hold by stockholders about the value of the prospective investments.

1.2 Modigliani-Miller-Diamond Demand Based Model

The presentation of the Modigliani-Miller-Diamond highlights the requirement of a stock pricing process based on the analysis of comparables. The contribution of Diamond (1967) insists on the necessity of having a comparables analysis based on production characteristics for the valuation of firms to ensure the relation of interest. As it will be explained, the notion of comparables is very strict. The logic of the Modigliani-Miller-Diamond will echo in the presentation of the required settings for technical efficiency to be in line with stockholder value maximization, as developed in Section 4.

1.2.1 Financial Equilibrium Model: Modigliani and Miller (1958)

The Modigliani-Miller (1958, hereafter MM) discounted cash-flow Model provides a long run determination of the cost of capital with the introduction of the risk discount factor. Their contribution is considered as a cornerstone of financial theory. It echoed empirically and theoretically in capital budgeting and financing topics and in the explanation of investment behavior under uncertainty.

First, they define the stock returns as the mean value of the streams of profit over time. These streams are supposed randomly distributed and subject to investors' subjective probabilities. Despite differences in the appreciation of returns distribution, investors agree on firm's future performance and it is assumed they are only concerned with average earnings over time. This stock price formation hypothesis is reasonable in the long run. In the short run, the returns of the firm is more likely to have little connection to the decision of the firm Leland (1974).

The next crucial hypothesis is the existence of *equivalent returns classes*. This assumption aims at classifiying firms into homogenous groups within which firms exhibit proportional returns. Firms i and j belong to the same risk class and are contained to provide equivalent returns if:

$$X_{i(t)} = \lambda X_{j(t)} \text{ and } I_{i(t)} = \lambda I_{j(t)} \tag{1.1}$$

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where $X_{i(t)}$ and $X_{j(t)}$ are the net cash flows before interest of the firms at t, $I_{i(t)}$ and $I_{j(t)}$ the cash outlays at t for investment and λ a scale factor. " *Whithin the same class, firms differ at most by a scale factor*" (Modigliani and Miller, 1958, p.266). Hence firms within risk classes are perfect substitutes and are perfectly correlated since probability distribution must be identical. The concept of homogeneous risk class is analogue to the concept of industry.

From these two hypotheses and the assumptions related to pure competitive Marshallian price theory and perfect capital market, they derive the following relation of expected return to current stock price:

$$SP_i = \frac{1}{\rho_k} \cdot \bar{X}_i \tag{1.2}$$

The equation expresses the stock price as a function of the capitalization rate $\frac{1}{\rho_k}$ for the expected value of an uncertain pure equity stream of profit of risk class k and $\bar{X}$ the expected streams of earning. Obviously, ρ_k is different from class to class and is increasing with uncertainty. It is also supposed to reflect the covariance with the returns in other classes. It follows from their Model that the price per dollar's worth of expected returns must be the same for all shares of any given class. Based on this framework, they define uncertainty as the risk associated with a return below the one required for the risk class subsumed from the peers' level of profit. However, their definition of uncertainty is not akin to variance nor semi-variance. They point out that variability and uncertainty are different concepts. The practical significance of the Model is the evaluation of the worthwhileness of an investment by the increase in market value it is expected to generate. Since undertaken investments increase valuation until their rate of returns are above the cost of capital; cost of capital and valuation are intimately related (Gordon and Shapiro, 1956).

1.2.2 General Equilibrium Model: Diamond (1967)

Diamond (1967) develops a general equilibrium model based on MM (1958). His modeling implies to redefine the risk class concept in a way that is more consistent with production decisions. Nevertheless, the redefinition of the risk class concept and the resulting development contains a strong assumption about the characteristics of technical efficiency.

Redefinition of Risk Class for Production Decisions

Even though MM (1958) has been extended for the effects of taxes, growth potential, payout policy and distress costs; few theoretical contributions attempted to connect this theory with the issue of optimal production. Diamond (1967) is the first and the main paper that provides a description of production decisions in the context of market equilibrium based on the discounted cash-flow model. Diamond (1967) treats the link of stock market to production equilibria under technological uncertainty. His contribution is well-known for the concept of *constrained efficiency* in a world of one-good incomplete market, but we are focusing here on the mutual influences between stock market and production.

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Diamond (1967) redefines the notion of risk class provided by MM (1958) by employing the notion of *pattern of outputs* that is the relative output given the occurrence of the state of nature. The use of pattern of outputs instead of risk class overcomes the intuitive shortfall of the MM (1958) condition. Indeed, defining risk class in terms of average streams of earnings does not imply that they are perfect substitutes for one another. Indeed, two firms having the same variance and the expected returns would not necessarily carry production at the same point given the state of nature. Equal average and variance does not mean equal probability distribution for each state of nature.

The need for precise definition of the class is relevant since the firm cannot extract the appropriate price for production allocation by its own. It needs to benchmark with similar firms - having the same pattern of outputs - to derive its marginal output. If there are more firms than states of nature and each pattern of outputs is sufficiently competitive; the firm can maximize its value by performing production marginal calculation based on its own value (Gordon and Shapiro, 1956). This process consists of maximizing its relative value, that is the maximization of profit of its outputs pattern.

Production Decisions and Technical Inefficiencies in Modigliani-Miller-Diamond Approach

Following the certainty equivalent definition, Diamond (1967, p.767 Eq. (21)) indicates the value of the firm corresponds with the marginal rate of utility of substitution of riskless asset for a firm's stock joined with the realization of the state of the nature. He formalizes the value V of the firm j as follow:

$$V_j = \frac{\int U_i' \pi_j(\theta) h_i(\theta) d\theta}{\int U_i' r h_i(\theta) d\theta} \tag{1.3}$$

where U represents the utility function for consumption of the individual investor i and $\pi_j(\theta)h_i(\theta)$ is the expected stream of profit conditional for the state of nature θ and r the riskless rate. The market value of output then is obtained by the equality:

$$V_j + k_j = \frac{\int U_i' y_j(\theta) h_i(\theta) d\theta}{\int U_i' r h_i(\theta) d\theta} \tag{1.4}$$

where k_j and y_j refer to the single input and the single output sets respectively. Given the relation between output and market value in Equation (1.4), the producer would carry production to the point where the derivative of the market value of output given input equals 0 so as to maximize the utility for future stream of consumptions. Equation (1.4) presents there exist a bidirectional relation of production decisions, and a fortiori technical efficiency, to stock return. On the one hand, the market value drives the volume of output and, on the other hand, stream of profit that arise from production activity are valued on the stock market. The effect of technical inefficiency is discussed by Diamond (1967, p. 767). Regarding Equation (1.4), the firm j exhibiting input excess k_j comparing with the technically efficient firm l which belongs to the same pattern of outputs. Hence, the value of the firm j will lower market value in order to restore the value potential of the firm with regard to the risk class. In this approach, the hurdle rate is given by the best peer sharing the same pattern of outputs.

The limit faced by the Diamond Model is the way the firm would be able to obtain the appropriate price for risk in order to perform its marginal calculation. About this issue, he writes:

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"this price might be found in the value of some other firm (or combination of firms) if the marginal pattern of outputs of the first firm coincided with the total pattern of the second at the equilibrium input levels. ... Note that exactly the same patterns of outputs are required for this calculation. Two firms with the same expected returns and the same variance (using someone's subjective probability) will not, in general, carry production to the same point.

It would be surprising if firms were capable of carrying out this calculation exactly. However, we might expect them to approximate it reasonably well if the major risks are decomposable into particular types which are fairly common. "

1.3 Traditional Mean-Variance Portfolio Models

The Mean-Variance approach provides a partial response to the limitation noticed by Diamond (1967). The Mean-Variance approach presents the relation of interest from the point of view of the stockholder. Contrasting with MM (1958), it considers that the risk corresponds with the variance of returns. This theoretical model completes Modigliani-Miller-Diamond by providing a framework to capture and decompose risk into particular types which are fairly common. Nevertheless, the modeling of the general equilibrium requires again the maintain of the perfect correlation assumption. In addition, issues related to the externality of efficiency improvements may alter the stockholder individual equilibrium. These latter issues will be discussed in the section IV. The present section is concerned with the explanation of the framework. It encompasses the definition of the Efficient Market Hypothesis (EMH), the explanation of the diversification principle and the presentation of the Capital Asset Pricing Model (CAPM).

1.3.1 Framework

Financial development about decisions under uncertainty has mainly been dedicated to the rational investment of individuals through portfolio theory. Then it is concerned with the investors rather than manufacturing firms (Markowitz, 1991). It is based on the investors' individual equilibrium and assets are reduced to the statistical behavior of their returns. Contrasting with MM (1958), uncertainty is defined in term of the variance of returns. However, they share the concept of idealized uncertainty that assumes investors implicitly agree on the relevance of information and its role about the distribution of expected returns. This framework raises assumptions about the financial market and the behavior of individual agents.

The financial market is supposed to be semi-strong informationally efficient in the sense of Fama (1970). This means that at any point in time the stock prices fully integrate the information set,i.e, prices integrate all available and relevant information about future earnings. Alternatively, this means there is no gain feasible on the basis of the information set (no arbitrage feasible) (Jensen, 1978). The expected returns are assumed to follow a random walk. They are stationary, independently and identically distributed of the information set. This specified conditions describes an environment in which the evolution of preferences about risk and time and the generating process of new information is combined to achieve equilibria where the distribution is repeating over time. The market

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is assumed free of transaction costs and prices reflect information to the extent of its marginal cost of acquisition is below the marginal benefit associated.

Individuals are rational and seek to maximize their future wealth through investment in securities. They can lend and borrow at the risk free rate, but their transactions cannot affect market prices. Individuals share homogenous expectations about future returns. They derive the same and correct assessments on the distribution of future returns from the information set. In addition, they perform investment decisions period after period and have the same time horizon. This assumption enables the correspondence between *ex ante* beliefs and *ex post* returns distribution. Individuals behave following the diversification principle described by Sharpe (1963).

1.3.2 Diversification Principle

The concept of diversification describes how an optimizing investor would behave. This concept has been introduced by Markowitz (1952) and refined by Sharpe (1963). Markowitz (1952) theory provides a rational investment behavior based on portfolio diversification (Tobin (1958); Roy (1952)). The rational is the minimization of the expected risk given the level of expected return. While, in certainty setting the rational investment behavior would be the selection of the asset providing the highest present value, the diversification based on probabilistic definition of uncertainty suggests the exploitation of securities' correlation through the holding of multiple assets. Except for the risk free rate, the correlation among assets is not null. Hence, the issue of asset selection is treated in the light of statistical characteristics of assets holding in the portfolio. The contribution had great implications on practices and theory of individual agent's equilibrium under uncertainty. In addition, the Markowitz (1952) principle is a cornerstone of modern finance: *"a rule of behavior which does not imply the superiority of diversification must be rejected both as a hypothesis and as a maxim."*

Sharpe (1963) improves the Markowitz procedure with both the addition of the risk free asset and the concept of market portfolio. The market portfolio is the market index composed of all firms in the economy in proportion of their market value (Black, 1972)[1]. The development of the concept of market portfolio relies on the idea that stock price variation is ultimately driven by common market factors that impact all firms. If the specific risk associated with the holding of a limited number of stocks may be offset by diversification, its advantage is limited by the average of their covariance. He suggests that the holding of the market portfolio is the ultimate diversification. It enables to reduce the risk exposure to the fundamental source of risk in the economy. Consequently, the risk of interest is the systematic risk that is the risk that impacts the economy as a whole. Since agents are assumed risk adverse, they hold the market portfolio.

The next insight of Sharpe is the implementation of financial opportunities in the opportunity set that allow investors to borrow or to lend money at the risk free rate so as to adjust the risk exposure of their portfolio. Likewise, the choice of proportion of risky and riskless assets allows investors to maximize their expected utility toward risk. This principle inherited from Tobin (1958) is the two funds separation theorem.

The contribution of Sharpe (1963) provides a considerable reduction of complexity of relations that shapes the stochastic dynamics of assets' returns. Sharpe (1963)'s contribution shifts the analysis of risk from the standard deviation of the portfolio's constitutive

[1] This is a necessary condition for the market equilibrium (Black, 1972)

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securities, like the Markowitz framework, towards the analysis of the returns distribution of the market portfolio. Likewise, a rational investor focuses on forecasting activities on the anticipation of the market portfolio rather than individual stocks.

1.3.3 Capital Asset Pricing Model

Sharpe (1964), Lintner (1965) and Mossin (1966) pioneered the appropriate quantification of the risk premium in a single period. The barest essential argument of Sharpe (1964) is to express the risk premium of a security as proportional to the market premium provided by the market portfolio. The proportionality is expressed with a single common factor coefficient.

The consequence of Sharpe (1963) developments in portfolio theory is to focus the analysis of the individual stock's risk on its covariance with the market portfolio. Sharpe, since specific risk is eliminated through diversification, argues the only risk that deserves to be compensated for investors is the systematic risk. We can infer the systematic risk of individual stock and estimate a corresponding premium by measuring the correlation coefficient between the asset and the market portfolio.

Given the stock i is a constituent of the portfolio M:

$$\beta_i = \frac{Cov(R_i, R_M)}{\sigma^2_{R_M}} \tag{1.5}$$

The β is a measure of the market value weighted average sensitivity of the stock returns i relative to the variation of the market index. The β is featured by its magnitude and its sign. Given β is greater or lower than 1, the stock price over-reacts or under-reacts to market variations. A β equal to 1 replicates market's variations. A negative β varies in the opposite direction of the market variation, while a positive one follows market variations. Intuitively, the closer a β is to 0, the less the asset adds risk to the market portfolio or alternatively the larger its proportion of diversifiable risk is. Indeed, the riskless rate of returns R_f has a β equal to 0. Sharpe (1964)'s model applied to individual stock assumes the risk premium of the stock i is a linear function of its covariance with the market portfolio as depicted by the Security Market Line (SML) in Figure 1.3.3.

Figure 1.3.3 depicts the linear relation of the firm i with the market portfolio M. Since the firm i provides a greater beta, that is to say provides more variance in response to the market portfolio's variations, the corresponding returns are higher. At the intercept, the only asset that provides returns is the riskless rate. Consequently, we can infer from β_i its corresponding risk premium given the Capital Asset Pricing Model that corresponds with the equation of the SML:

$$R_i = R_f + \beta i \cdot (E(R_M) - R_f) + \epsilon_i \tag{1.6}$$

where $(E(R_M) - R_f)$ is the expected risk premium, that is the compensation for switching from a riskless to a risky asset, and β_i is the coefficient that reflects the proportionality between the risk premium of asset i and the market premium. ϵ_i is the weighted sum of firms-specific random variables normally distributed with $E(\epsilon_i) = 0$. Given the law of large numbers, this risk must be avoided with a well diversify portfolio. ϵ_i is supposed to

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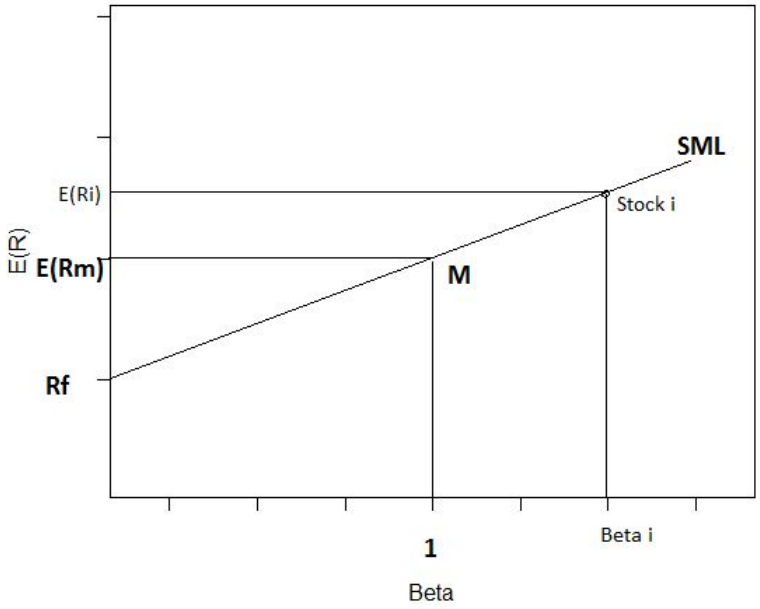

Figure 1.1: Security Market Line without ϵ

be independent from the β_i[2]. Finally, the variable of interest R_i is the required expected return on asset i given the risk incurred β. R_i corresponds with the cost of equity at which projects must be evaluated and stock of capital goods must be adjusted to run production.

The CAPM has important embedded implications that have been empirically tested by Fama and MacBeth (1973). First of all, at equilibrium the CAPM imposes the linearity of the relation of stock returns and its risk in the market portfolio. This property implies that the difference between $E(R_i)$ and $E(R_M)$ is proportional to the risk the asset adds to the portfolio. The second key implication is the completeness of the β as measure of risk assuming no other source of risk can significantly explain the average expected return. Finally, CAPM framework implies that higher risk must be associated with higher return. Finally, the CAPM is essential for the analysis of risk. It formalizes the intuitive feeling that the sources of risk balance between two extremes: the firm-specific and the common market factors.

1.4 Production Decisions in CAPM Framework

This section bridges the production decision making process with the stock pricing dynamics within the CAPM framework detailed previously. The interest of this section is twofold. First, it details the process by which efficiency and stock returns interact. Next, it provides evidence that the presence of strictly convex cost function and random prices are the necessary settings for the improvement in technical efficiency to be in line with stockholder interest.

[2]As Fama and MacBeth (1973) provide evidence in the Appendix A of their contribution, ϵ_i and β_i are not perfectly independent. A portion of the specific attributes captured in the random error is related to the common market factor.

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1.4.1 Schematic Relation

The CAPM deals only with the appropriate quantification of the cost of equity adjusted for the risk in stationary equilibrium. The relation between each equilibrium is depicted by Figure 1.2. Following the EMH and the method provided by Sharpe (1964), informational efficiency and exchange efficiency are required for prices to guide capital allocation to achieve capital budgeting efficiency and technical efficiency. Figure 1.2 depicted the process by which expectations drawn on the basis on the information set drive internal resources allocation. The red left square refers to the informational efficiency. This implies all valuable information is available on the market and investors trade on it such as no arbitrage is feasible. Based on information, traders draw expectations on the expected performance of the market portfolio and on specific assets. Given their preferences for future consumption and risk, they construct a portfolio more or less composed of riskless assets. Then they estimate the expected premium of the firm i is entitled to provide regarding the risk it adds to their portfolio. Likewise, investors are compensated by the risk incurred by the holding of the asset. It results from these operation the achievement of the exchange equilibrium and the estimation of the hurdle rate at which the firms must undertake investment and implement production. Value maximizing firms must allocate their resources given this hurdle rate to achieve the production equilibrium - production efficiency and capital budgeting efficiency. *Ex post*, information about the production equilibrium will complete the information set.

Nevertheless, the schematic relation between information and exchange efficiency with production efficiency requires specific settings, otherwise the achievement of one equilibrium can create disequilibria. If seminal contributions about stock market equilibrium developed with little or no connection with production equilibrium, a stream of theoretical research about general equilibrium investigated their relation within mean-variance. Despite debates about the cause of the disequilibria, all researchers agree about the incompatibility between the production equilibrium under certainty and the two-parameter based stock market equilibrium except in very restrictive settings (Stiglitz (1972); Jensen and Long John B. (1972); Fama (1972); Merton and Subrahmanyam (1974); Leland (1974)). The barest essential of the argument is that the externalities from production and investment decisions modify the portfolio distribution in a way that prevent the individual equilibrium defined by exchange efficiency. The issue lies in the undiversifiable risk component. At the industry sector level, differences in market value of value maximizing firms reflects differences in specific operations, as well as the market expansion against competitors, captured in the idiosyncratic risk. Hence, it will modify the structure of the value weighted market portfolio and thus the distribution of returns in a way that may dissatisfy investors.

This effect raises two sub-issues about the right corporate objective function of the firm. Should the firm maximize its market value? Given the resort of probabilities to assess the fair risk adjusted cost of equity, how the firm can achieve the production efficiency from a mean expected cost? These questions are answered in the following subsection.

1.4.2 Triptych Risk, Scale of Operation and Market Value: Leland (1974)

Leland (1974), inspired by Diamond (1967), proposes to reconcile production efficiency

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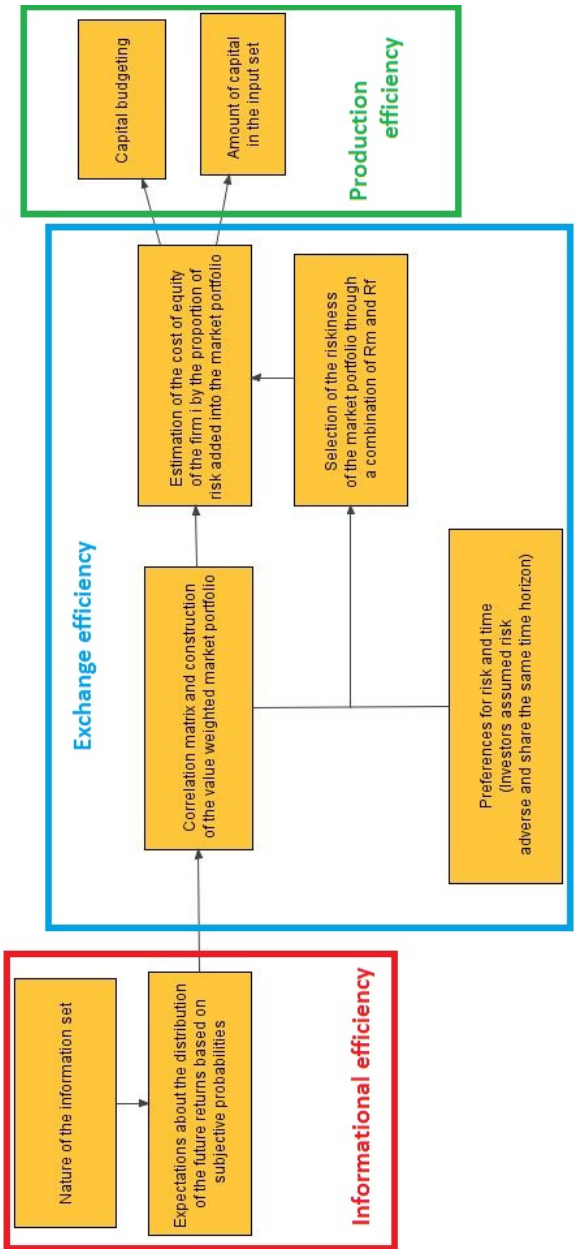

Figure 1.2: Stock Market Efficiency within CAPM Framework

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and exchange efficiency through the redefinition of the framework of the value maximization corporate objective function. He establishes that investors may reach the individual equilibrium by altering the distribution of assets that compose their portfolio through the adjustment of the level of output produced by firms. We detail here his integrated model of production in CAPM framework. He consider:

- The firm is a price taker. The selling price is supposed random, but the cost function is known.
- Profits depend on production decisions and on θ (an unknown state of nature).
- The financial equilibrium implies that the maximization of the expected utility of returns of the portfolio of investor $E_i[U_i(R_i, \theta)]$[3]
- Given the market value of the firm V equals the sum of firms' discounted profits π^j; V is a function of the level of output q. The market value and the return are expressed following the certainty equivalent method.

To ensure the financial equilibrium, the maximization of the expected utility of the investor i subject to profit function must be obtained by the first order condition:

$$E_i \left\{ U_i'(R_i, \theta)[p^j(\theta)q^j - C^j(q^j) - r\hat{V}^j] \right\} = 0 \tag{1.7}$$

where

$$\pi^j = p^j(\theta)q^j - C^j(q^j) - r\hat{V}^j \tag{1.8}$$

is the profit function.

$p^j(\theta)q^j$ is the revenue of the firm j for the quantity produced q and the output price p given the state of nature θ. $C^j(q^j)$ and $r\hat{V}^j$ are the variable cost and the fixed cost respectively. We note that the fixed cost refers here to the stock of capital goods involved in the production. The stock of capital goods is a function of the market value at equilibrium $\hat{V}$ and r the pure market interest rate.

Equation (1.7) tells the firm j must choose its profit stream in a way that maximize the expected utility of the investor i that depends on the structure of his portfolio. For the sake of tractability, the CAPM assumes all investors hold the same portfolio. Since the firm is a price taker, it can only alter the stream of profit by fixing the level of output k to maximize investors' expected utility. Then the choice of the level of production must be driven by (1.9):

$$\frac{\partial E_i[U_i(R_i, \theta)]}{\partial q^k} = 0 \tag{1.9}$$

that provides the increase in expected utility for wealth per unit of additional output produced. The financial equilibrium must be specified given the equilibrium of production decisions. In certainty settings, the production equilibrium is achieved when the production level is given by the equality between the marginal costs and the output price.

[3]Assumptions about investors arise from CAPM. Investors hold the market portfolio, rank investment opportunities given mean-variance approach, share homogeneous expectations for profits and have utility function $U'(R_i, \theta) > O$ and $U''(R_i, \theta) < O$.

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Hence, an alternative specification of Equations (1.7) and (1.9) taking into account the production equilibrium must be:

$$E_i \left\{ U_i'(R_i, \theta)[p^j(\theta)q^j - MC^j] \right\} \tag{1.10}$$

Where MC the marginal cost for the production q is given by:

$$MC^j(q^j) = \frac{dC^j(q^j)}{dq^j} \tag{1.11}$$

At this stage, Leland (1974) splits from the production equilibrium under certainty by introducing a new fundamental equilibrium condition in which the firm must reach its minimum cost, but does not maximize its production potential:

$$\frac{C^k(q^k) + r\hat{V}^k}{q^k} = MC^k(q^k) \tag{1.12}$$

This condition means the firm must select an output level q such that its average cost $\frac{C^k(q^k)+r\hat{V}^k}{q^k}$ equals its marginal cost. The implication of the model of production decisions is intrinsically linked with the current market value $\hat{V}$ and the expected return r . This relation between the cost function and the market value is in line with the one established by Diamond (1967) (see Equation (1.4)). It implies that a rise in fixed cost will lead to a rise in output scale without changing market value. Again a change in investors expectations will lead to a change in market value and output, but it will not affect costs.

In order to correspond to the mean-variance framework, Leland (1974) substitutes Equation (1.12) by (1.14). This is presented in Equation (1.13).

$$\hat{V}^j(q) = \frac{E\pi^j - kVar(\pi^j)}{r} \tag{1.13}$$

Equation (1.13) corresponds with the market value of the firm j expressed in certainty equivalent. Market value is a function of the variance of the profit π and the respective risk premium k. In order to adjust the equality in (1.12) for risk, the amount of output produced must be proportional to variance associated with the holding of the asset j:

$$E(p^j) - \frac{kVar\pi^j(\hat{q}^j)}{\hat{q}^j} = MC^j(\hat{q}^j) \tag{1.14}$$

It follows from (1.14) that the scale of operation is a negative function of the riskiness of the firm in order to lower the effect of the risky firm on the investors' wealth. Only a riskless firm would run production to its highest potential. Hence, firms sharing same exposure toward risk are supposed to provide the same quantity of output.

1.4.3 Perfect Correlation Property: A Necessary Condition for Market Efficiency

The modeling of Leland (1974) requires the satisfaction of the perfect correlation assumption. This assumption implies that firms having similar characteristics must exhibit

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the same expected rate of return. Likewise, a firm can infer their cost of equity from the cost of equity of its peers to perform marginal calculation required for the adjustment of capital goods. This property is incompatible with the presence of inefficiency. In addition, if this assumption is not met, the corporate objective function cannot be maximizing the value of the firm. This is detailed in the third paragraph.

Perfect Correlation Property

The perfect correlation assumption is a necessary condition for the simultaneous achievement of the production efficiency and exchange efficiency. The definition of the perfect correlation property differs between CAPM and MM frameworks, but its interpretation is the same. At its barest essential, the perfect correlation assumption states that two value maximizing firms facing the same investment and financial opportunity set and the same technology (that is to say production possibility set) must have the a valuation that differs at most by a scale coefficient[4]. In the MM (1958) framework, firms are perfectly correlated when they exhibited the same pattern of returns for any realization of the state of the nature. In the CAPM, firms are perfectly correlated if they have the same exposition to the systematic risk (Sharpe, 1964). King (1966) notes that similar correlation with market factors witnesses underlying common characteristics as well as firms belonging to the same industry exhibit greater correlation. He reveals the returns expressed with CAPM is a linear function of effects ranked according to their scope. Hence, the more the underlying technology that rules operations of firms is similar; the more their responses to changes in market factors converge. In the CAPM as well as the MMD model, comparable firms must carry production to the same point and exhibit the same inefficiency levels for every state of nature.

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[4]Financial theory frequently employ investment and production as equivalent. Even they are intrinsically related they are not strictly speaking the same. Investment is concerned with the allocation of financial resources in projects that maximize the return, while production is concerned with the implementation of the project.

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MMD model, comparable firms must carry production to the same point and exhibit the same inefficiency levels for every state of nature.

Implication for Production Efficiency

Perfect correlation assumption is a necessary condition because it assumes that at any point in time, the value maximizing firm subsumes its cost of equity at which it will value investment and adjust the stock of capital goods from the observation of its perfectly correlated peer. The operational implication is summarized by Leland (1974) in his Theorem 6:

There is, however, an environment in which firms, thinking they are maximizing market value, make decisions which coincide with the q^k (production level) *that stockholders wish.*

Theorem 6: *Value maximization in a competitive environment. Assume that a firm operates in an industry in which firms face the same random price and possess identical strictly convex cost functions. Then the firm will maximize its market value relative to other firms in the industry by setting qk=q, the output which is unanimously supported by stockholder.*

This setting imposes the absence of technological restriction and frictionless environment. Technical inefficiency can only be an externality of uncertainty. In a world characterized by uncertainty, the planner does not know whatever will occur between production decision and effective outcome. This uncertainty arises from technology or market supply and demand. Differences between planning and realization is the only source of inefficiency that is compatible with competitive market (Caves and Barton, 1990 and 1992 in Alam and Sickles (1998)). All other sources of technical inefficiencies, as well as technological restrictions or management incompetence, described as the dominant pattern of the economy by Leibenstein (1966) would violate perfect correlation property. The consequence would be to prevent stock market to achieve production efficiency.

Implication for Exchange Efficiency and Corporate Objective Function

The next important implication of the violation of the perfect correlation property is concerned with exchange efficiency. If the production and investment decisions are likely to affect the distribution of the future returns of the investors' portfolio, the firm must not be driven by the value maximization target. The unanimity theorem should prevail. It means that despite their differences in expectations and attitude toward risk, investor will agree on the production level of output to maximize their self interest given their portfolio. The specification of the right corporate objective function in a non-competitive situation gave raise to an extensive literature. Grossman and Hart (1979) proposes to maximize the value of original shareholders, while Dréze (1974) considers it is better to focus on new shareholders. Damodaran (2001) suggests to take decisions according to their effects on the expected wealth of the marginal stockholder. This latter is the more likely to be engaged in the next trade.

Anyway, disagreement among shareholders create distortions in the determination of the future production decisions. Consequently, the market would fail in its resources allocation role and in the determination of future production even though investors have

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rational expectations (Geneakopoulos et al., 1990; Stiglitz (1981); Newbery and Stiglitz (1982)).

1.5 Managerial Effectiveness under Equilibrium: Dow and Gorton (1997)

The Dow and Gorton (1997) equilibrium focuses on the relationship between stockholders and managers in the case of asymmetry of information about the value of projects in the investment opportunity sets. The equilibrium is concerned with the efficiency of the capital budgeting rather than technical efficiency, but the definition of the role of the stock market has an interesting property for our topic. Model differs from previous equilibrium models by considering the financial market has no direct role in the internal resources allocation. Then the allocation is performed by the manager empowered by stockholders.The managers aim at achieving economic efficiency by obtaining as much information as possible about the future value of projects in the investment opportunity set. Contrasting with Modigliani and Miller (1958) and Leland (1974):

- The stock price has not a direct allocative role. The allocation of resources is performed by management central planing instead of price mechanisms. Indeed, the management has the complete discretion about both the investment projects and the quantity of capital to raise. It does not need to derive optimal quantities from stock return. Stock price has an indirect allocation role since managers take decisions with regard to the information conveyed by stock prices about the prospective investment.
- The primary role of stock prices is informative. Stock prices convey information about the potential outlays of the firm and about past management performance.
- The information flow is bidirectional. It arises first from informed traders who have an incentive at producing information and trade on it because the managers take decision with respect to that information. Next, the manager has knowledge about the profitability of the available project. The manager is compensated for the effort of producing information about the potential investment.

The implication of this definition of the role of stock prices is that firms' cash flows are not assumed to be exogenous. The optimal allocation of investment is done by providing the right incentive for management to produce information and take decisions in a way that maximizes stock value. The management is entitled to make efforts to increase its information set about the prospective value of the investments. The process by which management makes optimal investment decisions is intrinsically relates to the production of information. The process is depicted by Figure 1.3.

Figure 1.3 focuses only on the prospective role of the stock market that is to say its role at producing information from informed traders and manager related to investment that has not been yet undertaken. The process contains 5 sequences. In the first one, traders provide favorable or unfavorable information about the future investment by buying or selling stocks. In the latter case, managers do not invest. In the former case, the manager

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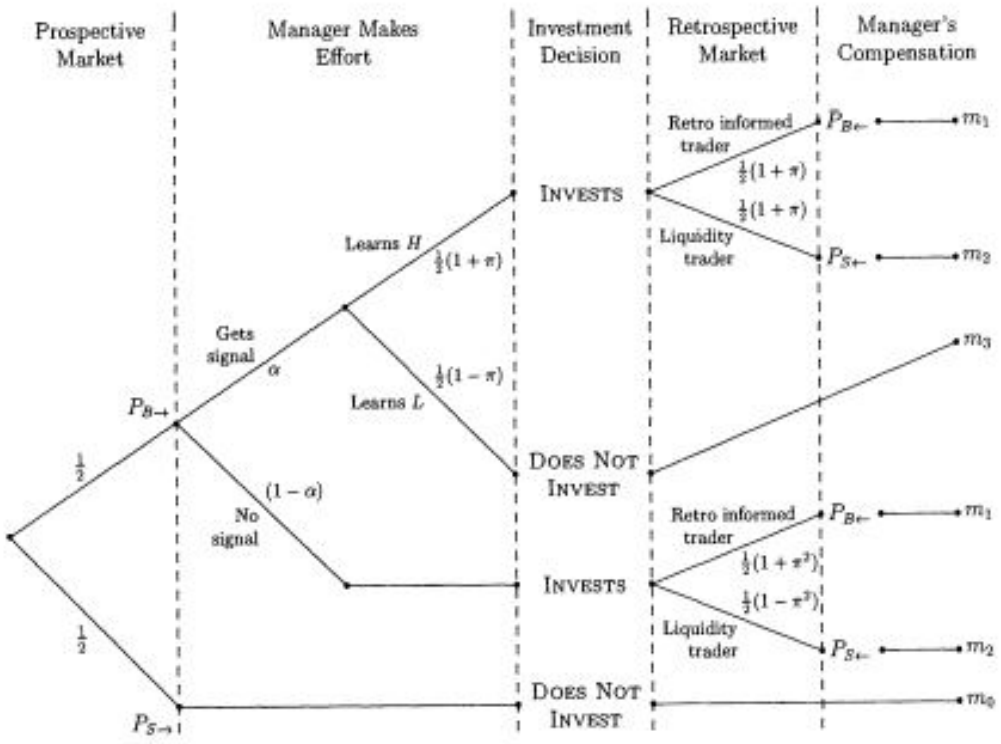

Figure 1.3: The Sequence of Events Starting in a Prospective Market *(Source: (Dow and Gorton, 1997, Figure 2 p.1101))*

may invest after seeking to guess a private information hold by traders into stock prices. This is the second sequence. If the management learns the project will provide a high return, so the stock price will increase. As soon as the project is undertaken (sequence 3), the stock price rises to take into account the expected future cash-flows. If the private information provided by traders is unfavorable, the manager will not invest (sequence 3). Nevertheless, the market that plays a retrospective role will value the skills and the faith of its manager that is to say its ability at seeking information to achieve efficient capital allocation. In this way, the market plays its retrospective role (sequence 4). This increase in stock valuation benefits to the manager which receives a compensation proportional to stock prices (sequence 5).

If the equilibrium model of Dow and Gorton (1997) deals with the efficiency in the selection of the investment projects, it implicitly involves technical dimensions related to their implementations[6]. The contribution deserves interest in the sense it insists on the effect of managerial quality on the production of firms cash-flows. Contrasting with previous models, the Dow and Gorton (1997) equilibrium insists on the importance of the managerial skills in the stock valuation. In this sense, management is a production factor. The production efficiency then is not concerned with an optimal state of the firm, but is related to the measurement of the quality of this latter production factor.

[6]The relation between the choice of the projects of investment and the technical efficiency is limited with respect to the economic modeling. The modeling is generally based on the assumptions of the IID of investment in the investment opportunity set and the additivity property. The relation between investments choices and technical choices is in practice intrinsically related. For instance, the search for synergies by producers is at odds with both assumptions.

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Conclusions

This preliminary theoretical chapter aimed at describing how financial equilibrium models deal with the existence of technical inefficiency. This issue is important because these equilibrium based models constitute the foundation of the empirical tools employed to perform the capital allocation. Three models have been investigated: The Modigliani-Miller-Diamond model, the CAPM framework and the Dow and Gorton (1997) equilibrium. The first two models differ from the Dow and Gorton (1997) in the explanation of the sources of cash flows and in the specification of the interaction between stock returns and investment and production decisions. The CAPM and the MMD models consider that cash-flows of the firms are mainly driven by exogeneous factors. In addition, they consider that stock returns plays a direct role in the capital allocation. On the one hand, the stock market prices guide investment and production decisions. On the other hand, the resulting allocation of capital for investment and production decisions produces streams of profit valued on stock market. The presence of technical inefficiencies is reflected by the stock market through the reduction of the market value proportional with the expected profit shortfall related to this inefficiency.

However, the CAPM framework, grounded on portfolio theory, reveals that the maximization of the production potential in uncertainty settings is likely to alter the value weight of the investors' portfolio and *a fortiori* the expected distribution of returns. This negative interaction between the production equilibrium and the exchange equilibrium is viewed of an externality of production decisions under uncertainty when the production function is non-convex and contracts are incomplete. To avoid these externalities Leland (1974) proposes to adjust the firms' scale of operation by their risk. He suggests to modify the corporate objective function by focusing on the unanimity of stockholders instead of the value maximization of the firm so as to preserve the expected distribution of assets' returns. These two objectives are consistent only in very restrictive settings incompatible with inefficiencies that result from something else than uncertainty about the technology.

In the case where technical inefficiency arises from something else than uncertainty and is persistent, the necessary perfect correlation assumption of the firms belonging to the same industry does not hold anymore. The presence of the perfect correlation assumption permits firms to infer from the observation of their peers the appropriate hurdle rate at which investment and production allocation must be performed. Consequently, the presence of such inefficiencies, if these are the dominant pattern as stated by Leibenstein (1966), make stock market unable at providing the appropriate price that will carry firms to their optimal production combination.

The Dow and Gorton (1997) model differs from the CAPM and the MMD model by introducing distances between production and investment decisions and stockholders. It states that the allocation is performed by manager and does not result from price mechanisms. This model focuses only on the informativeness role of stock prices and on the asymmetry of information between stockholders and the manager. The presence of inefficiencies that do not result from uncertainty is possible and may be solved by the manager by obtaining information about the investment opportunity set. Following this model, managers seek to maximize their compensation based on stock prices by maximizing the value of the investment they perform. Hence, these aim at obtaining as much information as possible from traders holding private information about the investment opportunity set. This effort at seeking information to optimize investment policy is valued by the stockholder and constitutes a measure of management effectiveness. Consequently,

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the manager is a full-fledged production factor whose quality is valued by the stock market. In addition, the importance of the perfect correlation assumption is lowered.

Despite the inconsistency between the first two equilibrium models and the existence of technical inefficiencies, the tools derived from these framework are compatible with the view of Dow and Gorton (1997). The CAPM framework is more flexible to account for differences within firms even after taking into account fairly common risk factors. This topic will be discussed in Chapter 3. The following theoretical chapters deal with the measurement of technical efficiency, its information content and its empirical relation with stock returns.

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Thèse de Matthieu Belarouci, Lille 1, 2013

Chapter 2

Analysis of Production Performance: Frontier Analysis Framework

The analysis of the performance of the firms always relies on a particular modeling of its activity and environment. Finance models firms as a collection of assets and seeks to maximize their value potential in an environment assumed to be driven by stochastic processes. The economic modeling of the theory of production, and frontier analysis in particular, approaches the firm as a collection of heterogeneous production factors and seeks to maximize the production potential of the firm in a engineering sense or to maximize some economic value function (e.g., profit). The measures provided by production frontier analysis differ depending on the data availability, the assumptions about the technical environment and the assumptions maintained about the behavior of the producer. This chapter discusses the implications of each of these aspects in the modeling and the interpretation of the performance of the firms.

The first section details the modeling of the production of the firm in frontier analysis. The second section presents the different performance measures provided by the decomposition of the production process into technical function and a value function. The third section presents data envelopment analysis as one of the methods of reference to assess performance in static setting following alternative modeling of technical efficiency. Finally, the fourth section develops the issue of the dynamic evaluation of technical efficiency based on multilateral productivity indices. The purpose of this last section is twofold. On the one hand, we discuss how the use of multilateral productivity indices based on DEA models enable to evaluate a complete measure of productivity. On the other hand, we present how productivity indices enable to distinguish the sources of efficiency and productivity changes. The Malmquist index and the complete Hicks-Moorsteen and Färe-Primont indices, according to the specification of O'Donnell (2010), are discussed.

2.1 Modeling Production

The measurement of efficiency by frontier analysis relies on a conceptual modeling of the production activity detailed in this section. The first subsection defines fundamental concepts employed in frontier analysis. The second subsection details the modeling in

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term of production possibility sets. A production possibility set contains all feasible input and output combinations feasible and reflects the characteristics of the technology. This modeling has valuable properties which enable to derive performance measures from each other due to the relation of equivalence. This relation is framed by the duality theory. Finally, the distance functions, which are the techniques that permit the measurement of efficiency, are introduced.

2.1.1 Production Approach of Firm

The analysis of productivity requires first to consider technical conditions that bound the set of feasible processes. This work is performed by technicians and engineers. Economic analysis of productivity requires the formalization of these constraints with regard to the environment to assess a fair estimation of the producer performance (Färe and Primont, 1995). This requires a particular modeling of the activity of the firm.

Production implies to collect and to convert production factors into goods or services. We refer to the term output to designate any outcome of the production activity. Output is a general term that covers various dimensions. For instance, some output may be valued on the market, while others may not. Outputs can be valued positively or negatively. The latter case is typically associated with negative externalities (e.g., pollutants or CO_2 emissions) that are inevitably jointly produced within a particular production process. The case of positive externalities is relatively rare and leads to positively valued byproducts. Similarly, we employ the general term input to designate any production factors and resources involved in the transformation process. Again, input refers to various situations. Some inputs are marketable, while other are not. Some are under the producer's control (meaning the producer can adjust the quantity), while some cannot be handled by anyone. For instance, the sun is an input in the corn growing process the farmer cannot control. Input and output balance between these typologies given the situation of the producer. For instance, the rain is another required input to grow corn that is not affected by producers decisions. Yet it may be substituted by artificial irrigation systems. The characteristics of the input and output determine the production constraints faced by the producer.

Anyone involved in the organization of production would consider obtaining as large as possible output given input as an indicator of success (Farrell, 1957). Inversely, producing less than expected given input transformation possibilities is assimilated to a failure. The purpose of frontier analysis is to quantify the maximal production potential within an industry sector or a strategic group as a reference to measure the performance of its constituent decision making units. The nature of performance provided depends on the data, the benchmarking techniques employed to assess the maximal productivity potential and the assumptions maintained about the behavior of the producer.

2.1.2 Duality Theory

Frontier analysis relies on the duality theory pioneered by Shephard (1953). The purpose of duality theory is to provide an economic meaning to production models through a relation of equivalence between economic and production frontier modeling. Figure 2.1 from (Färe and Primont, 1995) depicts the relation of distance functions to economic

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models. Each corner of the cube represents a different subset of the production technology. These correspond to different requirements about the behavior of the producer, the data availability and the assumptions about the price taking behavior of the firm. The

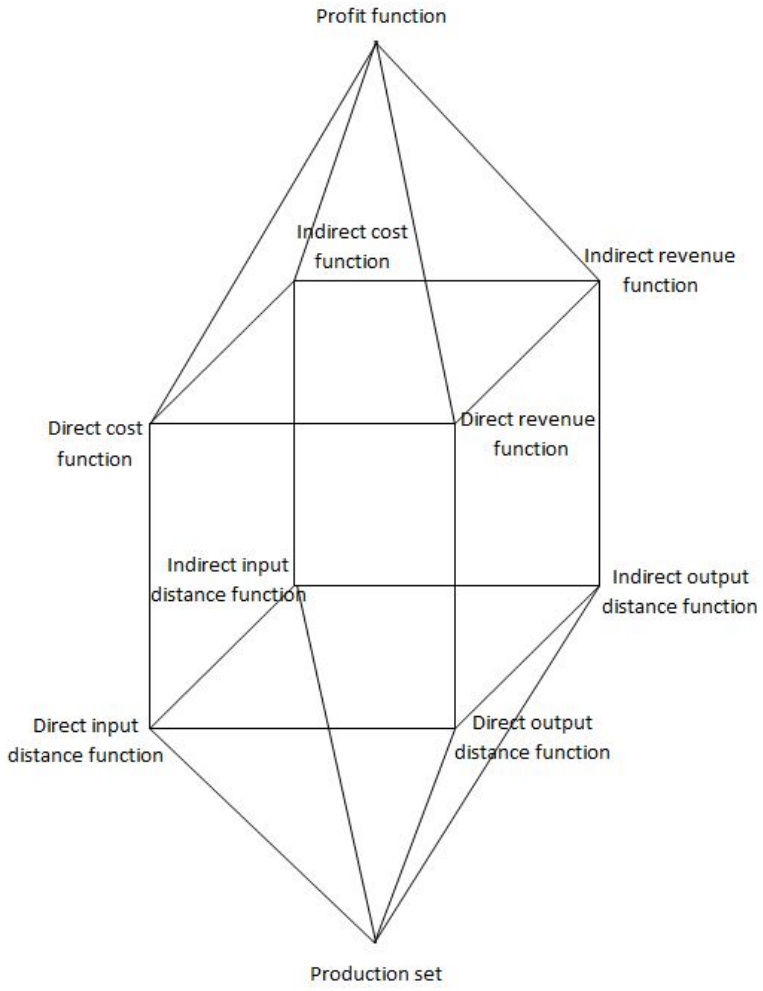

Figure 2.1: Duality Box *(Source: (Färe and Primont, 1995, p.5))*

lower part of the prism refers to the technical functions, while the upper region concerns value functions. The distinction is provided in Table 2.1. The virtue of the duality theory is to derive every performance measure in the duality box by starting from any other.

The representation of technical functions requires information about quantities employed in the production processes by each DMU and no information about prices. The production possibility set constitutes the starting point of the analysis and describes the characteristics of the technology. Technology may be defined as the state of knowledge about the possible ways to combine input to produce output at a given point in time. It is the upper bound of the set of technical feasible processes and depicts the most favored relation between input and output. Technology constitutes the production frontier of the feasible processes. Any firm located on this production frontier exhibit the highest efficiency level at its input scale.

In addition to data implied by the technical function, like value function includes information about prices and assumptions about the behavior of the producer and about the competitive prices. Both technical function and value function may be divided in two

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Table 2.1: Technical and Value Measures of Efficiency

TECHNOLOGY	VALUE FUNCTION
Input distance function	Cost function
Output distance function	Revenue Function
Indirect input distance function	Revenue Indirect Cost Function
Indirect output distance function	Cost indirect Revenue Function
Production possibility set	Profit Function

categories: input- and output-oriented distance functions depicted by the left corner and the right corner of Figure 2.1 respectively. Input- and output-orientations are consistent with the assumptions of revenue maximization or cost minimization behavior of the firm respectively. The front and back sides near the bottom of Figure 2.1 indicate the relation of direct and indirect distance functions. Indirect distance functions consists of combining orientations. For instance, indirect revenue function consists of maximizing revenue subject to the constraint of a cost target to achieve. It implies additional assumptions on the behavior of the producer.

Technical and value functions differ regarding their requirements in assumptions and the information they provide. The upper part of the duality box is dominated by the profit function. The profit function is the most restrictive in assumptions about producer behavior and prices and in data requirements. It provides information about technical efficiency and allocative efficiency of the firm with both cost minimization and revenue maximization targets. Hence, it encompasses all of the assumptions and information provided by the 9 remaining models. Its extreme counterpart is the production possibility set that provides the least restrictive modeling of the technology. The assumptions raised about the technology are technical rather than economic. These are joined with the specification of the benchmark employed to measure distance functions. Because of its flexibility, this work is focusing only on technical functions and the different specifications of the benchmark.

2.1.3 Distance Functions

Distance functions have been introduced by Shephard (1953) and Malmquist (1953). Distance functions are a representation of the technology and they allow the measurement of efficiency. Depending on the input or output orientation, the distance function is concerned with the minimal proportional contraction of the input vector given the output or the maximal proportional expansion of the output vector, given an input vector respectively (Coelli, Rao, O'Donnell, and Battese, 2005). There are several advantages to using distance functions:

- Contrasting with the neoclassical production functional form in single input-single output form, the specification of the production technology in terms of distance functions permits to easily handle multi-inputs multi-outputs settings.
- It does not require assumption about the shape of technology as it is usually made in economics (Cobb-Douglas, Leontief, Translog, ...). Hence, representation in tech-

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nological set and distance function allow for a great flexibility.

- Even though the duality theory implies a relation of equivalence between microeconomic theory and performance measures, the distance function *per se* does not involve assumption about the profit maximizing or the cost minimizing behavior of the producer. In addition, it does not require assumption about the degree of competitiveness of the market in which the firm buys input and values output.
- In non-parametric deterministic settings, the relation between input and output is measured with respect to extreme observations which are said to represent the best relation achievable consistently with the microeconomic concept of a production technology. However, the introduction of a functional form and the measurement of the distance allowing for stochastic error and inefficiency simultaneously is also possible with stochastic frontier analysis.
- Similar to the information content of the microeconomic production function, distance functions provide indications about the technology as well as the marginal product, the relations of substitution and the returns to scale etc.

It is important to note that there exist different formalizations of distance functions. These do not provide the same information and do not satisfy the same axiomatic properties. The comparison of the different formalizations of distance functions is beyond the scope of this investigation. We are focusing here only on the more widely used Debreu-Farrell distance functions. The latter is not restrictive regarding the assumptions about the shape of the technology.

2.2 Evaluation of Performance of Firms

Two sets of performance measures can be derived from the production frontiers: technical efficiency and economic efficiency. The former measures refers to the technical function, while the latter focuses on value function. Economic efficiency corresponds with the combination of technical efficiency and allocative efficiency. Table 2.2 summarizes the distinctive features of each efficiency measure. It specifies the indicators corresponding to technical efficiency and economic efficiency, their respective data requirements and the level of assumptions.

2.2.1 Technical Efficiency

Technical Efficiency is a gross aggregate measure of the performance of the firm while taking into account the production technical conditions. This measure is composed of pure technical efficiency and scale efficiency, which focus on separate aspects of production technical conditions. Pure technical efficiency is concerned with the optimization of the transformation process of input into output at any scale of operation. In contrast, scale efficiency focuses on the optimal scale of operation, that is the scale that provides the

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Table 2.2: Efficiency Measurements and Requirements

Category	Indicators	Data required	Assumptions
Technical efficiency	Pure technical efficiency Scale efficiency	Quantities	Low
Economic efficiency	Allocative efficiency Cost efficiency Revenue efficiency Profit efficiency	Quantities and prices	Strong
Other	X-Efficiency	Quantities x prices (e.g. accounting data)	Low

highest productivity[1].

Overall Technical Efficiency

The definition of technical efficiency implied by frontier analysis has been inherited from seminal works of Debreu (1951) and Koopmans (1951). Koopmans (1951) defines a technical efficient state as follow:

"A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus, a technically inefficient producer could produce the same output with less of at least one input, or could use the same inputs to produce more of at least one output." This definition is a generalization of Pareto optimality to the field of production analysis. That is why this definition is so-called a Pareto-Koopmans principle of allocation of resources.

Around same time, Debreu (1951) proposed a formalized definition more oriented towards the sake of commensurability and operationalization of technical efficiency as a performance measure:

"The technical efficiency is equal to one minus the maximum equiproportionate input reduction feasible. A score less than unity indicates the severity of technical inefficiency."

Farrell (1957) combined both approaches to propose an operational measure of technical efficiency. The information content of input- and output-oriented technical efficiency consists of answering these two questions[2]: *"By how much can input quantities be proportionally reduced without changing the output quantities produced?" or "By how much can output quantities be proportionally expanded without altering the input quantities used?" (Coelli, Rao, O'Donnell, and Battese, 2005).* Farrell (1957) proposes to infer from a set of homogenous firms a frontier of best production combinations that is to say the input-output combinations that provide the maximum productivity. Firms located at the frontier are technically efficient in the sense of Koopmans (1951) since they cannot increase

[1]We present in this subsection the traditional decomposition of technical efficiency. Refined decompositions will be introduced in Chapter 7 for the empirical analysis.

[2]Given the orientation selected, technical efficiency does not provide the same information except under constant returns to scale technology.

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output production without increasing at least one input. In Debreu (1951) words, such units cannot improve productivity by the equiproportionate reduction of input. Hence, those firms are technically efficient and exhibit scores equal to 1. In contrast, inefficient firms exhibit scores below 1.

Figure 2.2 depicts the method by which Farrell (1957) measured efficiency in a single input-single output representation under the assumption of strong disposability and variable returns to scale. X refers to the input vector and Y to the output vector. Each

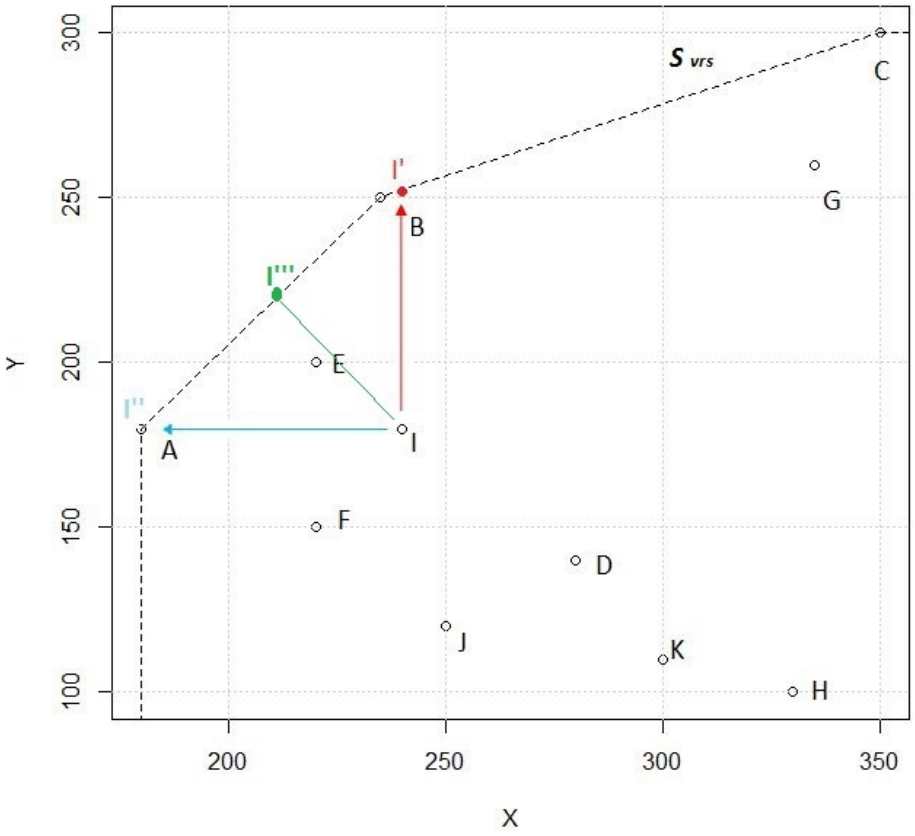

Figure 2.2: Production Frontier

point corresponds with the observed production of a decision making unit (DMU). The measurement of technical efficiency is performed in two stages. First, we infer the frontier of best practices (curve S_{vrs}) by connecting the best DMU's A, B and C through linear combination. The economic meaning of this frontier is akin to the concept of a production function. It quantifies the extreme relation of output to input providing the highest productivity. Production function bounds the feasible production possibility set with the set of technologically efficient combinations. In other words, the region that lies above the frontier represents the domain of technical infeasibility, while the region located beneath the frontier consists of the set of feasible but non-optimal production processes.

The next step consists of measuring technical efficiency as 1 minus the percentage of deviation from the highest productivity potential depicted by the frontier. Considering DMU I, the maximization of productivity is achievable in two ways. On the one hand, DMU I can achieve technical efficiency by the maximum equiproportionate output increase feasible, while keeping input constant. This movement is represented by the upward red arrow. Here, the technical efficiency is output-oriented . The technical efficiency

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score is given as the vertical deviation of I from its virtual efficient peer I' itself a linear combination of B and C:

$$TE_{output} = \frac{Y^{I'}}{Y^I} \leq 1 \tag{2.1}$$

where $Y^{I'}$ is the output quantity of I' the virtual efficient projection of I which maximizes output.

On the other hand, DMU (I) can alternatively achieve technical efficiency by the maximum equiproportionate input reduction feasible depicted by the left-sided blue arrow. Regarding observation I, its input-oriented technical efficiency score is given as the horizontal deviation of I from its virtual efficient peer I" itself a linear combination of A and B. Thus, input-oriented technical efficiency is given by:

$$TE_{input} = \frac{X^{I''}}{X^I} \leq 1 \tag{2.2}$$

where $X^{I''}$ is the input quantity of I" the virtual efficient projection of I which minimizes input.

Finally, technical efficiency can be achieved by simultaneously reducing input and maximizing output. Regarding I, the DMU can achieve technical efficiency by the switch from I to I"'.

Technical Efficiency Components

Technical efficiency is a gross aggregate measure decomposable into pure technical efficiency, scale efficiency and congestion efficiency. The present investigation is concerned with the information content of the first two components since the latter requires a particular specification of the benchmark. Congestion efficiency is concerned with the effect of the excess of input on the output destruction. To illustrate the concept of congestion efficiency, consider a farmer who produces corn. The sun is a necessary input that determines the corn's growth and quality. Nevertheless, too much sun will destroy corn. In this simple case, the input is not under the control of the producer, but this principle is easily extendable to various situations where the producer has the effective control.

Technical Efficiency vs Productivity: It is important to note that there is a fundamental difference between the traditional measure of productivity and technical efficiency. Indeed, technical efficiency may be defined as the ratio of the production of the firm to the highest production provided by a comparable peer. A traditional measure of productivity is a partial measure of the producer effectiveness based on physical quantities and is not relative to a comparable firm. Finally, technical efficiency and productivity do not call for the same interpretation. A firm can be technically efficient but less productive than a less efficient unit producing at a different input scale.

Scale Efficiency and Pure Technical Efficiency: The interpretation of technical efficiency depends on the returns to scale of the underlying true technology. If the techno-

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logy imposes constant returns to scale, it is assumed that, at the frontier of best practices, a proportional increase in input will provide a proportionate increase of output. These circumstances are in line with the microeconomic theory and market atomicity assumption, but they are generally not met in empirical tests. In contrast, if the underlying true technology exhibits variable returns to scale, the measure of technical efficiency must be decomposed to take into account the effect of scale efficiency. Then we distinguish pure technical efficiency assessed with respect to a variable returns to scale technology from scale efficiency that is the residual spread between constant returns to scale and variable returns to scale technologies for the same production possibility set. Figure 2.3 illustrates the meaning of scale efficiency and pure technical efficiency in single input-single output case. It depicts the differences between a CRS and a VRS frontier.

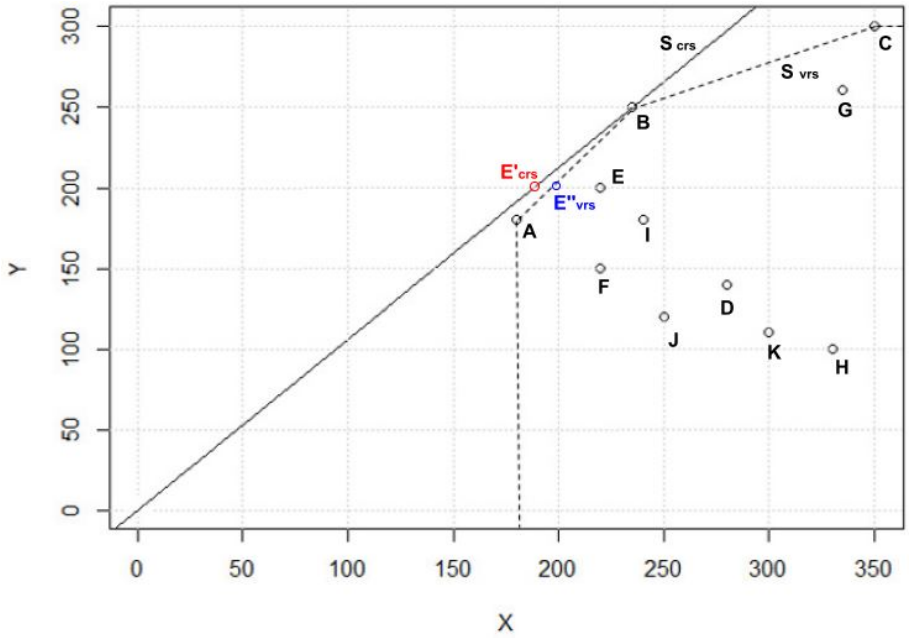

Figure 2.3: Pure Technical Efficiency and Scale Efficiency

There are two specifications of the technology $\boldsymbol{S}$. The variable returns to scale technology S_{vrs} is constructed with the observations A, B and C. Each is efficient at the input scale with respect to the VRS technology. In contrast, the constant returns to scale technology S_{crs} is inferred only from point B. B is the only point that is both technically and scale efficient. In order to clarify the measurement of each technical performance, we consider the input-oriented technical efficiency at E. E is technically inefficient with respect to both S_{vrs} and S_{crs} with E''_{crs} and E''_{vrs} its input-oriented efficient projection at the frontier. The distance between E''_{vrs} and E corresponds with the pure technical efficiency that is to say technical efficiency at the output scale. The deviation is measured relative to a local Pareto-Koopmans optimum. The distance between E''_{crs} and E takes into account the effect of the size of production and then is the overall technical efficiency. The overall technical efficiency is assessed with respect to the overall optimum E''_{crs}. Finally, the distance between the local optimum E''_{vrs} and the overall optimum E''_{crs} provides the measure of scale efficiency. In other words, scale efficiency measures the deviation of the technically efficient unit at the input scale from the technically efficient units at the optimal size. It translates the residual productivity gains achievable by changing the

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scale of operation. Hence, the input-oriented technical efficiency is decomposable by the following relation:

$$\begin{aligned} TE_{input} &= PTE_{input} \times SE_{input} \\ &= \frac{X^{E'',VRS}}{X^{E}} \times \frac{X^{E'',CRS}}{X^{E'',VRS}} = \frac{X^{E'',CRS}}{X^{E}} \leq 1 \end{aligned} \tag{2.3}$$

2.2.2 Economic Efficiency

Economic efficiency concerns the value functions. It refers to both allocative efficiency and overall efficiency. The former deals with the optimization of the input-output mix given their prices. The latter is an aggregate measure that encompasses the larger information content. Overall efficiency corresponds with the product of overall technical efficiency and allocative efficiency. Then it involves technical and value functions. Given the input- or output-orientations, the economic efficiency has not the same information content. The following subsection details the measures of allocative and overall efficiency. In addition, we make explicit the underlying assumptions.

Allocative Efficiency

Allocative efficiency measures the ability of the firm at using the input (at producing output) in optimal proportions given the prices and the technology (Coelli, Rao, O'Donnell, and Battese, 2005). Like the determination of technical efficiency, allocative efficiency is measured with distance functions as the deviation of the virtual technically efficient unit from the optimal price combination indicated by the cost function. Thus, only a technically efficient firm can be allocative efficient. To clarify the definition of allocative efficiency, we consider Figure 2.4.

Figure 2.4 depicts the input-oriented measure of technical efficiency and allocative efficiency. The isoquant $\boldsymbol{S}$ is the two inputs-single output technology under constant returns to scale. The isoquant $\boldsymbol{S}$ is the input-oriented representation of the technology at the output level Y at which the producer is technically efficient. The isocost line $\boldsymbol{w1w2}$ corresponds with the set of input price combinations for every technically efficient observation. We consider point G. G is technically inefficient regarding $\boldsymbol{S}$ and its technically efficient projection is given by G'. Allocative efficiency is measured by the distance between the efficient price $\boldsymbol{w1w2}$ combination at the input combination at X to the virtual point G'. Formally:

$$AE = \frac{0X}{0G'} \tag{2.4}$$

We note that only the observation C is allocative efficient, while it is not the only technically efficient unit. A, B, C and E are also technically efficient, but the only allocative efficient point is located on $\boldsymbol{w1w2}$ where the input costs is minimized for given input prices.

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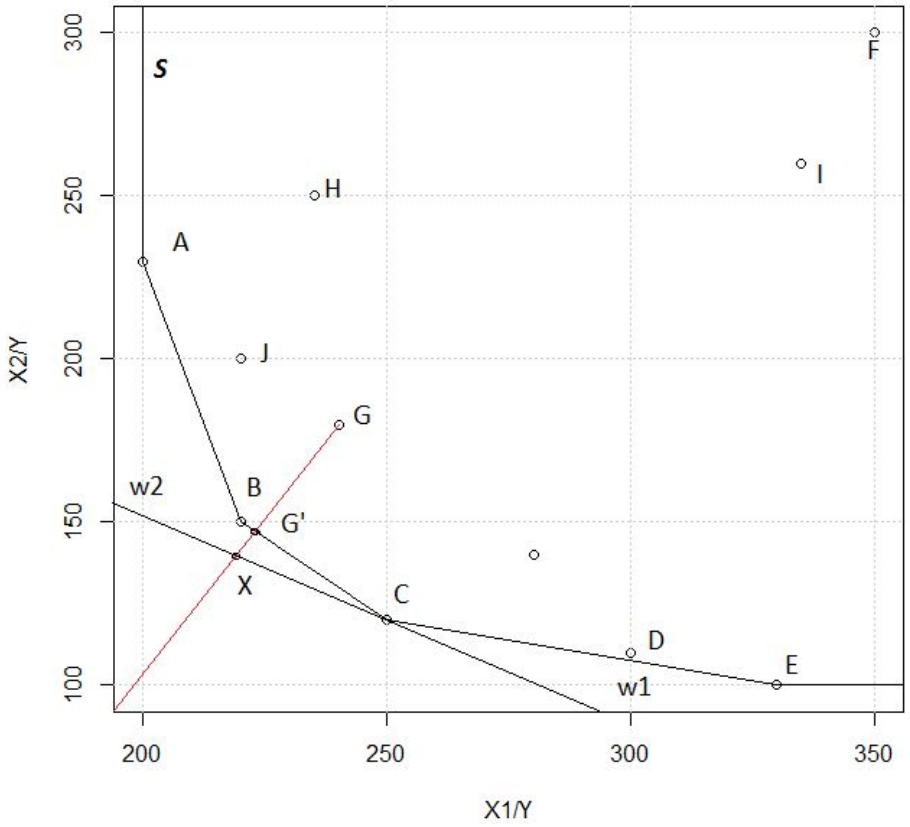

Figure 2.4: Technical and Allocative Efficiency

Definition of Overall Efficiency

The overall efficiency is concerned with the value functions. Overall efficiency covers revenue, cost and profit efficiency. As mentioned earlier it involves a larger set of assumptions. It is composed of two components: technical efficiency and allocative efficiency.

Cost Efficiency: The cost efficiency is given by the product of input-oriented technical efficiency and input-oriented allocative efficiency. Consider Figure 2.4 point G. Allocative efficiency is given by $AE = \frac{0X}{0G'}$ and technical efficiency by $TE = \frac{0G'}{0G}$, the cost efficiency at G is given by:

$$CE = \frac{0X}{0G} = \frac{0X}{0G'} \times \frac{0G'}{0G} = AE_{input} \times TE_{input} \tag{2.5}$$

Revenue Efficiency: Revenue efficiency is the output-oriented counterpart of cost efficiency. It is based on the same production technology. Figure 2.5 depicts the revenue efficiency where ***S*** is the production possibility curve of the single input-two outputs technology that bounds the set of feasible output combinations for any given level of input. Technology is assumed to satisfy constant returns to scale and strong disposability. The isorevenue line ***p1p2*** corresponds with the set of output's prices combinations. We note that points E, J, B, D and I are technically efficient, but only B is both allocatively

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and technically efficient and so revenue efficient. The measurement of revenue efficiency is akin to the cost-oriented case. Consider point A. A is technically inefficient since it is located below the frontier of best practices. The measurement of technical efficiency is determined with respect to its virtual efficient peer A' that is a linear combination of the two efficient points J and B. Technical efficiency is given by $\frac{0A'}{0A} \leq 1$.

Its allocative efficiency is given by the distance between the virtual efficient peer A' and the corresponding position on the isorevenue line X. Revenue efficiency combines again both efficiencies. It corresponds with the deviation of the observed point A from the isorevenue line ***p1p2***. Formally, revenue efficiency is given by:

$$RE = \frac{0X}{0A} = \frac{0X}{0A'} \times \frac{0A'}{0A} = AE_{output} \times TE_{output} \tag{2.6}$$

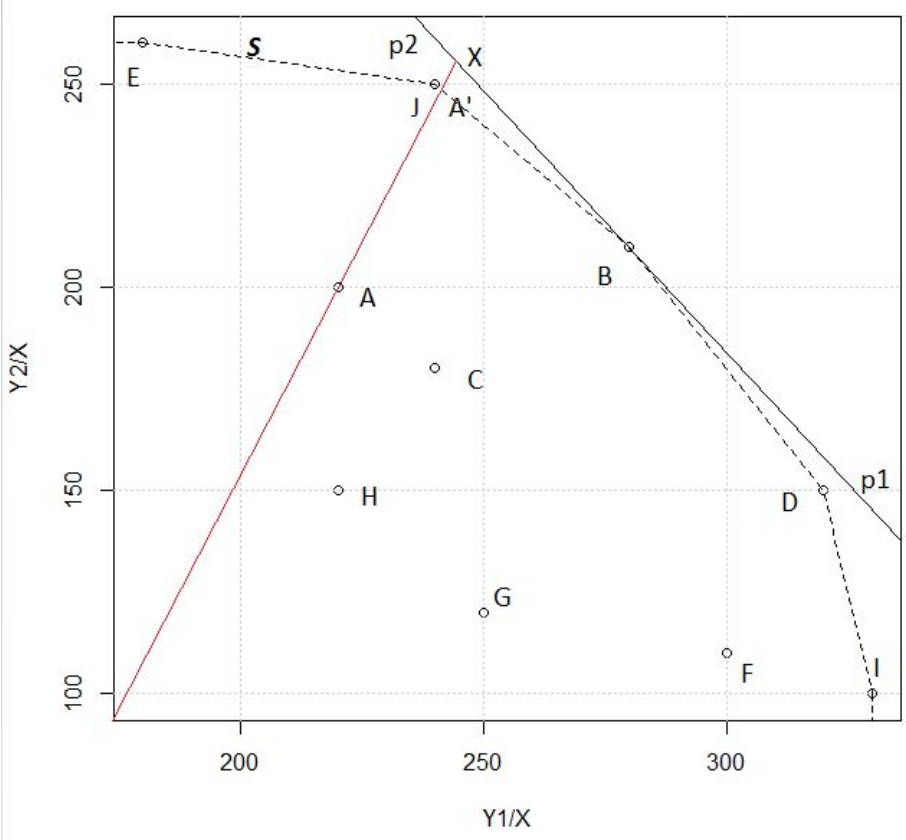

Figure 2.5: Revenue Efficiency

Profit Efficiency: Profit efficiency implies to simultaneously minimize cost function and maximize revenue function. This may be performed by the use of a directional distance function. Directional distance function is beyond the scope of this investigation. No attempt has yet been made to implement directional distance function in the analysis of the relation between efficiency and stock returns.

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2.2.3 X-Efficiency

X-Efficiency is a concept introduced by Leibenstein (1966). This measure arises from the observation that, contrasting with what neoclassical theory argues, firms' inefficiencies ensue mostly from something else than allocative inefficiency. Considering (i) the market is not perfectly competitive, (ii) the firms are knowingly able to affect market prices and quantities and, more important and (iii) the dependent relation between quantities (acquired/sold out) and prices; the performance of the firm may be assessed by looking directly at aggregated data. In such case, the distance function is constructed with accounting information as it would be for quantities in technical efficiency scores computation in Figure 2.2. The resulting score is a ranking of firms given the total cost reduction achievable.

Such measure of efficiency is the most employed in the literature and covers sometimes input- or output-orientation and a variety of production possibility set specifications. Since X-efficiency refers to the input minimization, we are using R-efficiency to designate output-oriented efficiency assessed with accounting data and revenues as output and P-efficiency to refer to the output-oriented efficiency with profit as output. It is of interest to note that in literature in management, researchers frequently employ interchangeably cost efficiency to designate X-efficiency (idem for P-efficiency and R-efficiency). Strictly speaking, this is inappropriate. X-efficiency would be equivalent to cost efficiency in the very restrictive case where all firms have the same size, face the same price for each production factor, and prices and quantities are strictly independent as implied by overall efficiency.

2.3 Benchmark Construction

Modeling production frontier requires techniques that are tractable and realistic. The measurement of efficiency requires to construct the frontier of best practices. This frontier reflects the set of technical constraints faced by the firm. The specification of the returns to scale is one of the constraints implementable in the computation of technical efficiency. Depending on the technical constraints formalized in the determination of the technology, efficiency would have a particular meaning. This section provides an overview of the most employed frontiers in the analysis. Two sets of methods exist: the non-parametric deterministic methodology and the parametric stochastic frontiers. In the first approach the technology is inferred with extreme observations without taking into account random noise associated with any sample construction. The second approach consists of specifying a parametric form and distinguish efficiency from random noise. Although both approaches claim to measure efficiency, their differences in estimation provide a different information content. This section is only concerned with data envelopment analysis.

2.3.1 Axioms and Representation of Technology

DEA represents technology in terms of production possibility set. This representation makes the multi-inputs and multi-outputs settings tractable. Technology defines the set of feasible production processes such that the input $x = (x_1, ..., x_n) \in \Re^n_+$ can produce

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the amount of output $y = (y_1, ..., y_m) \in \Re_+^m$:

$$S = \left\{(x, y) \in \Re_+^{n+m} : \text{x can produce y}\right\} \tag{2.7}$$

where S represents the set of all feasible input and output vector. The technology must satisfy a set of axioms:

- **The weak essentiality (no free lunch):** $(0, 0) \in S; (0, y) \in S \Rightarrow y = 0$. The production of some output requires at least some input.
- **Non-negativity:** The technology S is finite, non-negative and in real numbers.
- **Monotonicity:** $\forall (x, y) \in S, (x, -y) \leq (u, -v) \Rightarrow (u, v) \in S$. The consumption of an additional unit of input cannot decrease output.
- **S is a convex set.** It implies that any linear combination of input x^0 and x^1 will produce an output that is no less than the linear combination of their output y^0 and y^1.
- **S is a closed set.**

The technology is defined in terms of output set and input sets. These sets satisfy the following properties:

Input set

$$L(y) = \{x|(x, y) \in S\} \tag{2.8}$$

The input set is the input vectors $x \in \Re_+^n$ capable of producing a given output vector $y \in \Re_+^m$.

- $L1 : 0 \notin L(y)$ for $y \geq 0$ and $L(0) = \Re_+^n$
- $L2$: The sets $L(y)$ are closed
- $L3 : x$ is finite $\Rightarrow x \notin L(y)$ if y is infinite
- $L4$: x $\in L(y) \Rightarrow \lambda x \in L(y)$ for $\lambda \geq 1$
- $L5 : L(\lambda y) \subseteq L(y)$ for $\lambda \geq 1$
- $L6$:x' $\geq x \in L(y) \Rightarrow x' \in L(y)$ and $y' \geq y \Rightarrow L(y') \subseteq L(y)$
- $L7 : L(y)$ is a convex set for $y \in \Re_+^m$

Output set

$$P(x) = \{y|(x, y) \in S\} \tag{2.9}$$

The output set describes all output vectors $y \in \Re_+^m$ feasible by using a given set of input $x \in \Re_+^n$.

- $P1 : P(0) = \{0\}$
- $P2$:$P(x)$ is a closed set
- $P3 : P(x)$ is bounded for $x \in \Re_+^n$
- $P4 : P(\lambda x) \supseteq P(x)$ for $\lambda \geq 1$
- $P5 : y \in P(x) \Rightarrow \lambda y \in P(x)$ for $\lambda \in [0, 1]$
- $P6 : x' \geq x \in P(x') \subseteq P(x)$ and $y \leq y' \in P(x) \Rightarrow y \in P(x)$
- $P7 : P(x)$ is a convex set for $x \in \Re_+^n$

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Property (L1/P1) means no free lunch, (L2/P2) closed sets, (L3/P3) boundedness, (L4/P4) and (L5/P5) enable weak disposability of input/output, (L6/P6) strongly disposability of input/output, (L7/P7) convexity property.

2.3.2 Data Envelopment Analysis

DEA refers to the set of non-parametric and deterministic methodologies. The feature of DEA is to determine the frontier from the best performance that is observed. The main advantage to using DEA is the minimum requirements in assumption. It does not impose assumption about the shape of the frontier nor on the distribution of the efficiency scores. In addition, DEA techniques are more in line with technical constraints than other frontier based methods (e.g. SFA). Figure 2.6 depicts the different shapes available with DEA Models in a single input-single output case. The left part of Figure 2.6 illustrates the CRS DEA Models, while the middle part depicts the VRS. The free disposal hull, located at the left side of Figure 2.6, is the most realistic production frontier implementable since it takes into account the fixity of charges. DEA methods also have certain limitations that must be kept in mind. First, DEA does not consider the existence of random noise. Then it is likely to overestimate the inefficiencies in sample by considering outliers as most productive units. Nevertheless, bootstrapping techniques permit to lower this bias.

Strongly Disposable Technology with Constant Returns to Scale

DEA is an optimization method developed by Charnes, Cooper, and Rhodes (1978) (hereafter, CCR) based on the seminal contribution of Farrell (1957). Assuming the productive combination of each DMU is feasible, DEA determines the frontier of best practices through a linear combination of each DMU. The method consists of bounding DMU's by assigning weights to the input and output of each observation. Likewise, the frontier is composed of observed DMU's and virtual projections. Only the most productive projections are kept to draw the frontier of technical feasibility. The measure of technical efficiency is done by an iterative comparison of the output or input level of the DMU under analysis with those of all other DMU's (virtual or not). Hence, the method involves as many optimizations as there are observations in the sample. To introduce the computation techniques of DEA, we consider the following output-oriented fractional programming Model (2.10):

$$\begin{aligned} max_{u,v}\theta = \frac{\sum^{p} u_r Y_{r,o}}{\sum^{m} v_i X_{i,o}} \\ \text{subject to:} \\ \frac{\sum^{p} u_r Y_{r,j}}{\sum^{m} v_i X_{i,j}} \leq 1 (j = 1, ..., n) \\ u_r \geq 0 (r = 1, ..., p) \\ v_i \geq 0 (i = 1, ..., m) \end{aligned} \tag{2.10}$$

where X and Y are the matrix of the m input and the matrix of the p output of the firms under evaluation and u and v are vectors of non-negative variable weights respectively.

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The first two lines of (2.10) are a measure of productivity where weights are assigned to obtain the maximal productivity achievable. The DMU_j is evaluated by assigning its optimal weights solved over the range of n^{th} DMU's. The purpose of the DEA Model (2.10) is to construct a virtual ratio of output to input by using weights under the constraint it should not exceed one. By applying weights to every DMU, we can find the reference set that is the observation against which j is compared. A DMU is said technically efficient when θ=1. $\theta < 1$ means the productivity score of the firm under evaluation equals the highest feasible productivity computed, while keeping input level fix. The firm is inefficient if θ is below 1. The proportional increase in output achievable is given by 1-θ.

The first Models as (2.10) suffered problems of infeasibility intrinsic to the specification of the fractional programming Model that is why, in practice, users refer to the envelopment form which is more tractable. CCR overcome this limitation by choosing a specific solution of one the weight as $ux_0 = 1$. They provide the DEA with constant returns to scale and strong disposability as given by the following linear programming Model in multiplier form (2.11) equivalent to (2.10):

$$\begin{aligned} max_{u,v}\theta = \sum^{p} u_r Y_{r,o} \\ \text{subject to:} \\ \sum^{m} v_i X_{i,j} = 1 \\ \sum^{p} u_r Y_{r,j} = \sum^{m} v_i X_{i,j} (j = 1, ..., n) \\ u_r \geq 0 (r = 1, ..., p) \\ v_i \geq 0 (i = 1, ..., m) \end{aligned} \tag{2.11}$$

The CCR Model enables to construct a convex benchmark with local linearity. Convexity implies the benchmark of best practices is at any point constructed with the linear combination of two other observed points. Graphically, the CCR frontier corresponds with a convex polyhedral cone.

It is important to note that the CCR Model is based on the assumption of constant returns to scale. The implication for the measure is that the reference set is inferred from the DMU that provides the highest production. Hence firms are compared with an overall optimum instead of a local optimum in terms of the scale size. This limitation has been overcome by Banker, Charnes, and Cooper (1984).

Strongly Disposable Technology with Variable Returns to Scale

The strong disposal convex form with variable returns to scale is a constrained form of CCR. It relaxes the constant returns to scale assumption by adding a constraint. It has been introduced by Banker, Charnes, and Cooper (1984) (BCC). The BCC Model compares units according to their sizes and evaluates pure technical efficiency. The combination of CCR and BCC enables to isolate scale efficiencies as a component of overall technical efficiency. The difference between CCR and BCC is an additional constraint of

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convexity given by u_0 being a free variable. The BCC is given by programming Model (2.12):

$$\begin{aligned} max_{u,v}\theta = \sum^{p} u_r Y_{r,o} - u_0 \\ \text{subject to:} \\ \sum^{m} v_i X_{i,j} = 1 \\ \sum^{p} u_r Y_{r,j} - \sum^{m} v_i X_{i,j} - u_0 \leq 0 (j = 1, ..., n) \\ u_r \geq 0 (r = 1, ..., p) \\ v_i \geq 0 (i = 1, ..., m) \\ u_0 \text{ free of sign} \end{aligned} \tag{2.12}$$

The constraint u_0 applied to optimal solution may be negative in increasing returns to scale, positive in decreasing returns to scale or null in constant returns to scale (Banker, Charnes, and Cooper, 1984). In multidimensional settings, it forms a convex hull of intersecting planes. This frontier is more tight than the constant returns to scale envelopment. Comparing constant returns to scale (in Figure 2.6.a) with variable returns to scale (in Figure 2.6.b) frontiers, we observe that in the latter modeling the relation between input and output is not linear. Under this assumption, overall technical efficiency is the product of pure technical efficiency and scale efficiency. BCC Model is less restrictive than CCR, it measures the efficiency of the firm with respect to a local optimum that is to say at the input scale in contrast with CCR based on the most productive scale.

Free Disposal Hull

Similar to the BCC Model, the FDH is a constrained form of BCC. This latter linear programming model has been initiated by Deprins, Simar, and Tulkens (1984). Contrasting with CCR and BCC, FDH relaxes the convexity property. The efficiency computation is consequently made with a local reference set. In other words, firms are compared relative to their best next peers with respect to their input-output combinations. Figure 2.6 depicts the effect of non-convexity on the benchmark determination for single input-output technology. Model (2.13) under variable returns to scale consists of precising the constraint added in BCC (2.12):

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$$
\begin{aligned}
max_{u,v}\theta = \sum^{p} u_r Y_{r,o} - u_0 \\
\text{subject to:} \\
\sum^{m} v_i X_{i,j} = 1 \\
\sum^{p} u_r Y_{r,j} - \sum^{m} v_i X_{i,j} - u_0 \leq 0 (j = 1, ..., n) \\
u_r \geq 0 (r = 1, ..., p) \\
v_i \geq 0 (i = 1, ..., m) \\
u_0 \in \{0, 1\}
\end{aligned}
\tag{2.13}
$$

This constraint $u_0 \in \{0, 1\}$ changes the convex hull into staircases. FDH is the least restrictive Model in terms of assumption requirements since it relaxes convexity by taking into account charges fixity. In other words, FDH provides a local evaluation of efficiency and a more accurate description of the technology including in technological change analysis. Comparing with a convex envelopment such as CCR and BCC, FDH provides no over-estimation bias of technical efficiency.

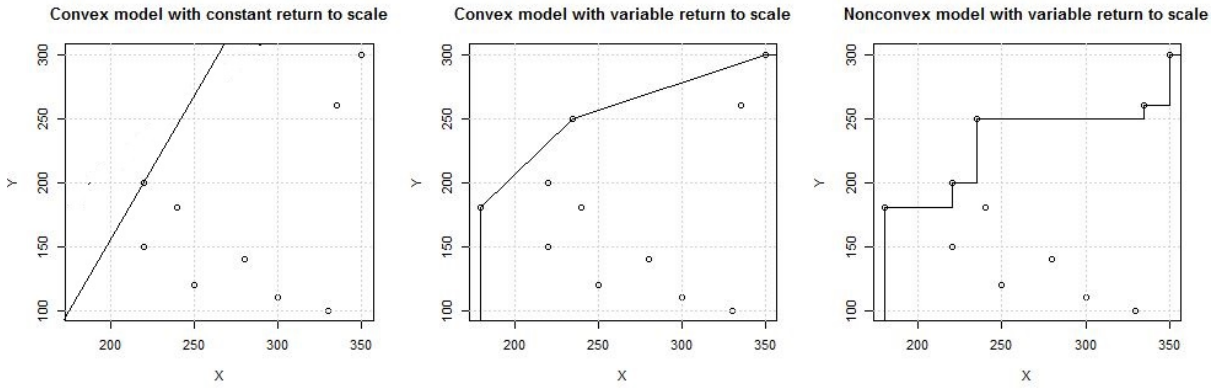

Figure 2.6: DEA Based Frontier under Convex and Non-convex Hull, Constant and Variable Returns to Scale and Strong Disposability

2.3.3 Digression to Slacks

The issue of slacks is concerned with the presence of inefficient DMU's located on the benchmark of best practices. This may be possible when the DMU is located in the portion of the frontier parallel with the axes. This is, for instance, the case for the DMU G in Figure 2.7. Despite its location on the frontier, G exhibits input excess in the use of X2. This excess, which corresponds with the distance between G and A, is the slack. A linear programming model that does not control for slacks would consider G technically efficient. The distinction between G and the other constitutive observations located on the frontier lies in the nature of the technical efficiency. The constitutive DMU's of the frontier, except G, are Pareto-Koopmans efficient, that is to say, they cannot improve

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technical efficiency by a simultaneous reduction of each input nor by the modification of the input mix. With regard to this latter condition, G is radially efficient but not Pareto-Koopmans efficient.

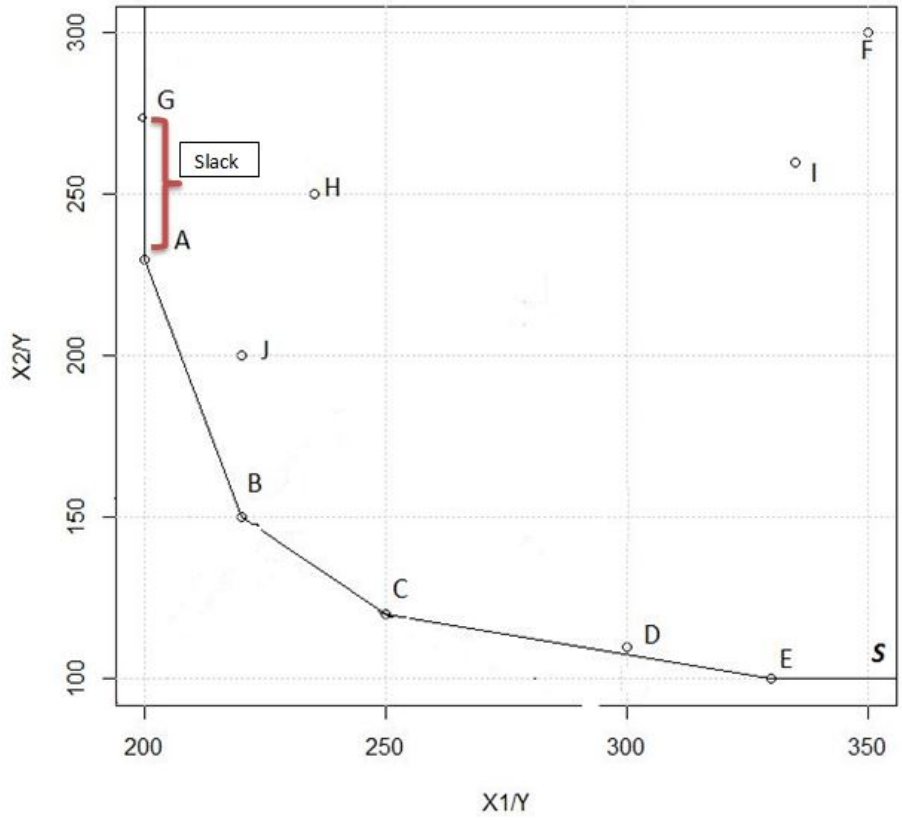

Figure 2.7: Issue of Slacks under a Convex and Strongly Disposable Technology: Illustration

Two kinds of control for slacks are employed in the literature of interest. The first is the SBM proposed by Tone (2001). Model 2.14 computes efficiency by imposing the restriction that the slacks must be equal to 0. The Tone (2001) SBM in linear programming form under CRS is provided in the Equation (9) p. 101 in Cooper, Seiford and Tone (2007) as follow:

$$\begin{aligned} \text{minimize } \theta = t - \frac{1}{m} \sum t \times s_i^- / x_i \\ \text{subject to:} \\ 1 = t + \frac{1}{s} \times \sum_{r=1}^{s} t s_r^+ / y_{ro} \\ x_o = X + s^- \\ y_o = Y + s^+ \\ \lambda \geq 0, s^- \geq 0, s^+ \geq 0, t > 0 \end{aligned} \tag{2.14}$$

where t is a non-negative scalar that permit the transformation of the fractional programming model into a linear programming model and θ is the measure of efficiency. The

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constraints of interest are the line 3 and 4 of Equation (2.14). In addition to the CCR Model, Tone (2001) adds the effect of slacks s^+ and s^- that correspond to the input excess and the output shortfall, while $X\lambda$ and $Y\lambda$ are the radial measures of technical efficiency. A firm is said Pareto-Koopmans efficient when, in addition to the technical efficiency, the slacks are null. Then the determination of efficiency is a two steps device that aims at measuring the deviation from the benchmark when slacks are minimized.

The second approach employed, in the literature about the relation between efficiency and stockholder value, is the ranking method of Andersen and Petersen (1993) which relies on super efficiency. Super efficiency results from a device that does not allow for the comparison of an efficient DMU with itself. The deviation of the efficient DMU of interest is measured relatively to a frontier which does not include it as a constituent of the reference set. If the score is greater than 1, the radially efficient DMU is also Pareto-Koopmans efficient. If the score is below or equal with 1, the DMU is likely to be virtually technically inefficient due to slacks .

2.4 Evaluation of TFP and its Decomposition: Productivity Indices

An index is a real number that reports changes in a set of related variables (Coelli, Rao, O'Donnell, and Battese, 2005). For instance the S&P500 reports the price deflator of national income provided by the greatest 500 capitalizations compared with the base period 1941-1943. Other well known price and quantity indices, e.g. the Paasche index, enable to disentangle the effect of price and quantities in the variation of sales or expenses.

Applied to efficiency analysis, multilateral indices enable to determine the total factor productivity. Total factor productivity (hereafter TFP) is a measure of productivity encompassing all production factors exploited and all outputs. It corresponds with the generalization of the traditional measure of productivity based on a single input such as the productivity per capita. Indices also enable to decompose changes in TFP into autonomous shifts in the production function over time. Indices distinguish whether relative improvement in productivity is related to actual achievement of waste reductions by the firm or whether is due to a technological change that may affect all competitors in the industry.

Several approaches exist to measure TFP. We review only the complete Hicks-Moorsteen and the Caves, Christensen, and Diewert (1982) (CCD) - so-called Malmquist top-down - approaches. The Hicks-Moorsteen approach consists of the ratio of an output index to an input index as:

$$TFP(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{Y(y^{t+1})/X(x^{t+1})}{Y(y^t)/X(x^t)} \tag{2.15}$$

where Y and X refer to non-negative non-decreasing and linearly-homogenous aggregated functions of output and input respectively. The TFP change is provided by the output growth net of input growth. Indexes fulfilling this condition are said *multiplicatively complete* because they provide unambiguous decomposition of TFP change into efficiency change and technological change. These are also potentially decomposable into a wide variety of components and they satisfy a set of convenient properties for meaningful economic interpretations (ODonnell, 2012a). It is of interest to note this formulation enables to deal easily with multi-outputs production possibility sets.

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The second approach introduced by Caves, Christensen, and Diewert (1982) consists of comparing observed output with the maximum output feasible given the input set x_t and x_{t+1} with respect to each technology in t and $t+1$. TFP is expressed as the ratio of two distance functions. Decomposition is done by comparing changes in input consumed with changes in output produced over two periods of time or relative to input and output variations exhibited by comparable firms within the industry. This approach is the most employed in efficiency analysis and the only one in the relation of efficiency components to stock returns.

2.4.1 Incomplete Malmquist Indices

The index the most frequently used in the operation research literature for TFP decomposition is the Malmquist index. Malmquist has been introduced by CCD (1982 a and b) based on works of Malmquist (1953) to disentangle the effect of technological change in TFP changes. The Malmquist may be defined as the geometric mean of these two questions: *"How much output could firm in t produce if it used t+1 technology with its own inputs? Then: how much output could firm in t+1 produce if it used technology in t with its inputs?" (Hulten, 2001).* Each question is answered with the use of distance functions. An output distance function, given by (2.16), measures the differential between an observed production with the input levels x^t to the maximal production feasible, while keeping x^t constant.

$$D_o^t(x^t, y^t) = min\left\{\theta : (x^t, y^t/\theta) \in T^t\right\} \tag{2.16}$$

where x^t and y^t are the input and output that form the boundary and the structure of technology T. In the output distance function, inputs are held fixed and the information provided is the reciprocal of the maximal output expansion feasible for any given set of input. T^t corresponds with the maximal output feasible and then bounds all feasible x^t and y^t combinations in t.

The output-oriented Malmquist index as outlined by CDD is defined in Equation (2.17). It is based on the ratio of output distance functions with respects to the technology at different point in time T^t and T^{t+1}:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)}\right) \times \left(\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}\right)\right]^{1/2} \tag{2.17}$$

The first term of (2.17) compares the required switch in technology t to make y^{t+1} given x^{t+1} feasible with technical efficiency in t, while the second term provides the required change in output for the firm to be as technically efficient as in $t+1$ with respect to the technology in $t+1$. The result of these ratios is the maximal proportional increase in output provided by switching from technology t to $t+1$ for a fixed level of input.

The use of Malmquist for TFP decomposition has been extended by Färe, Grosskopf, Norris, and Zhang (1994), but several alternative specifications have been developed. It is important to note that given the specification, the change in TFP and in TFP components do not yield the same information. We present here the specifications employed in the literature on the link between TFP and stock returns.

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Constant Returns to Scale Based Malmquist

Färe, Grosskopf, Norris, and Zhang (1994, hereafter FGNZ) extended the use of the Malmquist with a threefold contribution. On the one hand, they relax the set of assumptions maintained by CCD (1982b) about the underlying translog production function reflected in the Malmquist and the inability at taking into account inefficiencies. On the other hand, given Malmquist is a ratio of two distance functions, they develop an empirical methodology based on DEA to assess the boundary of the frontier. Next, FGNZ decompose changes in TFP into three components: pure efficiency changes ($dTPE$), technological changes ($dPTECH$) and scale efficiency changes (dSE). The feature of their specification is the focus on a strong disposal with constant returns to scale frontier. They rewrite the CCD Malmquist in Equation (2.17) as follows:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})}{D_o^{t,CRS}(x^t, y^t)} \times \left[\left(\frac{D_o^{t,CRS}(x^{t+1}, y^{t+1})}{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})} \right) \times \left(\frac{D_o^{t,CRS}(x^t, y^t)}{D_o^{t+1,CRS}(x^t, y^t)} \right) \right]^{1/2} \tag{2.18}$$

The second term of Equation (2.18) catches the technological change ($dPTECH$). It corresponds with the shifts in the frontier related to changes in production conditions:

$$dPTECH = \left[\left(\frac{D_o^{t,CRS}(x^{t+1}, y^{t+1})}{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})} \right) \times \left(\frac{D_o^{t,CRS}(x^t, y^t)}{D_o^{t+1,CRS}(x^t, y^t)} \right) \right]^{1/2} \tag{2.19}$$

Equation (2.19) implies the computation of technical efficiency with productivity scores for each period with respect to the technology of the two time periods. This measures the maximal proportional change in output required to obtain productivity of $t+1$ with respect to the technology in period t. If $dPTECH > 1$, the maximum feasible in t+1 exceeds the maximum feasible in t which is an indicator of technological progress. A score below 1 reveals technological regress, while a score equal to 1 implies that technological conditions remain unchanged. The use of the CRS benchmark implies change is caught by looking at the potential productivity change of the firms producing at the most productive scale size (MPSS) (Zofio, 2007). In other words, this change corresponds with the change in highest productivity potential if there is no technical nor scale inefficiency. This implies dPTECH is an outer approximation of technological change.

The second term of Equation is (2.18) rate of change in pure technical efficiency is given by the ratio $TE^{t+1,CRS}/TE^{t,CRS}$, that is equivalent in distance function form to:

$$dPTE = \frac{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})}{D_o^{t,CRS}(x^t, y^t)} \tag{2.20}$$

Again, pure technical inefficiency is viewed as the deviation from the maximal productivity potential.

Following Banker, Charnes, and Cooper (1984), scale efficiency is obtained by the ratio of CRS to VRS efficiency scores. Hence, changes in scale efficiency scores are solved with:

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$$dSE = \frac{TE_o^{t+1,CRS}/TE_o^{t+1,VRS}}{TE_o^{t,CRS}/TE_o^{t,VRS}} \tag{2.21}$$

Scale efficiency is interpreted as the deviation of an optimal DMU given the input scale from the MPSS that yield the maximal productivity. It is obtained by comparing over two periods the productivity at the contemporary MPSS with the highest contemporary productivity at input scale. It reports the potential gain achievable by changing scale of operation. Changes in TFP in (2.18) may be recomposed by the product of the changes in each TFP sources:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = dPTE \times dSE \times dPTECH \tag{2.22}$$

Variable Returns to Scale Based Malmquist

Ray and Desli (1997), in a reply to FGNZ, pointed out the internal inconsistency of the TFP definition provided by a CRS benchmark. Although FGNZ is tractable, the CRS is generally not the true underlying technology and technological change component may be biased by changes in scale efficiency. Zofio (2007) notes that FGNZ definition is not consistent with the commonly admitted definition of best practices since every measure is relative to the MPSS and not the input scale. Hence, to catch the underlying *true* technology, Ray and Desli (1997) propose to rewrite $PTECH$ as:

$$dPTECH = \left[\left(\frac{D_o^{t,VRS}(x^t, y^t)}{D_o^{t+1,VRS}(x^t, y^t)}\right) \times \left(\frac{D_o^{t,VRS}(x^{t+1}, y^{t+1})}{D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \tag{2.23}$$

Equation (2.23) measures the shift in best practices given the input scale. It catches variation in the benchmark of best practices at the input scale over two periods. In this way, Ray and Desli (1997) individualize the technological change that is usually not neutral.

Ray and Desli (1997) also propose to reconstruct scale efficiency change to take into account the effect changes in the productive performance and changes in the MPSS. Nevertheless, they make confusion in their specification between changes in returns to scale (RTS) and changes in scale efficiency. The latter measures the existing or potential productivity shortfall associated with the suboptimal scale of operation. RTS represents *the productivity variation coming from a change in the scale of the evaluated firm with respect to the base technology* (Zofio, 2007). Ray and Desli (1997) specified scale efficiency changes as Equation (2.24):

$$\begin{aligned} dRTS &= \left[\frac{SE_o^t(x^{t+1}, y^{t+1})}{SE_o^t(x^t, y^t)} \times \frac{SE_o^{t+1}(x^{t+1}, y^{t+1})}{SE_o^{t+1}(x^t, y^t)}\right]^{1/2} \\ &= \left[\left(\frac{D_o^{t,CRS}(x^{t+1}, y^{t+1})/D_o^{t,VRS}(x^{t+1}, y^{t+1})}{D_o^{t,CRS}(x^t, y^t)/D_o^{t,VRS}(x^t, y^t)}\right)\right. \\ &\left. \times \left(\frac{D_o^{t+1,CRS}(x^{t+1}, y^{t+1})/D_o^{t+1,VRS}(x^{t+1}, y^{t+1})}{D_o^{t,CRS}(x^{t+1}, y^{t+1})/D_o^{t,VRS}(x^{t+1}, y^{t+1})}\right)\right]^{1/2} \end{aligned} \tag{2.24}$$

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Equation (2.24) is not a measure of scale efficiency change. By comparing comparisons of scale efficiency changes, they evaluate the variation in output scale, but not the variation of the scale efficiency. Hence, given overall efficiency change is provided by the product of scale efficiency and pure technical efficiency, the measure provided by Ray and Desli (1997) is incomplete. This confusion and the inability of the Ray and Desli (1997) decomposition at accounting for MPSS changes in the analysis of changes in scale efficiency has been corrected by Simar and Wilson (1998) and Zofio and Lovell (1998).

Scale of Technological Change Based Malmquist

While Ray and Desli (1997) recognized the importance of frontier changes in the assessment of changes in scale efficiency, they fail to correctly measure it. Stating scale efficiency change as the final net result of the comparison between how the firm changes its productive performance from scale perspective to how optimal scale changed (Zofio, 2007); SW and ZL achieved to catch the bias associated with changes in VRS frontier (Grifell-Tatjé and Knox Lovell, 1995). Indeed, local shifts in the frontier - changes in curvature - are likely to affect the measure of scale efficiency. This effect, so-called scale of technological change (hereafter STC), is defined as *"the productivity variations on scale efficiency coming from the change in the technology with regard to the comparison period firm, i.e. the scale bias of technical change (Zofio, 2007)."* They formalize scale of technological change as follow:

$$dSTC = \left[\left(\frac{D_o^{t,CRS}(x^{t+1}, y^{t+1}) / D_o^{t,VRS}(x^{t+1}, y^{t+1})}{D_o^{t+1,CRS}(x^{t+1}, y^{t+1}) / D_o^{t+1,VRS}(x^{t+1}, y^{t+1})} \right) \times \left(\frac{D_o^{t,CRS}(x^{t}, y^{t}) / D_o^{t,VRS}(x^{t}, y^{t})}{D_o^{t+1,CRS}(x^{t}, y^{t}) / D_o^{t+1,VRS}(x^{t}, y^{t})} \right) \right]^{1/2} \tag{2.25}$$

Equation (2.25) measures the change in the shape of the technology between t and $t+1$ for the i^{th} firm. This specification provides a measure of change in the scale of technology for each firm perspective.

It is of interest to note how scale efficiency is intrinsically related to RTS and dSTC:

$$dSE_o^{t,t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = RTS_o^{t,t+1}(x^t, y^t, x^{t+1}, y^{t+1}) / STC_o^{t,t+1}(x^t, y^t, x^{t+1}, y^{t+1}) \tag{2.26}$$

As well as the relation of technical efficiency to scale efficiency, STC is the scale counterpart of technological change:

$$dTECH = dPTECH \times dSTC \tag{2.27}$$

where $dPTECH$ corresponds with the VRS specification of technological change provided by Ray and Desli (1997). However, it may be specified with CRS as well as FGNZ to catch the change in the highest productivity potential. The relation in Equation (2.22) holds and may be rewritten as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = dPTE \times dSE \times dPTECH \times dSTC \tag{2.28}$$

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Pure technical efficiency and scale efficiency remains unchanged with regard to the FGNZ specification. Pure technological change corresponds with the Ray and Desli (1997) specification of technological change.

The great virtue of the Model provided by Simar and Wilson (1998, , hereafter SW) and Zofio and Lovell (1998, ,hereafter SW) ZL is its flexibility. Given we specify VRS or CRS benchmark, the model is able to catch pure technological change as well as potential productivity change. The different Malmquist specifications and their feasible information content are summarized by Zofio (2007) in Figure 2.8. It records the components provided by each Malmquist computation from the initial CCD (1982) specification to the more detailed form of Simar and Wilson (1998).

Limits of Malmquist

Despite its wide range of application, the Malmquist decomposition involves several intrinsic pitfalls related to its incompleteness. Malmquist is only complete (exact and superlative) if the underlying production function is a translog or if it is inversely homothetic and exhibits constant returns to scale with strong disposability (CCD, 1982; Färe et al., 1994). Unfortunately, these specifications are generally not the true technology and the desirable conditions for Malmquist to be complete are usually not met. Hence, Malmquist provides unreliable TFP measures (ODonnell, 2012a). Moreover, Malmquist provides systematic biased scores of technological change. The bias is an increasing function of the returns to scale and is magnified given the frontier determination techniques (Grifell-Tatjé and Knox Lovell, 1995).

Malmquist is incomplete also in the sense that it provides only a local TFP measure oriented towards output expansion or input contraction. Finally, its inability at individualizing returns to scale and the confusions associated with its interpretation make it unreliable for decision making. A tool for performance evaluation is implementable only if its meaning is commonly understood by decision makers. In addition, its incompleteness prevents sometimes Malmquist at providing feasible solutions to TFP decomposition.

2.4.2 Hicks-Moorsteen Index

The Hicks Moorsteen has been developed by Bjurek (1996). It consists of the geometric mean of two ratios proposed by Hicks (1961) and Moorsteen (1961). Contrasting with Malmquist, the Hicks-Moorsteen provides a true and unambiguous TFP even in VRS benchmark and strong disposability (Briec and Kerstens, 2004). It does not require orientation and does not face infeasibility. The multiplicative completeness of HMTFP does not require assumption about the competitiveness of the environment nor the underlying technology (ODonnell, 2012a). In addition, HMTFP may be decomposed into an infinite number of components providing information on the DMU and the benchmark as well.

The Hicks-Moorsteen approach consists of the ratio of output to input as:

$$TFP(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{Y(y^{t+1})/X(x^{t+1})}{Y(y^t)/X(x^t)} \tag{2.29}$$

where Y and X refer to non-negative non-decreasing and linearly-homogenous aggregated functions of output and input. The TFP change is provided by the output growth net of the input growth.

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Proposal	Productivity change $\bar{M}_O^{1,2}$	Potential productivity change[a] $PTC_O^{1,2}$	Efficiency change[b] $EC_O^{1,2}$	Technical change $TC_O^{1,2}$	Technical efficiency change $TEC_O^{1,2}$	Returns to scale[c] $RTS_O^{1,2}$	Scale efficiency change $SEC_O^{1,2}$	Scale of technical change $STC_O^{1,2}$
$M_O^{1,2}(x_i^1, y_i^1, x_i^2, y_i^2)$ (Caves *et al.*, 1982)	NO	NO	NO	YES	YES	NO	NO	NO
$\bar{M}_O^{1,2}(x_i^1, y_i^1, x_i^2, y_i^2)$ (Färe *et al.*, 1989, 1994)	YES	YES	YES	NO	NO	NO	NO	NO
$\bar{M}_O^{1,2}(x_i^1, y_i^1, x_i^2, y_i^2)$ (Färe *et al.*, 1994)	YES	YES	YES	NO	YES	NO	YES	NO
$\bar{M}_O^{1,2}(x_i^1, y_i^1, x_i^2, y_i^2)$ (Ray and Desli, 1997)[d]	YES	NO	NO	YES	YES	YES	NO	NO
$\bar{M}_O^{1,2}(x_i^1, y_i^1, x_i^2, y_i^2)$ (Simar and Wilson, 1998; Zofio and Lovell, 1998)	YES	YES	YES	YES	YES	YES	YES	YES

Notes: [a]$EC_O^{1,2} = TEC_O^{1,2} \cdot SEC_O^{1,2}$.
[b]$PTC_O^{1,2} = TC_O^{1,2} \cdot STC_O^{1,2}$.
[c]$RTS_O^{1,2} = SEC_O^{1,2} \cdot STC_O^{1,2}$.
[d]Ray and Desli's (1997) proposal is equivalent to that of Grifell-Tatjé and Lovell (1996, 1999), Balk (2001) and Lovell (2003) in the single output case.

Figure 2.8: Information Content of Malmquist Specifications *(Source: Zofio (2007, Table 1, p. 2383))*

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Bjurek (1996) proposes to catch the net growth in X and Y. The variations in input and output across two periods with reference to the technologies t and $t+1$ are given by the aggregated input and output distance functions respectively. Likewise, the variation of aggregated input is given by:

$$\begin{aligned} X(x^{t+1})/X(x^t) &= \left[MI^t(y^t, x^t, x^{t+1}) \times MI^{t+1}(y^t, x^t, x^{t+1})\right]^{1/2} \\ &= \left[\frac{D^t_{i,VRS}(x^t, y^t)}{D^t_{i,VRS}(x^{t+1}, y^t)} \times \frac{D^{t+1}_{i,VRS}(x^{t+1}, y^{t+1})}{D^{t+1}_{i,VRS}(x^t, y^{t+1})}\right]^{1/2} \end{aligned} \tag{2.30}$$

The same, Y is provided by the geometric mean of output-oriented Malmquist indices with reference technology t and $t+1$.

$$\begin{aligned} Y(y^{t+1})/Y(y^t) &= \left[MO^t(y^t, y^{t+1}, x^t) \times MO^{t+1}(y^t, y^{t+1}, x^t)\right]^{1/2} \\ &= \left[\frac{D^t_{o,VRS}(x^t, y^{t+1})}{D^t_{o,VRS}(x^t, y^t)} \times \frac{D^{t+1}_{o,VRS}(x^{t+1}, y^{t+1})}{D^{t+1}_{o,VRS}(x^{t+1}, y^t)}\right]^{1/2} \end{aligned} \tag{2.31}$$

Given X and Y, HMTFP is expressed as the geometric mean of two ratio of output-oriented to input-oriented malmquist indices:

$$\begin{aligned} HMTFP(x^{t+1}, y^{t+1}, x^t, y^t) &= \frac{Y(y^{t+1})/X(x^{t+1})}{Y(y^t)/X(x^t)} = \left[\frac{MO^t(y^t, y^{t+1}, x^t)}{MI^t(y^t, x^t, x^{t+1})} \frac{MO^{t+1}(y^t, y^{t+1}, x^t)}{MI^{t+1}(y^t, x^t, x^{t+1})}\right]^{1/2} \\ &= \left[\frac{D^t_{o,VRS}(x^t, y^{t+1})/D^t_{o,VRS}(x^t, y^t)}{D^t_{i,VRS}(x^t, y^t)/D^t_{i,VRS}(x^{t+1}, y^t)} \frac{D^{t+1}_{o,VRS}(x^{t+1}, y^{t+1})/D^{t+1}_{o,VRS}(x^{t+1}, y^t)}{D^{t+1}_{i,VRS}(x^{t+1}, y^{t+1})/D^{t+1}_{i,VRS}(x^t, y^{t+1})}\right]^{1/2} \end{aligned} \tag{2.32}$$

Consistently with Bjurek (1996), distance functions are defined under VRS settings and strong disposability. This TFP formulation does not suffer the systematic bias associated with VRS identified by Grifell-Tatjé and Knox Lovell (1995).

2.4.3 Färe-Primont Index

The second index satisfying completeness we investigate is the Färe-Primont. Similar to the Hicks-Moorsteen index, the Färe-Primont is the ratio of output to input distance functions. Although it has been introduced by Färe and Primont (1995, pp. 36-38), it has been only employed by (ODonnell, 2011) in econometric decomposition of TFP. The distinctive feature of this index is to focus on a specified reference set to assess the change in TFP components. Färe-Primont TFP is given by Equation (2.33):

$$FPTFP(x^i, y^i, x^l, y^l) = \frac{D^t_i(x^{i,t}, y^0)}{D^t_i(x^l, y^0)} \times \frac{D^t_o(x^0, y^l)}{D^t_o(x^0, y^{i,t})} \tag{2.33}$$

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The first term of Equation (2.33) is the ratio of two input distance functions. It measures the input-oriented productivity of the DMU k with respect to the technology of the reference DMU^l where y^0 is a given output vector. Likewise, the second term of Equation (2.33) measures the productivity with regard to the output reference set y^l. The reference set DMU^l is chosen arbitrary. As well as Hicks-Moorsteen, Färe-Primont does not require a particular orientation nor strong economic assumption. In addition, it does not face infeasibility. FPTFP contrasts with HMTFP in the sense that FPTFP is transitive.

2.4.4 O'Donnell (2010) TFP Decomposition

Similar to Malmquist, HMTFP and FPTFP are decomposable into various components. (ODonnell, 2010), (ODonnell, 2012b) and (ODonnell, 2012a) and provides several decompositions based on different levels of aggregation. The O'Donnell decomposition of Hicks-Moorsteen is less familiar than the one provided by Malmquist. We solve Hicks-Moorsteen and Färe-Primont TFP level and changes with the Decomposing Productivity Index Numbers (DPIN) software provided by the Centre for Efficiency and Productivity Analysis (CEPA). Hence, we follow the O'Donnell decomposition described bellow.

TFP Efficiency (TFPE) corresponds with the deviation of the observed productivity from the maximum productivity potential where there is no technical nor scale inefficiency, that is to say at the MPSS. Considering $TFP^* = Y^*/X^*$ is the productivity at MPSS. TFPE is provided by:

$$TFPE = \frac{TFP}{TFP^*} = \frac{Y/X}{Y^*/X^*} \tag{2.34}$$

TFPE then is equivalent to technical efficiency computed relative to a CRS benchmark. Changes in TFP^* is a measure of technological change akin to FGNZ.

Output Technical Efficiency (OTE) is a ratio of observed aggregate output to the maximum aggregate output at the input scale with regard to the restricted possibility set. The restricted possibility set defines the maximal productivity at input scale, while output mix and input scale are held fixed. Output technical efficiency is provided by the ratio of observed output to restricted optimal output:

$$OTE = \frac{Y}{\bar{Y}} \tag{2.35}$$

Y is the observed output and $\bar{Y}$ corresponds with the maximum productivity achievable at the input scale with respect to the restricted possibility set. It implies the proportionate increase in TFP at the output level results from a scalar multiple of the input level. This definition implies proportionality axiom hold. Therefore, pure technical efficiency is a constrained performance measure. It differs from the standard DEA based technical efficiency based on the deviation from the unrestricted frontier.

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Ouput Scale Efficiency (OSE) corresponds to Banker, Charnes, and Cooper (1984) except it is determined with respect to the restrictive possibility set. Hence the deviation of the maximum potential gain achievable at the input scale is assessed from the *mix invariant optimal scale* (hereafter MIOS). MIOS is the mix restricted counterpart of MPSS. Given the MIOS production combination is given by $\tilde{Y}/\tilde{X}$, output scale efficiency is:

$$OSE = \frac{\bar{Y}/X}{\tilde{Y}/\tilde{X}} \tag{2.36}$$

where the numerator corresponds with the maximum feasible productivity at input scale with regard to the mix restricted production possibility set and the denominator is the MIOS productivity. The measure provided is the deviation of the restricted technically efficient firms at the input scale from the MIOS. The result corresponds with the productivity shortfall associated with the wrong exploitation of the RTS.

Output Mix Efficiency (OME) focuses on the output mix. OME measures the deviation of firms' productivity given the output diversification from the best productivity achievable only by changing the output combination. It reports the distance between the restricted and unrestricted maximum productivity potential at the input scale.

$$OME = \frac{\bar{Y}}{\hat{Y}} \tag{2.37}$$

where $\bar{Y}$ is the maximal output achievable at the input scale with respect to the mix restricted production possibility set, while $\hat{Y}$ is its unrestricted counterpart. ODonnell (2010) interprets it as the potential gain that can be raised by exploiting economies of scope since it reports the TFP gains at the input scale when restrictions about output mix are relaxed. In other words, OME computation, in multi-outputs settings, implies there exist a particular output combination that permit to achieve best productivity, while keeping input constant. In the case of single output technology or if there is no mix inefficiency, there is no distance between mix restricted and unrestricted frontiers and OME must equal 1. Taken in its input orientation, input mix efficiency (IME) is more concerned with input substitution. Input mix inefficiency highlights the existence of a particular input excess in the input set instead of the aggregated input excess as measured by standard DEA based input-oriented technical efficiency.

Residual Output Scale Efficiency (ROSE) is a measure of scale efficiency as provided by comparison of BCC with CCR. ROSE is the mix unrestricted counterpart of OSE. It measures the deviation of the productivity located at the unrestricted frontier given the input scale from the MPSS. The term is said residual because the shift along the unrestricted frontier implies there is no inefficiencies except scale inefficiency.

$$ROSE = \frac{\hat{Y}/X}{Y^*/X^*} \tag{2.38}$$

$\hat{Y}/X$ is a technically efficient production combination at the input scale with respect to the mix unrestricted frontier, while the denominator is the maximum productivity achievable (at MPSS).

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Output Scale Mix Efficiency (OSME) measures the distance between the MPSS and the technically efficient DMU at the input scale with respect to the mix restrictive production possibility set . It is provided by the ratio:

$$OSME = \frac{\bar{Y}/X}{Y^*/X^*} = ROSE \times OME \tag{2.39}$$

It is an aggregate measure of scale inefficiency and mix inefficiency.

Residual Mix Efficiency (RME): is the distance of productivity at MIOS from productivity at MPSS. RME implies there is no inefficiency except in both input and output mix inefficiency.

$$RME = \frac{\text{productivity at MIOS}}{\text{productivity at MPSS}} = \frac{\tilde{Y}/\tilde{X}}{Y^*/X^*} \tag{2.40}$$

RME catches any improvement in TFP is related to improvement in mix efficiency.

TFP components are linked by the following relation:

$$TFPE = \frac{TFP}{TFP^*} = OTE \times OME \times ROSE = OTE \times OSE \times RME \tag{2.41}$$

The input-oriented decomposition corresponds with the inverse by the output components specification (for more details, see ODonnell (2010)).

Conclusions

This second chapter presents the framework of duality theory equivalence for tools of production evaluation under static and dynamic settings. In the static approach, two sets of measures are derivable. On the one hand, the overall technical efficiency focuses on physical quantities and on technical constraints to measure the deviation of the firm from the highest production. On the other hand, value functions such as cost efficiency provide a more complete measure by including the effect of input mix. However, this gain of information content is at the sacrifice of strong requirements in data and assumptions. Both sets of efficiency are computable with DEA. DEA is a non-parametric deterministic benchmarking techniques employed to infer the maximum productivity achievable at the input scale. The advantage of this method is its adaptation to various technical constraints as well as the variable returns to scale or the fixity of charges.

The dynamic evaluation raises the issue of the evaluation of the sources of efficiency change. The use of productivity indices, based on DEA models, enable the dissociation of overall technical efficiency changes in pure efficiency components, related to the firm's specific practices, and in technological changes, associated with shifts in the benchmark of best practices. Another great virtue of the complete productivity indices, especially the Hicks-Moorsteen and the Färe-Primont, is their ability at evaluating the TFP. We make explicit the decomposition and the limits of the incomplete Malmquist index and we propose the use of the Hicks-Moorsteen and Färe-Primont indices following the (ODonnell, 2010) decomposition.

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Finally, it is important to precise that the framework provided through duality theory equivalence differs from the interpretation based on neoclassical theory of production. First, neoclassical production function does not allow technical and allocative inefficiencies. For production function the efficiency is only a borderline case, while it is the dominant pattern in frontiers. Another important distinction is summarized by (Simon, 1962). He notes that the process by which marginal computation are performed with frontier analysis has nothing to do with the fixing of quantities and prices by the market. In former case, the quantities of interest are computed with a process of iterative computation which requires the centralization of information. By contrast, the market provides quantities of interest in a decentralized manner. (Simon, 1962) notes:

"... the introduction of formalized decision procedures incorporating such tools as linear programming has tended to centralize the decision-making process. To be sure, the optimal solution of a linear programming can be interpreted in terms of classical marginalist principles, and quantities appear in the solution that have all the properties of prices. Nevertheless, in practice solutions are invariably obtained by centralized computations using algorithms like the simplex method and not by the tatonnement process of a market."

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Chapter 3

Financial Information Content of Technical Efficiency

If financial equilibrium models do not allow for technical inefficiencies, tools derived from these models are more flexible. Following the CAPM paradigm, they consider that the realized stock returns balances between fairly common market factors to firm specific events. Nevertheless, the importance of management discretion about the implementation, the riskiness and the time pattern of production and investment decisions magnifies the importance of the idiosyncratic components. In that sense, it contrasts with the CAPM and MMD arguments. The characterization of the empirical relation between technical efficiency and stock returns requires to define the extent to which technical efficiency reflects systematic and specific variations of stock returns. This raises the issue of the nature of the information provided by frontier based performances.

The Efficient Market Hypothesis of Fama (1970) states that the nature of the information set defines the degree of market efficiency. Three degrees of market efficiency are defined: The weak form in which trades are based on historical prices. The semi-strong form based on public information such as public announcements and macroeconomic information. The strong form of market efficiency defines a situation where traders have a monopolistic access to private information (such as insiders or analysts).

Another approach of the information set is to rank information given the scope of its effect. King (1966) demonstrates the intuitive idea that since the stock price is subject to the investors' expectations formed from information inflows; it is reasonable to believe that their impact on stock returns differ depending on the scope of the information set. Some information impact various classes of assets, while others impact only few. For instance, public information like monetary policy is likely to affect most of the assets in the economy, while an increase in military expenses would affect only few sectors. In contrast, information about future dividends would affect a specific firm. He notes, however, that all firms are not necessarily equally impacted by the information flows. The returns expressed with CAPM is a linear function of effects ranked given their scope.

According to Roll (1988), the stock price reaction differs depending on the category of information, that is to say, its scope and its nature. The purpose of this chapter is to investigate the kind of information conveyed by technical efficiency computed with data envelopment analysis. The first section reports the relation between the scope of information and the stock returns through market models derived from CAPM. The

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second section presents the relation between private information and the firm-specific components of stock returns. The third section analyses the extent to which the stock returns reflects public or private information and under which circumstances. Finally, the information content of technical efficiency is introduced in the fourth section.

3.1 Common Market Factors

The fundamental contribution of Sharpe (1964) has given raise to prolific developments for the measurement of stock performances without equilibrium conditions. While these contributions are theoretically less restrictive than the CAPM framework, they do not fundamentally split with its general philosophy. As well as the CAPM, the framework is mean-variance and investors are assumed well diversified. In addition, their analysis is focusing on the structure of covariances of returns with systematic factors to determine the expected returns of stocks. However, the models differ in the number of pervasive market factors introduced to explain a larger portion of intertemporal returns volatility. The performance of a model is assessed with the adjusted R-squared that is to say the proportion of variance explained by the factors. According to Roll (1992), the more the response of stock prices to common factors is the more trades on public information is intensive. Following Connor (1995), the market models may be classified given the scope of their information.

3.1.1 Arbitrage Pricing Model and Macro Economic Based Models

The APM is a multi-factors model introduced by Ross (1976) based on factor analysis. Factor analysis aims at identifying the set of essential factors that affect the stock price variation. The APM differs from CAPM in the sense that it does not require equilibrium conditions nor the assumption of quadratic utility function and Gaussian distribution of returns.

Nevertheless, it does not split with the CAPM's general philosophy. While CAPM states systematic risk is captured in a single factor related to the market portfolio, the APM considers stock price dynamics is driven by a set of common market factors. In addition, the holding of the market portfolio condition is replaced by the holding of a well diversified portfolio. Hence, the idyosincrasic risk is insignificant since investors are assumed well diversified. In addition, the arbitrage pricing theory holds the linearity relation of risk to returns grounded on the Law of one price. The expected returns over a subset of assets is a function of their exposure with systematic factors. The relation is formalized as follow:

$$R_p = R_f + \sum \beta_{ij}\delta_j + \epsilon_i \tag{3.1}$$

where R_p is the portfolio return. β_{ij} is the sensitivity coefficient of the asset price i for the unanticipated variations of a common market factor δ_j. Finally, ϵ_i is the independently and identically distributed random error with 0 mean associated with the risk specific

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effect. Factors δ_j are assumed uncorrelated between each other. Again, the β of the portfolio is the weighted average of the betas of individual stocks.

The riskiness of the portfolio may be summarized into a single Beta factor β_p that encompasses the covariances of portfolio returns with changes in macroeconomic factors:

$$\beta_p = \sum \frac{COV(\delta_{ij}; R_i)}{V(R_i)} \tag{3.2}$$

The following formalization clarifies the need for risk premium estimation and the weight of each δ:

$$E(R_i) = R_f + \beta_1[E(R_1) - R_f] + \beta_2[E(R_2) - R_f] + ... + \beta_n[E(R_n) - R_f] + \epsilon_i \tag{3.3}$$

where $E(R_1)$ is the expected returns on the portfolio for the factor $F1$. In other words, $[E(R_1) - R_f]$ is the risk premium for the factor δ_1 with a sensitivity coefficient β_1. It is assumed that the only information that firms seek is the amount of each factor contained in each undertaken project.

Chen, Roll, and Ross (1986) empirically confirm the equity returns rewards for the risk associated with market wide unanticipated events. Chen, Roll, and Ross (1986) identify 5 relevant factors on NYSE. i) The monthly growth of industrial production, ii) the change in expected inflation , iii) the unexpected inflation, iv) the debt rating based risk premium and v) the term structure. Aber (1976) provides evidence of the importance of macroeconomic factors in stock price behavior, especially i) 30-day Treasury bill rate, ii) 20-year corporate Aaa bond rate, iii) FRB Index of Industrial Production, iv) Consumer Price Index. Even though these factors have been identified as of importance, the relation with asset prices depend on their exposure to those macroeconomic factor.

3.1.2 Industry Factors

King (1966) was the first to empirically establish the relevance of industry factors in cross-sectional dependencies in returns. He tests on NYSE from 1927 to 1960 the co-movement of firms sharing two-digits in SEC industry classification. He reveals that a small number of factors, industry and market explain the essential co-movements of stock returns. The results enhance analysts to group firms to obtain the maximal homogeneity. Despite biases related to the sample and the empirical tests, Meyers (1973) generally support the importance of industry factors in cross-sectional inter-dependencies. His cluster analysis strengthens the concept of risk class of Modigliani and Miller (1958). Fertuck (1975) performed a study similar to King (1966) with three-digits. His results are consistent with Meyers (1973). He observed, however, the 3 digits SEC industry index accounts for 11.5 percent of the total variance, while one and two digits explain 3 percent of variance. The market factor accounts for about 25 to 30 percent of the variance.

Lessard (1974) confirms industry factors remain far less important than the national factors to cluster firms that share common return features and are diversifiable away. Aber (1976) provides a similar evidence. Industry clusters are outperformed by alternative

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grouping strategies and macroeconomic factors. [1]

Nevertheless, the importance of industry factors for the cost of equity estimation has increased over time. Tests of relative value relevance performed by Roll (1992) on 22 countries from 1988 to 1991 showed industry factors explain 40 percent of the volatility of the market. The relative importance of industry factors in the explanation of stock returns seems to shift up as demonstrated by Cavaglia, Brightman, and Aked (2000) and Urias, Sharaiha, and Hendricks (1998). The globalization of firms' sources of revenues and operations as well as the concentration of industry, related to the decline in national trade laws and protections since the last thirty years, changed firms' strategies in favor of internationalization. The biggest firms must be viewed as a portfolio of international activities (Cavaglia, Cho, and Singer, 2001). Hence, the diversification performed by investors is more concerned with industry factors. Phylaktis and Xia (2006) provide evidence that the importance of industry factors over country factors is true for European and North American markets and is observable since 1999. They confirm Wang, Lee, and Huang (2003) who delivered similar results for the US and Japanese markets.

However, the analysis of industry factors must be taken with caution. Fertuck (1975) wrote:

"it is necessary to be very careful when deciding whether to use an industry index to remove systematic movements. In some industries, the industry effect is trivial and can be safely ignored. In others, it can be as large as a third of the market effect" (Fertuck, 1975, p. 847).

The causes of the varying importance of industry factors is discussed in section 3.

3.1.3 Fundamental Model: Fama-French-Carhart Model

The Fama-French-Carhart model is composed of the 3 factors Model of Fama and French and the behavioral model of Jegadeesh and Titman (1993). Each factor consists of a different investment strategy: *"high versus low beta stocks, large versus small market capitalization stocks, value versus growth stocks, and one-year returns momentum versus contrarian stocks" (Carhart, 1997, p.61).*

The distinctive feature of the Fama and French model (1992a, 1993, 1995, 1996, 1997, 1998) is the integration of specific characteristics of size and Book-to-Market ratio (BM) in the formation of the portfolio. The resulting premia is employed as proxies for systematic factors. They argue that fundamental information captures cross-sectional variations on average returns related to load factors with greater accuracy than CAPM or macroeconomic models do (Connor, 1995).

These authors express the expected returns as a function of the linear combination of:

$$E(R_i) = R_f + \beta^M(R_M - R_f) + \beta^{SMB}E(R_{SMB}) + \beta^{HML}E(R_{HML}) + \beta^{MOM}E(R_{MOM}) + \epsilon_i \tag{3.4}$$

where, $\beta^M(R_M - R_f)$ is the CAPM, β^{SMB} and β^{HML} are the load factors for *growth* and *value* stocks and $E(R_{SMB})$ and $E(R_{HML})$ their respective premia expressed in proportion of average monthly returns and ϵ_i the random error. They apply the premia in Model (3.4) corresponding to the deciles of the returns of the value weighted and equally weighted

[1] *"Six stock groups: high quality, glamour, cyclical, defensive, conglomerate, growth. (Obtained from Tekmatics Indexes, Brush Slocumb and Company, San Francisco.)"* in Aber (1976, p. 620)

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portfolios on the US non-financial firms quoted on NASDAQ, NYSE and AMEX from 1962 to 1990 following Fama and MacBeth (1973) regressions.

Results reveal that high book to market value stocks (*value stocks*) have different patterns of returns compared with small book to market value stocks (*growth stocks*). Pattern of returns means how the stock returns fluctuate from month to month, how much they move and the degree to which they move in tandem with other stocks (Daniel and Titman, 1998). Fama and French observe *value stocks* moves together alike *growth stocks*. However, *value stocks* and *growth stocks* do not move together. As a matter of fact, *value stocks* exhibit persistent performance advantage. They conclude this is due to a greater risk incurred by a risk of distress and business cycle proxied with size and book to market (Fama and French, 1993). In addition, when size is taken into account, the β^M from CAPM does not explain cross-convectional differences. Despite the use of firm-specific information, their purpose is to trace unobserved common market factors with the use of firms-specific variables to CAPM. They considers size and book to market mirror the sensitivity to common market factors with a greater accuracy than macroeconomic models do. In Fama and French (1993) words:

"... portfolios constructed to mimic risk factors related to size and BE/ME capture strong common variation in returns, no matter what else is in the time series regression. This is evidence that size and book-to-market equity indeed proxy for sensitivity to common risk factors in stock returns".

The one year momentum load factor $\beta^{MOM}E(R_{MOM})$ differs from the other three factors in the sense it does not reflect sensitivity to common risk, but the overreaction bias of investors to firms-specific information. Jegadeesh and Titman (1993) and Jegadeesh and Titman (2001) provide evidence that a relative strength portfolio deciles based on the prior 3-12 months returns exhibits cumulative positive abnormal returns over the 12 months that follow portfolio formation, but is followed by a reversal after this holding period. Following Carhart (1997), the momentum premium corresponds with the monthly average returns of two equally weighted portfolio of the 30% firms that exhibit highest returns and the 30% firms that exhibit lowest returns over the 11 past months respectively.

3.2 Firms-Specific Variance of Returns and Private Information

After taking into account the influences of common market factors and industry returns, the remaining variance of firms' returns is expected to be related to firms-specific information. Such information concerns, for instance, disclosure about future earnings. Its effect on stock returns is particularly high in period surrounding the release of firms' official reports. Empirical literature observes this remains the most part of the returns variation even after removing periods of firms-specific news releases. Indeed, Roll (1988) notes that it accounts for 65 percent of the US monthly returns after removing the effect of systematic macroeconomic and industry influences[2].

According to Roll (1988) this specific variation of returns is assimilated to trading with private information. Private information is an information not fully reflected into stock prices. Contrasting with public announcement, the effect of private information

[2]Across industries and taking into accounts official reports releases, CAPM and APT explain 0.3438 % and 0.3607 % of the total variance.

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on stock prices ensues from the trading of investors having a monopolistic access to a particular information source as well as specialists and insiders (Fama (1970), and Fama (1991)). As soon as arbitrage is based on that information, the price system makes it publicly available and the informativeness of stock price increases (Grossman and Stiglitz, 1980). The trading on private information contributes to the efficiency of the stock market. Durnev, Morck, Yeung, and Zarowin (2003) and Durnev, Morck, and Yeung (2004) empirically confirm Roll (1988). They establish that firm-specific returns variation corresponds with more informative stock prices since it contributes to closer market value of the firm with its fundamental value.

3.3 Relative Importance of Market Factors and Firm-Specific Events in Stock Returns Forecasts

The degree of correlation among stock returns depends on *the relative amounts of firm-level and market-level information capitalized into stock prices* (Morck, Yeung, and Yu, 2000). Less synchronicity implies more informative stock prices and more efficient stock markets. Figure 3.1 provided by Morck, Yeung, and Yu (2000) depicts the average synchronicity of stock returns for 40 countries for 1995. The synchronicity is estimated through regressions of bi-weekly stock returns to the domestic value weighted index plus GDP per capital based on Data Stream historical data. We observe that in the USA (the market place of interest here) the variation of stock returns explained by the relation with market portfolio and domestic GDP is the lowest. This means that most of the returns variation depends on the specific returns' variation. Again, USA exhibits the lowest proportion with only 57% of stocks co-varying. This confirms results provided by Roll (1988) where synchronicity is assessed with CAPM and APT. The relative importance of systematic factors based on public information over private information depends on the one hand on the competitiveness of stock market and on the other hand on the competitive environment in which firms evolve.

3.3.1 Conditions of Financial Market

Two sets of factors may explain the relative importance of stock synchronicity in different stock markets. The first is concerned with the legal system that frames the financial market and the production of information. Morck, Yeung, and Yu (2000) provide evidence that stock synchronicity is higher in countries where the shareholder protection law is less developed. They suggest investors have less incentive to trade on private information. Wurgler (2000) confirms Morck, Yeung, and Yu (2000) and indicates the stock synchronicity is higher in countries featured by interventionism and public ownership. Likewise, La Porta, Lopez-de-Silanes, Shleifer, and Vishny (2001) suggest that common law countries oriented towards the protection of the investors have better financial market adjustment to specific information than civil law countries. Obviously, the relative trading on private information over public information also depends on the market structure of the information producer. Bushman, Piotroski, and Smith (2004) provide evidence that the trading on private information is higher for countries where financial analyst press and freedom to speech is more developed.

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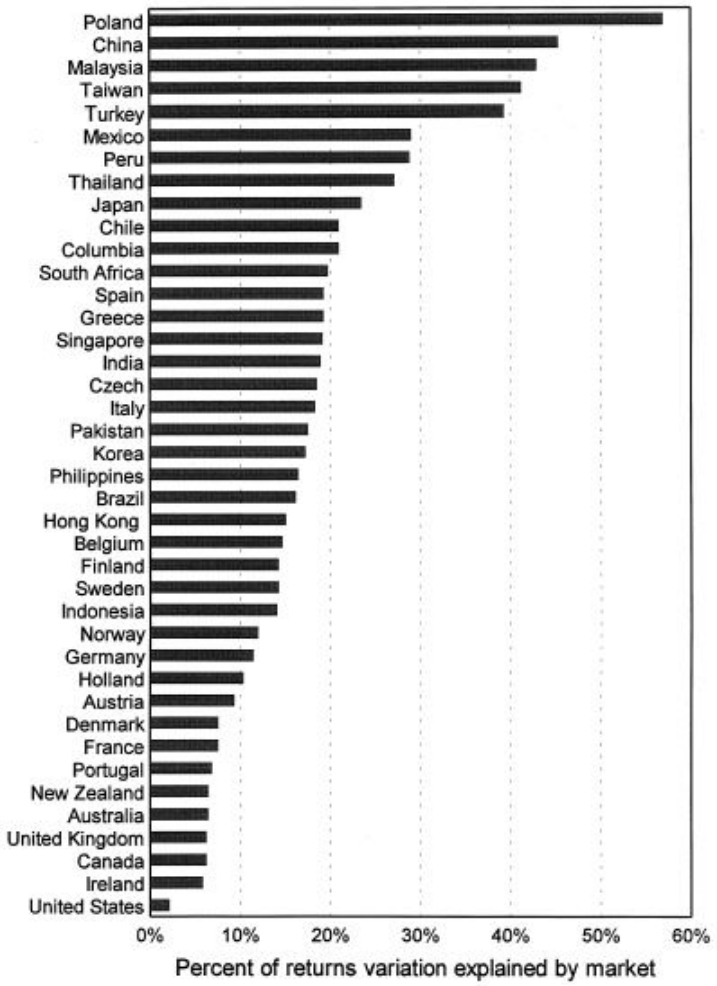

Figure 3.1: Stock Price Synchronicity in Various Countries (*Source: Morck, Yeung, and Yu (2000)*)

The second set of reasons is more technical. Roll (1992) points out a technical reason. It is concerned with the construction of the industry index. The degree of diversification of some index reduces the correlation of the index with individual securities. Industrial diversification may depend on the heterogeneity of firms' activities within the index including firms geographical diversification of their activity. Thus, industry returns are likely to reflect different international perturbations of industries. In addition, some indices are driven by changes in exchange rates in a way that differs accross countries.

3.3.2 Competitiveness of Firm's Market

The degree of synchronicity of a particular stock depends first on the way the underlying firm goes through its environment. At their barest essential interpretation, the relation of the performance of the firm to common market factors assumes that the profitability of the firm is exogenously determined since it is mainly driven by stochastic processes. This approach is consistent if the activity of the firms is indeed a function of stochastic factors due to technological uncertainty or, more importantly, to uncertainty

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about future macroeconomic aggregates like supply and demand. On the one hand, technological uncertainty considers events that impact production conditions - positively or negatively - and that cannot be avoided (e.g. as the farmer cannot avoid flood). On the other hand, the second source of uncertainty is more concerned with effect of unpredictable macroeconomic changes resulting from aggregated transactions in a competitive economy. In this latter case, every decision taken by any individual firm interacts with other firms' decisions and with multiple and complex variables in a way that makes the outcome of the firm function of a law of probability. The law of large numbers at work makes the outcome of the firm independent of its will.

This description is the feature of contingent decisions. In other words, the firm contributes to the construction of its global economic environment that rules its business, but is unaware of that. Therein, Chen, Roll, and Ross (1986) write *"No satisfactory theory would argue that the relation between financial markets and the macroeconomy is entirely in one direction. However, stock prices are usually considered as responding to external forces (even though they may have a feedback on the other variables). It is apparent that all economic variables are endogenous in some ultimate sense. Only natural forces, such as supernovas, earthquakes, and the like, are truly exogenous to the world economy, ..."*. In that case, the synchronicity of stock returns with systematic macroeconomic influences would be expected to be larger than the firm-specific return. Nevertheless, a sufficient number of firms is the necessary condition for this setting.

However, many industries are highly concentrated and firms are not price takers. This is the case for instance for the US airlines industry with a Herfindahl index of 0.3 during the last 10 years. In such case, the interactions between firms are not necessarily dominated by the law of large numbers and stochastic patterns and firms may be aware of the effect of their decisions on their economic environment. Stiglitz (1981) notes *"If there are a finite number of firms in a market, as there always are, the action of any one firm will have effect on the price and/or the actions of other firms; when there are a small number of firms, the strategic interactions of firms is an essential part of the analysis of the markets. When there are a large (but still finite) number of firms, however, we ignore these interaction effects."* In this case, it's expected that the performance of the firm would be more driven by specific attributes and decisions than market factors.

Hence, the degree of synchronicity also depends on the extent to which the performance of the firms balanced towards exogenous rather than endogenous factors that itself depends on the degree of competition. Hou and Robinson (2006) provide evidence that the pattern of returns of competitive industries differs from concentrated ones. They demonstrate that the most competitive industries exhibit higher returns than the least. They also note that a measure of industry concentration contains information not captured by common Fama-French-Carhart and macroeconomic factors. Moreover, Durnev, Morck, and Yeung (2004) introduce the Herfindhal index as a control variable in their market model to take into account the effect of concentration on expected return. This is confirmed by Roll (1992) to explain differences among index correlations.

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3.4 Relation between DEA Efficiency Measures and Stock Returns

With regard to the financial taxonomy of the information set and the computation device of technical efficiency, it is expected that technical efficiency conveys public and private information. Hence, its effect on stock returns may be related to systematic factors and firms-specific attributes. In addition, we note that the empirical literature confirms the bidirectional relation between efficiency and stock returns. The analysis and the preliminary evidence provided here will be completed and deepened with the survey in the next Chapter.

3.4.1 Information Content of Technical Efficiency

Effect of Macroeconomic and Industry Factors

Technical efficiency reflects the effect of common market factors on the business of the firm that impact its productivity. In addition it includes the effect of industry events on the maximal productivity feasible. Indeed, the measurement of technical efficiency requires at first to pool firms given common characteristics of production costs and constraints. This way at pooling firms is akin to 4-digits SIC groups. The performance of the firm computed relative to its comparable peers in the industry catches common exposure to systematic economic influences. In addition, technical efficiency includes information about the state of the technology of the sector that is to say the maximum productivity achievable. This latter component encompasses the effect of unexpected events on the production potential in the industry. Consequently, it is expected that technical efficiency mirrors exposition to common market factors related to public information.

Firm-Specific Information

The second step of technical efficiency evaluation consists of differentiating comparable firms. The method consists of establishing a ranking of firms with regard to their level of productivity. This enables the distinction between winners and losers. These differences in performance within a set of comparable firms reflect the ability of the firm at maximizing productivity despite the economic environment. In that sense, pure technical efficiency, that removes the effect of technological changes on productivity is interpretable in the same manner as the specific component of the factor models. Moreover, Edirisinghe and Zhang (2007b) and Edirisinghe and Zhang (2010) employ DEA based efficiency on firms' fundamental data to perform successful relative strength portfolio strategy.

3.4.2 Bidirectional Relation

As discussed in Chapter 1, the relation of technical efficiency is bidirectional. On the one hand, stock prices convey signals for managers about the prospective investment. In addition, the required rate of return is the threshold variable at which capital budgeting

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decisions are evaluated. In that sense, the relation of stock returns to future efficiency is top-down. On the other hand, discounted profit from productivity gains directed towards the increase in the stockholder value are reflected into changes in stock prices. This relation is concerned with the forward looking information content of stock prices (bottom-up).

This bidirectional relation stated by theory is highlighted by empirical contributions with various evaluation of efficiency. Durnev, Morck, and Yeung (2004) provide evidence of the relation of the efficiency of capital budgeting, measured by the deviation from the industry optimal Tobin's Q, with the lagged specific returns variation. They interpret it as the confirmation that stock market plays a role in the achievement of functional efficiency. In addition, they observe the capital budgeting response to change in specific returns variation is particularly high in industries featured by low synchronicity. This result confirms the relation between the informational efficiency and the functional efficiency. In addition, it suggests capital budgeting efficiency is concerned with private information and firms-specific performance. Their results are a confirmation of Wurgler (2000). He provides evidence, in a analysis performed on 65 countries, that efficiency in capital budgeting measured by investment on value added is more responsive to returns in markets featured by less synchronicity. On the economic efficiency side, Rao (2005), Sufian and Majid (2007) and Haddad, Hall, Kenjegalieva, Santoso, and Simper (2010) provide similar evidence in the banking sectors for cost efficiency, while Cummins and Xie (2008) find such relation for technical efficiency.

The bottom-up relation is more investigated. The survey, detailed in Chapter 4, records 67 articles confirming the relation of revenue efficiency, cost efficiency or technical efficiency and its components to stock returns. These contributions represent 151 tests providing a statistical relation of efficiency to stock returns.

Conclusions

Financial theory argues the observed returns of the firms balance between firms-specific events and common market factors that correspond with trades on private and public information respectively. This chapter defends the assumption that technical efficiency mirrors exposure to common market factors, but also firms-specific attributes. Indeed, changes in technical efficiency measure the changes of the productivity of the firm, while taking into account modifications of its competitive environment. The extent to which technical efficiency catches the effect of pervasive factors depends on the one hand on the degree of competitiveness of the financial market where securities are traded and, on the other hand on the competitiveness of the environment in which the firm evolves.

In addition, the empirical evidence confirms the bidirectional relation between returns and technical efficiency as stated by the equilibrium theory. The evidence is reviewed and detailed in the next chapter.

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Thèse de Matthieu Belarouci, Lille 1, 2013

Chapter 4

Empirical Relation between Efficiency Measures and Stockholder Value

Introduction

The purpose of this Chapter is to provide a survey of the existing contributions about the relation between frontier based efficiency measures and stockholder value creation. The description and the classification of the evidence seeks for the characterization of the relation between efficiency solved with frontier methods and stock returns or valuation. It is important to note that the information conveyed by the efficiency score depends on the data used, the methodological paradigm employed, the specification of the frontier, and the characteristics of the environment in which the firms interact. In addition, the relation itself may differ depending on the time window and the estimation model. Hence, a survey based on a taxonomy is necessary to obtain consistency in the interpretation. Gattoufia, Orala, and Reisman (2004) note about the interest of the production of a taxonomy:

"Graphically, symbolically or both, will vividly display the similarities and the differences among the various contributions, thus demonstrating the relationship of all contributions and the practical applications of each to other. It will provide a framework by which all of the existing knowledge can be systematically filed and therefore recalled efficiently and effectively. By providing what amounts to an aerial view- a picture of the territory- it will identify the voids in the literature... Knowledge consolidation is a means to various ends, and it is also an end itself. It is a means toward the end of more efficient and more effective teaching and learning of new or existing knowledge. It is a means toward the end of more efficient storage and more effective recall and/or retention of knowledge. It is a means toward a more efficient and more effective processes of research leading to the yet unknown, to the design of the yet unavailable, and it is a means toward more efficient problem solving..." (Gattoufia, Orala, and Reisman, 2004, pp.4-5)

This chapter proposes a taxonomy that decomposes research designs in the investigation of the relation between efficiency and stockholder value. The first section briefly positions our research in the recent frontier literature. The second section focuses on the

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taxonomy produced and the collection process. Based on the taxonomy, the last section provides descriptive statistics to characterize the existing relations.

4.1 Evolution in DEA literature

As most other fields, the DEA applications increased over the last 35 years. Figure 4.1 reports the evolution of the literature since the seminal contribution of Charnes, Cooper, and Rhodes (1978). It distinguishes between purely methodological articles and applications.

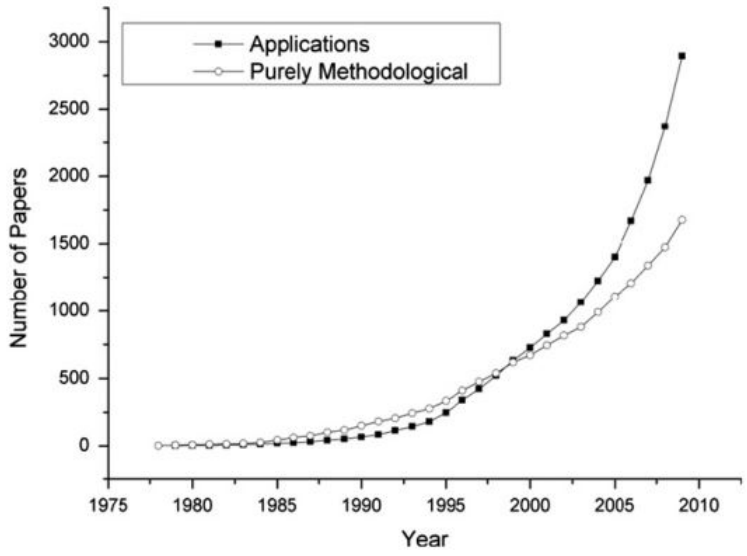

Figure 4.1: Accumulated Number of Purely Theoretical and Application DEA Papers *(Source: (Liu, Lu, Lu, and Lin, 2013, Figure 2 p.896))*

The survey of Liu, Lu, Lu, and Lin (2013) indicates that the application of DEA in finance more than doubled over the period 2005-2009. The research about the relation between efficiency and stockholder value creation belongs to this field, but is relatively small. The collection presented here managed to inventorize only 67 articles that investigate the relation with DEA or SFA paradigm over the period 1993-2013.

4.2 Collection Process and Taxonomy

4.2.1 Collection Process

The main source for the collection of contributions was the bibliographies of articles on the topic of the relation between SFA or DEA based efficiency measures and stock returns or valuation. The rest of the contributions reviewed have been collected through searches on the following data sources:

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- EBSCO
- Google
- Google Scholar
- Google Book
- Google Lab Applications (does not exist anymore)
- Institut de l'Information Scientifique et Technique (INIST)
- Publish or Perish software
- Social Science Research Network (SSRN)

The search on numeric data sources has have been done with combinations of keywords listed in Table 4.1. The left part refers to keywords related to the field of frontier analysis, while the right part concerns financial variables.

Table 4.1: Keywords Employed in Search for Contributions

Frontier Analysis	Finance
DEA	Returns
Data envelopment analysis	Market value
Technical efficiency	Stock returns
Cost efficiency	Stock valuation
Frontier	Security
Productivity	Value
SFA	Shareholder value
Stochastic frontier analysis	

4.2.2 Sample

The sample contains 67 contributions over the period 1993-2013. It is composed of 50 published articles, 16 working papers submitted in international conferences and 1 subsection of a Phd thesis. In one case, the contribution was not available for a precise reviewing. This concerns the working paper of Chen (2006). The review has been performed with the power point of the conference instead of the working paper.

Contributions report 151 tests of the relation between efficiency and stock returns or price. Figure 4.2 depicts the cumulative number of contributions released about the relation between frontier based efficiency measures with stockholder value. We observe that the number of contribution per year constantly increased. This is consistent with the rise of contributions about DEA in Figure 4.1 even though the topic of interest did not increase proportionally.

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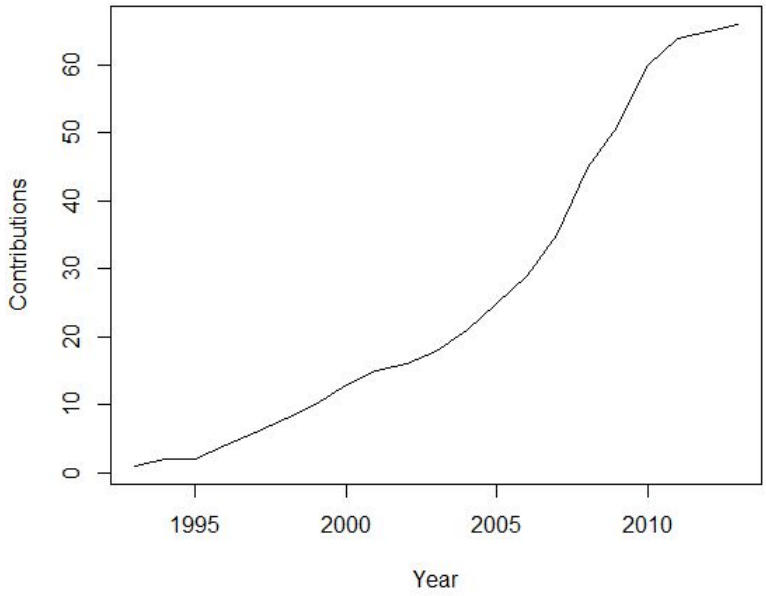

Figure 4.2: Cumulative Number of Contributions about Relation between Frontier based Efficiency Measures and Stockholder Value Creation since 1993

4.3 Results

Two sets of results are provided in this section. The first results consist of the presentation and the analysis of main designs of research reviewed in the empirical literature. They encompass the different measures of efficiency tested and the evaluation method. The second set of results focuses on the description of the relation between frontier based efficiency measures and stockholder value creation.

4.3.1 Performance Tested

Figure 4.3 reports the cumulative number of contributions and the cumulative number of tests per class of performance evaluation over the period 1993-2013. Contributions and tests have been pooled into 6 distinctions.

The efficiency indicators can be sorted in two categories. The first one refers to the standard efficiency indicators as provided by the Figure 2.1 in Chapter 2. The second category is concerned with the production of new indicators based on frontier methods.

Technical Efficiency and Overall Efficiency

The first article released is the X-efficiency analysis of the US computer industry by Thore (1993). His contribution proposes a relative strength investment portfolio strategy based on X-efficiency ranking. Given his production possibility set, the measure he provides corresponds with a marketability efficiency since one of the output is the year end market value.

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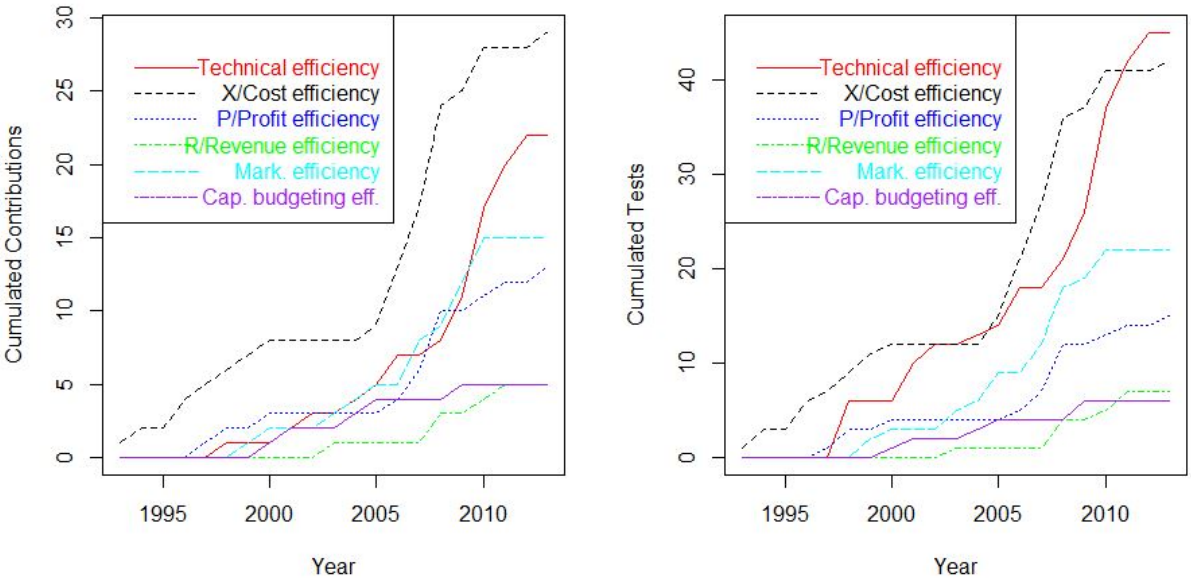

Figure 4.3: Frontier Based Performance Investigated in Cumulative Number of Contributions and Cumulative Number of Tests since 1993

The analysis of X-efficiency and cost efficiency attracted most attention regarding the number of tests and papers. However, regarding the orientation employed to solve efficiency for standards and alternative measures of efficiency, tests are mainly output-oriented. The literature started with the analysis of cost efficiency and X efficiency which initially where the most frequently tested indicators. This may be explained by the supposition that management is expected to have more control on input rather than output (see Goddard, Molyneux, Wilson, and Tavakoli (2007)). However, the development of new efficiency measures and the increasing penetration of financial designs of research shift the interest towards the use of output-oriented measures more in line with the profit maximization principle. It is important to note that only 5 contributions focused on cost efficiency, while 32 focus on X-efficiency. In contrast, the output-oriented counterpart revenue efficiency has been relatively less investigated. Only 2 contributions focus on revenue efficiency and 3 on R-efficiency respectively. This is explained by the greater interest for profit efficiency and P-efficiency which correspond with 2 and 11 articles and 2 and 15 tests. Since stockholders are interested in the information about the future cash-flows; profit is generally considered to be more appropriate to forecast stock returns. Comparative analyses systematically provide evidence of the greater explanatory power of profit efficiency over cost efficiency.

Technical efficiency has also been widely investigated. It has been first analyzed by Alam and Sickles (1998) in the analysis of the US airline industry. It represents one third of the contributions and much more regarding the number of tests. Indeed, technical efficiency is mainly tested with its components or in cross-paradigms analyses. The cross-paradigms analysis consists of comparing the value relevance of efficiency indicators obtained with stochastic and non-parametric frontiers. For 45 tests of technical efficiency, 25 were dedicated to overall technical efficiency, 8 to pure technical efficiency and 12 to scale efficiency. Moreover, 11 tests arise from Malmquist decomposition and 8 from cross-paradigms analysis.

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Alternative Efficiency Measures

An important evolution shown by the survey is the development of new efficiency measures based on frontier modeling. The most important issue that emerged was the measurement of the marketability efficiency. It corresponds with one quarter of the contributions and 16.6% of tests. The marketability efficiency, a concept introduced by Seiford and Zhu (1999), is measured for the 55 biggest US banks with a two stages convex DEA model. Figure 4.4 depicts the implementation of this two stages device. Seiford and Zhu

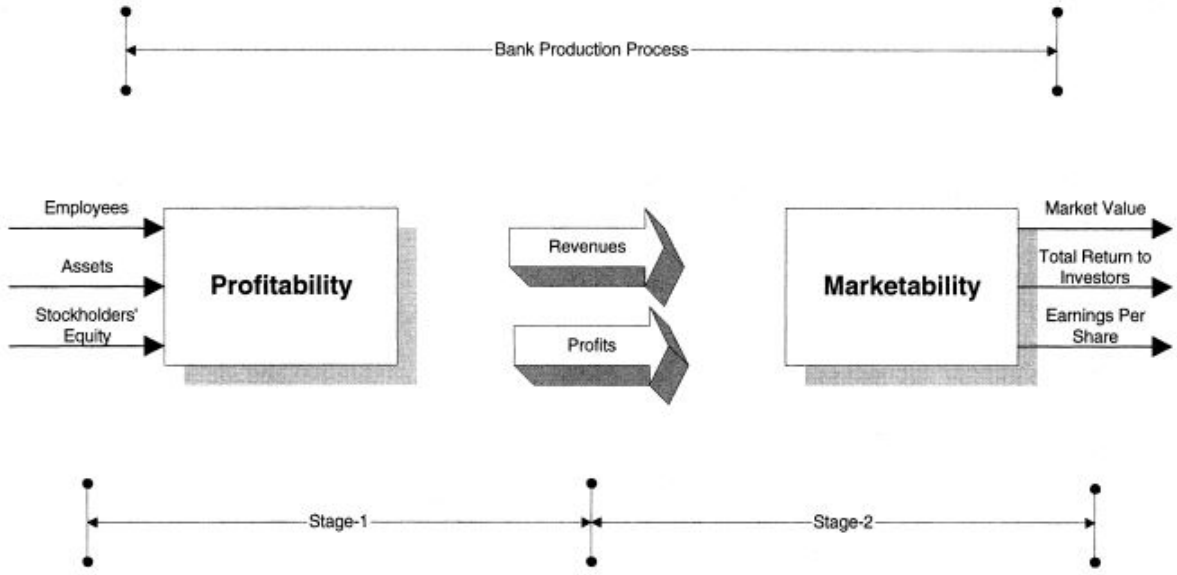

Figure 4.4: Measurement of Marketability Efficiency *(Seiford and Zhu, 1999, Figure 1 p.1272)*

(1999) consider that the market valuation is a two step process. First, the firm maximize profitability given its input set. Next, the stream of profits must be integrated into stock prices. Our category of marketability efficiency generalizes the concept of Seiford and Zhu (1999) and also encompasses heterogeneous measures.

Our category contains every efficiency evaluation that aims at describing the market valuation process by using market value or returns as output. This category is subdivided in two typologies. Table 4.2 lists the contributions about non-standard efficiency measures given their data requirements and reports the main contributors. The first set of efficiency measures focus on accounting data as input. In addition to the Seiford and Zhu (1999) (i) marketability efficiency, it encompasses (ii) shareholder value efficiency, (iii) relative financial strength indicators and (iv)capital budgeting efficiency. We now discuss each of these sub-categories in turn.

Shareholder Value Efficiency: The aim of shareholder value efficiency is to provide a profit function taking into account opportunity cost and risk. By using Economic Value Added (EVA) they reach a larger scope than profit efficiency by carrying information on firms-specific, industry specific and macroeconomics variables (Fioderlisi and Molyneux, 2010b). Shareholder value is proxied with economic value added measured as the difference between net operating profit after taxes and differed capital investments. The cost of

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Table 4.2: Non-Standard Efficiency Measures

Inputs	Models	Authors
Accounting data	Marketability efficiency	Seiford & Zhu (1999) Luo (2003) Abad, Thore & Laffarga (2009) Thore et al. (1994, 1996)
	Relative strength Financial Strength	Edirisinghe & Zhang (2007, 2010) Avkiran & Morita (2010)
	Shareholder value efficiency	Fioderlisi (2007) Kumar & Charles (2009) Fiordelisi & Molyneux (2010)
Market data	Focus on risks, earnings per shares and prior returns	Power & McMullen (2000) Oliviera & Tabak (2005) Sufian, Harun & Majid (2007) Sahoo & Meera (2008)

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capital investment is determined through a standard Capital Asset Pricing Model. Close to the alternative profit efficiency outlined by Berger and Mester (1997), shareholder value efficiency is measured by the ratio of predicted actual shareholder value to predicted maximum shareholder value. Yet, Fioderlisi and Molyneux (2007) provides evidence that shareholder value efficiency explains less value creation in banking than cost efficiency, alternative profit efficiency or revenue efficiency. Other attempts have been made to link shareholder value efficiency with stock market returns, such as Fioderlisi and Molyneux (2010b), who provides a decomposition of shareholder value efficiencies determinants with Malmquist. Kumar and Charles (2009) provide a similar analysis in the Indian food processing industry.

Relative Financial Strength Performance: Edirisinghe and Zhang (2007b, 2008, 2010) laid the foundation of the relative strength performance that aims to optimize selection of stocks. It focuses on tests of specification of input and output sets through an iterative two stages process to choose the production possibility set that explains the most the market response. They perform the following procedure: A production possibility set formed from experts advice is compared with other sets obtained from iterative selections of a variety of input and output referring to financial ratios such as earning per share, returns on asset or debt to equity, etc. The purpose is to test whether other choices of input-output sets can beat the expert information to forecast future profits. The estimator is performed with DEA model.

Capital Budgeting Efficiency: Finally, the capital budgeting efficiency is inherited from financial theory especially from the works of Wurgler (2000), Durnev, Morck, Yeung, and Zarowin (2003) and Durnev, Morck, and Yeung (2004). It evaluates the extent to which the firm achieves optimal investment decisions. The evaluation consists of measuring the deviation of the firm from the optimal expected Tobins'Q assessed with stochastic frontiers. It represents 4 contributions and 4 % of the tests reviewed. Results reveal a strong statistical bidirectional relation between the measure of capital budgeting efficiency and stock return.

Table 4.3 completes Table 4.2. It reports each article about new efficiency measures given the number of stages in the method. Each measure detailed in Table 4.2 is joined with a method that requires one or multiple stages of optimization. The choice of the number of stages may underlay a different approach of the valuation process and of the corporate objective function of the firm. Shareholder value efficiency and capital budgeting efficiency are computed in a single stage. In contrast, the computation of marketability efficiency and relative financial strength indicators require a two steps procedure. The output of the first step is the input of the second step. This approach has only been performed within the DEA framework.

4.3.2 Returns to Scale and Orientations

The nature of the returns to scale depends on the specification of the frontier. The specification of a constant returns to scale implies that an increase in input leads to a proportional increase in output. This assumption means that DMU's have the same size.

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Table 4.3: Typology of Non-Standard Efficiency Measures

Optimization	Accounting data	Market data
One stage	Fioderlisi (2007) Kumar & Charles (2009) Fiordelisi & Molyneux (2010)	Power & McMullen (2000) Oliviera & Tabak (2005) Sufian, Harun & Majid (2007) Sahoo & Meera (2008)
Multiple stages	Seiford & Zue (1999) Luo (2003) Abad, Thore & Laffarga 2009) Thore et al. (1994, 1996) Edirisinghe & Zhang (2007, 2010) Avkiran & Morita (2010)	

By using a constant returns to scale assumption, the model provides an outer approximation of the benchmark of best practices. Hence, the inefficiency is over-evaluated since the measure is relative to the production at the most productive scale of operation. In contrast, the specification of a variable returns to scale provides a more accurate evaluation of efficiency. The evaluation of the firm's efficiency is performed given the scale. Then it does not encompass a scale inefficiency effect. Table 4.4 reports the proportion of tests focusing on variable and constant returns to scale. Results indicate that the frontiers are mainly specified with variable returns to scale assumption. We note that 8 articles extract scale efficiency by comparison between constant returns to scale and variable returns to scale frontiers.

Table 4.4: Returns to Scale and Orientations

	Input	Output	Total
VRS	35%	32%	67%
CRS	12%	21%	33%
Total	46%	54%	100%

4.3.3 Methodological Paradigms: Frontiers and Efficiency Computation

The information content conveyed by efficiency measures differs depending on the methodology employed. Literature in frontier analysis is mainly dominated by two methodological paradigms: non-parametric frontiers versus parametric frontiers. The former paradigm refers to DEA and linear programming models. It is the dominant paradigm in the literature. It aggregates 63.7% of the number of tests. The second relies on regressions analyses and stochastic modeling. It represents 21.8% of tests. 14.6% provides cross-checking studies. The taxonomy differs given the frontier employed. Differences are depicted by Figure 4.5.

On the one hand, the use of DEA involves the specification of returns to scale, the shape of the frontier and the strong or weak disposability assumption. Since all DEA models

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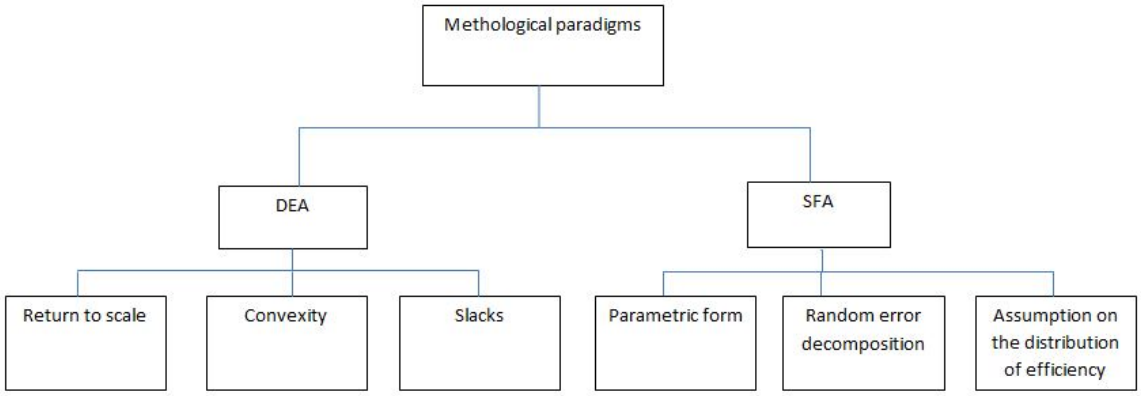

Figure 4.5: Taxonomy for Alternative Frontier Specifications

reviewed are based on strong disposability, we ignore the issue of weak disposal in our analysis. However, some contributions implement treatments of slacks to avoid spurious efficiency scores. On the other hand, the stochastic frontier analysis requires to specify the functional form and the decomposition techniques to estimate efficiency. This latter requirement is joined with an assumption about the distribution of efficiency scores.

Data Envelopment Analysis

DEA models tested in the financial literature differ depending on the specification of the structure of the technology. Four categories are recorded: the strongly disposable convex model with constant returns to scale (CCR), the strongly disposable convex model with variable returns to scale (BCC), the strongly disposable non-convex model with variable returns to scale (FDH) and the slack based models (SBM). The distinctive characteristic of the latter category is to account for the determination bias associated with slacks under strongly disposable frontier. Hence, it corresponds with an additional device implemented in one of the first three models.

The number of tests performed per DEA model is reported in Table 4.5. Among these

Table 4.5: Number of Tests per DEA Specifications

Models	Tests
CCR	47
BCC	39
FDH	2
SBM	13
Andersen & Petersen (1993)	7
Tone (2001)	2
Tone (2002)	3
Other	1

tests, 19 correspond to the computation of the scale efficiency by comparison between

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the BCC and the CCR models. Only Alam and Sickles (1998) attempted to test the relevance of FDH based technical efficiency changes with the stock returns forecasts. They find a better relation with FDH variable returns to scale efficiency score than with CCR. Sahoo and Meera (2008) is the only one article at referring to SBM provided by Tone (2001; 2002). The treatment for DMU's ranking from Andersen and Petersen (1993) is implemented by Chu and Lim (1998), Beccalli, Casu, and Girardone (2006) and Thoraneenitiyan (2008).

In addition, Seiford and Zhu (1999), Luo (2003), Abad, Thore, and Laffarga (2004) and Fioderlisi and Molyneux (2010b) employ multiple stages DEA computations. They represent 6 tests. We note that Fioderlisi and Molyneux (2010b) refer to a multistage DEA based on Coelli (1998). This model permits to overcome the issues of slack maximization inherent to a standard linear programming DEA model and of unit invariance which occurs in the second stage of the computation.

Stochastic Frontier Analysis

Stochastic Frontier Analysis (SFA) relies on econometric modeling. The approach is twofold. First, it aims at providing consistent estimates of the parameter that describes the structure of the technology. Next, it estimates efficiency scores. The feature of the approach consists of imposing a functional form to the technology to estimate efficiency and parameters of the frontier. The method relies on works about deterministic regression based frontiers (Afriat, 1972) and the works of Meeusen and Van Den Broeck (1977) and Aigner, Lovell., and Schmidt (1977).

They introduced a composed error method for the decomposition of the residuals into random noise and technical inefficiencies. This technical advantage over DEA is at the sacrifice of a strong assumption about the distribution of the technical efficiency scores which are, by construction, independently and identically distributed. The second advantage is that parameters of the regression provide an accurate description of the technology as well as returns to scale and elasticity of substitution even in the case where there is no inefficiency. Nevertheless, SFA methods construct mainly the frontier with a parametrization of the least squares method or maximum likelihood. Contributions based on SFA may be sorted with respect to the functional form and the decomposition of residuals. We discuss both of these distinctions in turn.

Functional Forms: Only two functional forms are employed in the literature discussed. The linear Cobb-Douglas and the Translog functions. The latter, formalized in Equation (4.1), is a flexible form introduced by Christensen, Jorgenson, and Lau (1973):

$$ln(y) = \beta_0 + \sum \beta_i ln(x^i) + \sum \sum \beta_{ij} ln(x^i) ln(x^i) + \epsilon \tag{4.1}$$

where x and y are the input and output and β are the parameters to be estimated with the production possibility set. The advantage of using a Translog functional form is that it does not impose restrictions about the structure of the technology (that is to say, the returns to scale nor the elasticity of substitution of production factors). In contrast, in the Cobb-Douglas linear form the elasticity of substitution as well as the returns to scale are assumed constant.

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In 73% of tests, the functional form imposed is the translog. In addition, research in the stochastic profit and cost functions in the banking sector, which represents 61% of the contributions reviewed, suggests the use of the translog (Berger and Mester (1997); Berger and Humphrey (1997)). In 24% of cases, a Cobb-Douglas form is employed. The remaining 3% correspond to the flexible Fourrier specifications tested by Rao (2005).

Residual decomposition: The estimation of efficiency within the stochastic framework implies both to select a decomposition method for the random error and to make an assumption about the distribution of the inefficiencies. This estimation of inefficiencies has been introduced by Meeusen and Van Den Broeck (1977) and Aigner, Lovell., and Schmidt (1977) (ALS). Considering Equation (4.1), the random error ϵ is decomposed in two IID terms u, the random noise such that $E(u) = 0$, and v a left skewed inefficiency term. The distribution of v relies on an assumption about the shape of the distribution of the inefficiencies. Two assumptions are most often made about the distribution of inefficiencies in the literature of interest. The half-normal Model and the zero truncated half normal distribution. The latter assumption permits to reject the possibility that modal value of inefficiencies is null. Nevertheless, this approach is less tractable (see Kumbhakar and Knox Lovell (2003)).

The limit of ALS is that the estimation of inefficiency corresponds with the mean average efficiency of the overall sample given by $TE = 1 - E[v]$. Jondrow, Lovell, Materov, and Schmidt (1982) (JLMS) improved the ALS device: they individualize the measure of efficiency by expressing the distribution of v as conditional of the distribution of ϵ for each individual i. The inefficiency of the DMU i is:

$$TE_i = E[u_i|\epsilon_i] = -\epsilon_i \left(\frac{V_v}{V_\epsilon}\right) \tag{4.2}$$

where ϵ_i is assumed negative, otherwise there is no inefficiency. Battese and Coelli (1988) modified JLMS by transforming inefficiency into efficiency expressed as $TE_i = E(exp\{-v_i|\epsilon_i\})$. Table 4.6 records the decomposition method and the assumption about the distribution

Table 4.6: Efficiency Estimation with SFA

	Half-Normal	Zero Truncated	NA	Total
ALS	4%	0%	4%	8%
JLMS	16%	0%	4%	20%
Battese & Coelli (1988)	20%	44%	0%	64%
NA	0%	8%	0%	8%
Total	40%	52%	8%	100%

of technical inefficiencies. Results indicate that the estimation has been mainly oriented to the estimation of efficiency as provided by Battese and Coelli (1988). Regarding the assumption about the distribution of the residuals, Kohers, Huang, and Kohers (2000) employs a 5% and 10% truncated normal distribution. We note that 8% of the contribution focus on the mean efficiency score of the sample following ALS. It corresponds with studies that focus on the relation between the efficiency of the industry sector and the industry returns.

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Malmquist Decompositions

Given its specification, the Malmquist index enables to decompose the sources of TFP changes into pure technical efficiency, scale efficiency, technical change and change in scale of technical change. In total, 6 contributions decompose efficiency with 3 different approaches[1]. These contributions are summarized in Table 4.7. While they account only for 6 articles, they represent 18.5% of the tests performed.

Table 4.7: Malmquist Decompositions in Relation between Efficiency Components and Stock Returns

Year	Authors	Malmquist	Decomposition	Orientation
1994	Thore et al.	Färe et al. (1994)	Marketability efficiency	Input
2002	Fernandez et al.	Simar & Wilson (1998)	Technical efficiency	Output
2008	Cummins et al.	Simar & Wilson (1998)	X-efficiency	Input
2009	Kumar et al.	Ray & Desli (1997)	Marketability efficiency	Output
2010	Fiorderlisi et al.	Färe et al. (1994)	Profit efficiency	Output
2010	Lin	Zofio & Lovell (1998)	Technical efficiency	Output

4.3.4 Methodological Paradigms: Panel Data Treatments

The information content, but also the reliability and the accuracy of the efficiency scores, ensue directly from of the number of observations. In DEA, the more observations we have, the less efficiency scores are exposed to biases. In SFA, the quality of the estimation of parameters is again a function of the number of observations. The treatment of the panel data sets differs according to the paradigm maintained and to the purpose of the measure. The differences are depicted in Figure 4.6.

The choice of the panel data treatment for DEA computation balances between short time windows for the sake of comparability and long time windows to increase degrees of freedom. Obviously, the information provided by each sample treatment and the choice primarily depends on the purpose of the analysis. This is discussed in the following subsection. In contrast, SFA approach seeks to maximize the sample size to provide consistent estimates, but the estimation of time-varying efficiency implies the use of sophisticated methods. Since the investigation of SFA is beyond the scope of this thesis, we present only the main specifications.

Deterministic Paradigm and Panel Data Treatments

The measurement of efficiency with panel data raises the issue of the number of cross-sections to include in each computation. The choice of a long time horizon permits to take into account the variability of fixed input not subject to variation. Nevertheless, the comparison of firms within a long time horizon implies to assess efficiency with respect to a benchmark that may reflect production conditions that do not exist anymore. Hence, it

[1]The decompositions provided by Simar and Wilson (1998) and Zofio and Lovell (1998) are similar.

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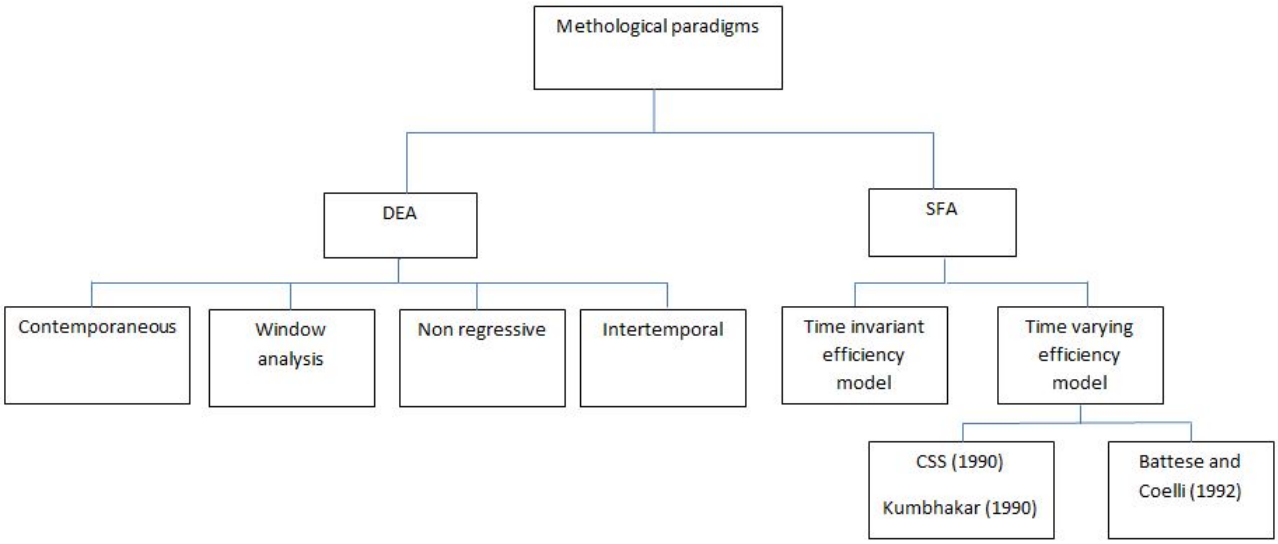

Figure 4.6: Techniques of Panel Data Treatment for SFA and DEA

may provide inappropriate scores for financial analysis. If the evaluation of efficiency must be ideally done in line with the time pattern of the investments cycles or the products life cycles, as suggested by Thore (1993), this is not empirically tractable.

Consequently, research on deterministic frontiers provides a methodological framework to drive the panel data treatment given the purpose of the user. The set of panel data treatments implemented in the literature is depicted by Figure 4.7. It represents each panel data treatment from the short run to the long run orientation. Figure 4.7 fol-

Figure 4.7: Techniques of Panel Data Treatment for DEA

lows the taxonomy established by Tulkens and Vanden Eeckaut (1995). The panel data treatment oriented to the shortest run is the contemporaneous approach that consists of selecting only one cross-section to solve technical efficiency. The purpose of this method is to focus only on the current production conditions at the moment of the observation. Nevertheless, this may suffer efficiency over-evaluation due to data limitation. The extreme opposite approach is the intertemporal model. It consists of taking the overall sample to solve efficiency at any point in time. This pattern is of interest for the description of the evolution of the productivity over time. However, the measure of efficiency is done by comparison of the oldest units featured by obsolete processes with the most recent patterns. The model then is valuable when there is no technological change over the sample period.

The two remaining computation techniques have two advantages. They take into con-

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sideration the effect of technological change and they generally encompass sufficient number of observations to avoid biases related to data availability. The window analysis has been introduced by Charnes, Clark, Cooper, and Golany (1985). It consists of handling the same number of cross-sections within a given time window that shifts through time. As one progresses over the time series, one adds a new period to the existing ones and one removes the oldest cross-section. Likewise, it is possible to maintain consistency regarding the underlying production conditions and to have a sufficient number of DMUs to solve efficiency. In most cases, only the efficiency scores of the last cross-section added are kept. The previous cross-sections within the window are employed for a purpose of comparability and degree of freedom.

The non-regressive model, introduced by Diewert (1981), integrates sequentially and cumulatively all periods to catch innovations effect on the production frontier taking the form of upward shifts. The same as window analysis, the cross-sections are added period after periods, but the past cross-sections are kept. Moreover, the new cross-section integrates into the production possibility set the new feasible processes. Nevertheless, this approach cannot encompass technological regress featured by an inward shift of the benchmark of the best practices. That is why this approach is named non-regressive.

The differences of panel data treatment implied by non-regressive model and window analysis are presented in Figure 4.8. The upper part depicts the panel data treatment under window analysis. The blue cells illustrates the cross-sections, from 1 to 7, involved in the computation of each frontier from the first to the fifth. It depicts that, at for each new frontier, the next cross-section is included to construct the technology and the oldest is removed. In contrast, the non-regressive model, depicted with red cells in the lower part of Figure 4.8, maintains all previous cross-sections in its definition of the production possibility set.

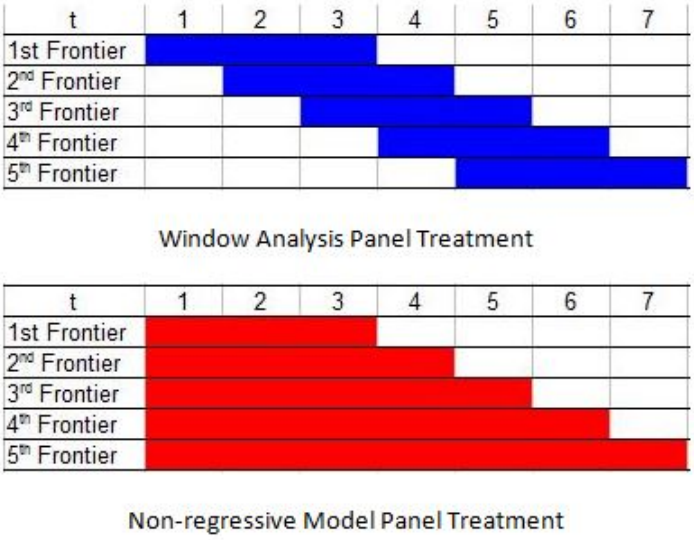

Figure 4.8: Differences in Panel Data Treatments between Window Analysis and Non-Regressive Model

Figure 4.9 reports the proportion of each panel data treatment implemented in the DEA methodologies regarding the number of contributions. In addition to the (Tulkens and Vanden Eeckaut, 1995) taxonomy, the results include the number of Malmquist computations that focus on adjacent cross-sections. It is surprising to note that a significant

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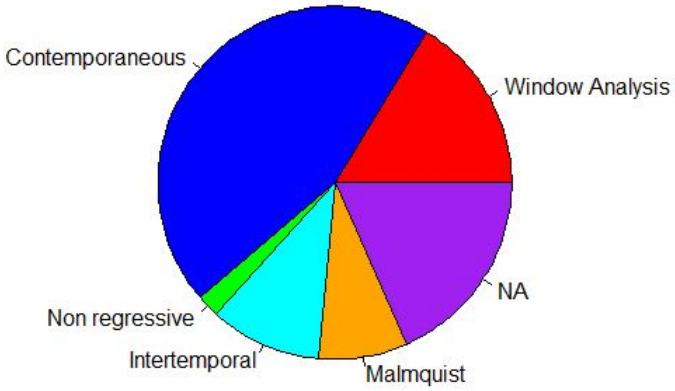

Figure 4.9: Proportion of Contributions Implementing Panel Data Treatments

portion of contributions do not report the number of cross-sections they employ to solve efficiency. Next, we note that the use of few cross-sections for each stage of efficiency computation is the dominant methodological pattern. Since the purpose of the measure is to coincide with the investors' judgment it is no surprise that the contemporaneous approach and the window analysis are the most implemented tests. Contemporaneous approach and window analysis account for two thirds of all studies. Window analysis has been implemented by Sufian and Majid (2007) and Sufian and Majid (2009) with three cross-sections as based period. Thore (1993), Thore, Kozmetsky, and Phillips (1994), Kohers, Huang, and Kohers (2000) and Fioderlisi and Molyneux (2010b) propose to apply window analysis with just two successive periods.

The non-regressive model has only been employed by Alam and Sickles (1998) in a comparison with the intertemporal model. They find that the latter is less relevant to explain stock returns. The intertemporal approach has been implemented in 5 articles. The average length of the time series employed for intertemporal analysis is 9.25 years.

In addition, it is surprising to note that no contribution deals with the issue of the panel data treatment in Malmquist based TFP decomposition. All of the articles focusing on Malmquist decomposition compare DMU's over the adjacent periods. Nevertheless, it is of interest to control for TFP change over longer time horizon to catch with more accuracy the structural changes in production conditions.

Stochastic Paradigm and Panel Data Treatment

The development of time-varying efficiency has been introduced by Cornwell, Schmidt, and Sickles (1990) (CSS) and Kumbhakar (1990). CSS developed a method based on fixed effects regression to capture time- and firm-specific effects. These methods has been extended by Battese and Coelli (1992) who provide an alternative way to catch the time pattern of efficiency. This work has been completed by Battese and Coelli (1995) who enable the introduction of firm-specific instrumental variables in the estimation of efficiency. These last two approaches (Battese and Coelli (1992) and Battese and Coelli (1995)) are the most employed in the literature with 20% and 60% of SFA tests respectively. Only Alam and Sickles (1998) implemented the CSS Modeling for the estimation of efficiency

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levels, but did not report the relation with stock returns.

4.3.5 Sector Analysis and Level of Aggregation

Sector Analysis

The research on the relation between efficiency and stock returns or stock prices with micro level data has been mainly dedicated to the banking industry. It represents more than 60% of the tests performed. At a higher level of aggregation the analysis of sectors with at most two-digits codes represents 17% of the tests. Table 4.8 reports the number of article per industry investigated. The upper part of the table reports information about contributions focusing on each sector with micro-level data. The lower part refers to the analysis at higher level of aggregation. It encompasses the manufacturing sector, the sector of services and cross-analyses of SIC-codes from the SEC categories.

Table 4.8: Level of Aggregation and Sectors in Number of Contributions

Industry	Branch level	Firm level	Cross-countries	Total
Computer	0	3	0	3
Banking	3	25	13	41
Property liability insurance	2	0	0	2
Airlines	0	1	0	1
Food processing industry	0	1	0	1
Electronic industry	0	1	0	1
	Single sector	Cross-sectors	Cross-countries	Total
sector	8	9	1	18

Level of Aggregation

The detail of contribution according to geographic region is provided in Table 4.9. Contributions focus mainly on the USA and on Eastern Asia. Except the contribution of Pasiouras, Liadaki, and Zopounidis (2008) who provide a cross-comparison between Latin America and Asia and the study of Wurgler (2000) who focus on a capital budgeting efficiency over the world, no other attempt has been made to provide cross-continental analysis.

Special Case of Banking

Since the investigation of banking industry represents 41 of the 67 contributions, the production possibility set specification deserves particular attention. The analysis of banking industry relies on three main specifications of the production possibility sets that are usually common with property and liability insurance industry. The most often employed is the intermediation approach introduced by Sealey and Lindley (1977). This approach considers bank as financial intermediaries whose purpose is to transform funds

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Table 4.9: Number of Contributions Regarding Industry Sector and Country

Industry	USA	North America	Western Europe	Eastern Europe	Western Asia	Eastern Asia	Australia	Latin America	Africa	World
Computer	3	0	0	0	0	0	0	0	0	0
Banking	7	1	8	6	3	14	1	1	1	0
Insurance	2	0	0	0	0	0	0	0	0	0
Airlines	1	0	0	0	0	0	0	0	0	0
Food	0	0	0	0	0	1	0	0	0	0
Electronic	0	0	0	0	0	1	0	0	0	0
sector	11	0	2	0	0	3	0	0	0	1
Total	24	1	10	6	3	19	1	1	1	1

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from savers to make loans to others. The production possibility set is composed of shareholder's funds, interest expenses and operating expenses for the input set and annual increase on average asset, total income and profit for the output set. Many variations of this approach are employed in the literature. Second, is the production approach of Bentson (1965). It considers banks as a producer of services. Labor and physical capital are input, while deposits and loans are output. This latter modeling of banking activity is mainly used to analyze bank branches. Note that in the intermediation approach, deposits are an input. The third specification of the production possibility set is the value added approach introduced by Berger and Humphrey (1992). It includes in the input set labor, physical capital and financial capital. Total loans, demand deposits and other earnings assets constitute the set of output.

The intermediation approach or its variation is the most employed, while only Seiford and Zhu (1999) and Luo (2003) employ the production approach for the determination of the marketability efficiency. The second mostly implemented approach is the value added approach of Berger and Humphrey (1992). Finally, Pasiouras, Liadaki, and Zopounidis (2008) use a profit approach. It includes in the production possibility set the interest expenses and the total operating expenses including provisions for loans as input and the net income as output.

Regarding the SFA modeling of performance, the alternative profit efficiency estimation from Berger and Mester (1997) is the most investigated especially for the value added approach. In DEA settings, a measure of alternative profit efficiency has been provided by Kirkwood and Nahm (2006) (see the survey of Fethi and Pasiouras (2010)).

4.3.6 Relation Between Efficiency and Stockholder Value Creation

The existence of a relation between efficiency and stockholder value creation is no surprise. It has been demonstrated theoretically and empirically. Nevertheless, the purpose of this survey is to present the characteristics of this relation. It implies to presents the direction of the relation, its time pattern and its sign. In addition, it is important to review the results provided by cross-paradigms approaches.

Interactions between Efficiency and Stock Returns

As stated in Chapters 1 and 3, the relation between efficiency and stock returns is bidirectional. On the one hand, the stock returns are the signals which drive the capital budgeting decisions. On the other hand, the firms' inefficiencies imply an existing or potential profit shortfall reflected into stock prices. The analysis of the relation between efficiency and returns has mainly focused on the latter approach with 60 contributions that correspond to 88.1% of tests. Only 7 articles investigated the influence of stock price or returns on efficiency:

- Rao (2005)
- Sufian and Majid (2007)
- Cummins and Xie (2008)

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- Haddad, Hall, Kenjegalieva, Santoso, and Simper (2010)
- Durnev, Morck, and Yeung (2004)
- Durnev, Morck, Yeung, and Zarowin (2003)
- Wurgler (2000)

Efficiency Changes vs Levels

The relation differs depending on whether we focus on changes or levels of efficiency. In the first case, the measure reports the evolution of the production of the firm with respect to the evolution of the production of its competitors and the modification of the competitive environment. Hence, efficiency is a flow variable. In the second case, the efficiency is a static measure of the competitive advantage of the firm. Strictly speaking, it describes the ability of the management at picking investments and selecting production combinations efficiently. Another interpretation is the ability of the firm at sustaining profitability despite the exploitation conditions and the competition. In case of level of efficiency, the measure is a stock variable.

The percentage of tests performed in both categories is reported in Table 4.10. It distinguishes tests of the relation between changes or level in efficiency and market value or returns. Results demonstrate that changes in efficiency is more tested than level. In addition, it is relatively more tested in tandem with stock returns than stock valuation. This is because changes in efficiency is considered as a flow variable as well as stock returns. Nevertheless, the level seems more persistent than changes in efficiency in the explanation of stock returns over time lags.

Table 4.10: Proportion of Tests on Changes and Levels of Efficiency

	Returns	Market value	Total
Level	22%	17%	39%
Changes	49%	8%	58%
Both	2%	2%	3%
Total	73%	27%	100%

Time Pattern of Relation

Contributions provide evidence of a persistent effect of efficiency on return. Fioderlisi and Molyneux (2010b), who investigate banking efficiency in Europe, report the time pattern of the relation between efficiency and stockholder value. Table 4.11 records their regression tests. The returns and efficiency are estimated on a yearly basis. The left part of Table 4.11 records the change or level in the independent and the dependent variables. The right part focuses on the efficiency lag and the sign of the relation. Results indicate that lagged changes and level in efficiency may be correlated with current EVA or stock return. Nevertheless, the sign of the relation differs over tests and time.

These results are confirmed by Nguyen and Swanson (2009) and Cebenoyan (2003). They provide evidence of the lagged effect of efficiency on returns. This pattern may be

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Table 4.11: Time Pattern of Relation between Efficiency and Stockholder Value

Authors	Independent variables	C/L	Dependent variables	t-2	t-1	t
Fioderlisi-2007	Cost efficiency	C	EVA	0	0	0
	Profit efficiency	C	EVA	0	+	+
	Shareholder value efficiency	C	EVA	-	0	+
Fiorderlisi & Molyneux - 2007	Cost efficiency	C	Shareholder value	+	-	+
	Profit efficiency	C		+	0	+
Fiorderlisi & Molyneux - 2010a	Profit efficiency	C	Shareholder value	0	+	+
Fiorderlisi & Molyneux - 2010b	Technical efficiency	L	Expected returns	0	0	+
	Allocative efficiency	L		-	+	0
	Scale efficiency	L		0	0	0
	Cost efficiency	L		-	+	-
	Technical efficiency	C		0	+	+
	Technological change	C		+	+	0
	Pure technical efficiency	C		+	+	+
	Scale efficiency	C		0	+	0
	TFP	C		+	+	+

Note: C/L = Change/Level

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explained by the underlying auto correlations of efficiency scores over time. This is verified by Kwan and Eisenbeis (1997), Habib and Ljungqvist (2005) and Nguyen and Swanson (2009). This means that an increase in efficiency is more likely followed by an increase than a reversal. This pattern is verified especially for the highest and lowest quartiles. Two underlying causes might be advanced as an explanation. The first one is a natural regression towards the mean due a stochastic behavior of efficiency. Most efficient firms over a given period are more likely to decrease over the next periods. The second reason is associated with the cost structure. The fixity of input as well as the internal resistances to changes incur opportunity costs related to changes in production combinations. Hence, most efficient firms are less likely to modify their production structure to implement technological changes over the next few periods.

The consequence of the persistency is the strong effect of efficiency on returns. In most cases, efficiency is better than accounting based ratios to explain stock return. This is consistent with Chan, Chan, Jegadeesh, and Lakonishok (2006) who provides evidence that investors are more likely to over-react to persistent or recurrent information than to transitory information.

Sign of Relation

It is important to note that the sign of the relation between efficiency and stock returns is sometimes negative. This result is counter intuitive. It is expected that improvements or level of efficiency would generate future cash-flows reflected into stock prices by a rise of their value. Vardar (2013) illustrates that cost efficiency is negatively related to stock return. Likewise, Lin (2010), who provides cross-countries Malmquist decomposition in the Asian banking sector, demonstrates that the relation of TFP components with stock returns is negative in some countries. Similar results are provided by Fioderlisi and Molyneux (2010b) with some lagged TFP components, as reported in Table 4.11. Nguyen and Swanson (2009) highlight a similar relation with capital budgeting efficiency. They provide evidence that a five year contrarian buy and hold portfolio strategy exhibits an average cumulative returns of 44% in favor of the most inefficient firms.

Several explanations are possible. First, the improvement in efficiency leads to a rise in stock value if the firm maximizes stockholder value. If the surplus of the value associated with productivity gains is not attributed to stockholders, but distributed to stakeholders; the relation would not be the expected one. Nevertheless, all of the contributions cited above deal with accounting data. Consequently, the computed change in efficiency must include both the productivity surplus and the value surplus related to the repartition among all stakeholders. Then this explanation is not sufficient, but deserves to be investigated.

With regard to the persistency of efficiency observed in some industries, another explanation is that a persistent increase in efficiency implies a risk reduction. Hence, the required rate of returns adjusted for risk decreases. This is defended by Nguyen and Swanson (2009).

The second explanation is concerned with methodological bias. Durnev, Morck, and Yeung (2004), who focus on the relation between firms-specific returns and capital budgeting efficiency, note that the presence of latent factors common to the dependent and independent variables can provide spurious regression results. *"..., latent common factors related to both capital budgeting quality and firm-specific returns variation might cause a*

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spurious relationship between the two... A negative relationship between capital budgeting quality and firm-specific returns variation might simply reflect the effects of industry concentration on both variables." (Durnev, Morck, Yeung, and Zarowin, 2003, p.81).

Cross-Checking Analyses

In total 5 articles provide cross-paradigms analyses. Table 4.12 reports the cross-checks performed and the best relations found. The left part of Table 4.12 records the different envelopment forms and the corresponding data panel treatment. The right part provides the stochastic specifications. Finally, the last column indicates which paradigm has been the best forecasting stock returns. It is of interest to note that even though Alam and Sickles (1998) have tested stochastic frontier, they do not report the significant results because of their low explanatory power.

Table 4.12: Summary of Cross-Checking Analyzes

Contribution	Frontier	Panel treatments	Functional forms	Residuals	Best
Kwan & Eisenbeis (1996)	BCC	Intertemporal	Translog	JLMS	SFA
Alam & Sickles (1998)	FDH	Non-regressive	CSS 1990	NA	DEA
Kohers et al. (2000)	BCC	Window analysis	Translog	JLMS-Time invariant	DEA
Beccali et al. (2006)	CCR	Contemporaneous	Translog	Battese & Coelli (1992)	DEA
Amess & Girma (2009)	CCR	Intertemporal	Translog	Battese & Coelli (1992)	DEA

Kwan and Eisenbeis (1996) found that SFA is better to forecast the returns of smaller firms (first two quartiles). Otherwise, SFA and DEA are equivalent. The remaining 4 articles provide evidence of the greater relevance of DEA over SFA. DEA is likely to provide more dispersed efficiency scores than SFA. Since the tests reported in Table 4.12 are based on regressions, the estimation of the relation is sensitive to the dispersion of efficiency scores among DMU's.

4.4 Discussion

The taxonomy enables to detail most effective research designs and permits to characterize the interaction between efficiency and stockholder value. Results concern research designs and characteristics of the relation between stockholder value and efficiency.

4.4.1 Evolution of Research

First, regarding the evolution of the design of research and the level of analysis, we observe that the interest of researchers has been mainly oriented to the relevance of X-efficiency/cost efficiency. The interest is now shifting towards the investigation of profit

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efficiency and technical efficiency. On the one hand, profit efficiency is expected to be of greater relevance since it is more related to cash-flows distributed to stockholders. In addition, cross-efficiency tests seem to provide a better relevance of profit efficiency over cost efficiency to forecast stock returns. On the other hand, the increasing interest in the analysis of technical efficiency is related to the Malmquist decompositions of the sources of performance. Another important development of the literature is the creation of new performance measures and tools based on frontier analysis and in line with financial preoccupation. It represents a dynamic stream of research and is an important evolution of the field.

Regarding the methods employed to solve/estimate efficiency, DEA dominates the literature. Even though DEA and SFA provide similar results, cross-checking analyses suggest that DEA is of greater value relevance for stock returns forecasting. One explanation is that DEA magnifies efficiency scores comparing with SFA. It is likely that the regression analyses, employed to assess the relation between efficiency and stock return, are sensitive to the spread of efficiency among DMU's. The relation between DEA modeling and financial modeling is paradoxical. Despite their contradiction, regarding their paradigms about the determinants of the firm, the merger of their designs of research seems to provide better representation of the underlying relation.

Focusing on the panel data treatments, we note that the number of cross-sections introduced into DEA computations is limited for the sake of temporal comparability. Indeed, the contemporaneous approach and the window analysis are the most widely applied methods. It suggests contributions seek to be in line with the time horizon of the investors' judgment.

Finally, we note that the increasing interest for marketability efficiency and profit efficiency as well as the use of short run panel data confirms the literature is more in line with financial preoccupations since the last ten years. In addition, the use of more sophisticated designs as well as SBM or Malmquist decompositions signals the progression of the literature.

4.4.2 Interaction between Stock Returns and Efficiency

Results confirm a linear statistical relation between efficiency and stockholder value creation. The current literature globally confirms that this relation is bidirectional. It means that the financial market contributes to drive internal resources allocation, while it reflects, at the same time, the value of expected cash-flows associated with productivity gains. In addition, this relation is persistent. It implies that efficiency is a potential source of recurrent information. Moreover, several contributions provide evidence of autocorrelation of efficiency over time. We observe that most efficient firms tend to be less efficient over the next few years whereas the least efficient tend to improve. This pattern may be due to the stochastic behavior of efficiency. Nevertheless, it seems more likely that it reflects the state of the competition and the underlying cost structure of the firms.

An important result is the unstable nature of the signs of the relation between efficiency and stock return. Some studies provide negative relation given the time window or the country in which evaluation is performed. This counter intuitive result may be explained by the reduction of risk associated with increases in efficiency. A reduction of the riskiness would provide a proportional reduction in the hurdle rate of return. This deduction is consistent with the time pattern of efficiency scores. Another explanation is

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that, given the underlying drivers of performance of firms, the efficiency does not convey the same information content about the risk exposure over time. This hypothesis can be tested with a decomposition of efficiency scores over long time series. In addition, it is possible that this pattern is observable for non value maximizing firms only. In such case, the improvement associated with improvement in efficiency can be offset by the distribution of the value added to a stakeholder. However, the hypothesis of a data bias cannot be rejected.

Finally, value relevance studies provide evidence that efficiency measures beat accounting based ratio in the prediction of stock return. This may be explained by the large number of variables handled simultaneously by frontier evaluation and the information it contains about the competitors. In addition, the recurrence of efficiency enhances the reaction of investors to this information.

Conclusions

This survey aims at presenting contributions about the relation between efficiency and stockholder value creation. In addition, it aims at identifying theoretical and empirical gaps. It is concerned with every contribution focusing on the relation between efficiency measured with DEA or SFA frontiers and stock returns or value. It encompasses 67 contributions including 50 articles, 16 working papers and 1 Phd dissertation. Contributions are ranked given their research designs in 39 criteria pooled over 8 categories.

Results confirm the relation between efficiency and stock returns. We observe that the relation between efficiency and stock returns is bidirectional and rather persistent over time. In addition, several cross-checking analyses seem to provide evidence of the better relevance of DEA over SFA. However, it is surprising to note that the relation between efficiency and stock returns is sometimes negative. Several explanations are proposed, but all of these ideally require additional tests.

Finally, it is important to note that the results have some limitations. Most of contributions focus on the banking sector only and their results cannot be generalized. In addition, we compare here various efficiency measures usually constructed with different accounting standards. Hence, the measures can have different relations. Then applications in other sectors and the investigation of technical efficiency computed with physical quantities seems more relevant to understand the relation between efficiency and stock reactions.

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Conclusions of Part I

The purpose of this investigation is to analyse the relation between technical efficiency and stock returns. Technical efficiency and stock returns are two performance measures derived from production theory and financial microeconomic. In addition, the relation between technical efficiency and stock returns has been early described by the theories of Financial Equilibrium. These theories consider that technical efficiency and the stock returns are the results of the equilibrium of the production and financial decisions. When both equilibria are achieved, the firm maximizes its production and value potentials. Three equilibrium models are discussed in this part:

- The Modigliani-Miller-Diamond model refers to a demand based theory. It is concerned with the derivation of the appropriate cost of equity, at which the firm takes the decisions of the allocation of investments and capital goods, from the returns of the exact comparable peers. A peer, in this model, is another firm that produces the same quantity of output with the same quantity of input for every state of nature. The resulting decisions of allocation produce a stream of profits valued on the stock market. Technical inefficiencies are integrated into stock prices proportionally with the profit shortfall associated.

- The second model is derived from the CAPM and is grounded on the investors equilibrium. Similar to Modigliani-Miller-Diamond, the cost of equity is common to firms belonging to the same category of assets. A category of assets defines a set of firms that have the same exact exposure to common market factors. Hence, firms inside a category are perfectly correlated. The relation between the CAPM and the production equilibrium reveals that the maximization of the production potential is in line with the value maximization in very a restrictive setting that does not allow for technical inefficiency. Otherwise, externalities of the production decisions are likely to disturb the investors' equilibrium (Leland, 1974).

- The Dow and Gorton (1997) model maintains less assumptions than the previous two models. It considers the stock market has a primary informative role and a secondary allocative role. The internal allocation of resources is performed by the manager. Through trades, investors inform the manager of the existence of investment opportunities and reward him for making efforts at inferring the information about these opportunities contained into stock prices. In this model, the relation between technical efficiency and stock returns does not reflect the interaction of two partial equilibria, but the valuation of the quality of management as an input apart.

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The three models agree on the bidirectional relation between technical efficiency and stock returns. Nevertheless, as Leland (1974) demonstrates, the specified relation holds in very restrictive settings. Even though the Dow and Gorton (1997) model is not as restrictive as the Modigliani-Miller-Diamond nor the CAPM framework regarding the assumptions maintained, it does not specify the nature of the relation when market conditions specified by the first two equilibrium models are not met.

In line with the CAPM paradigm, the empirical literature about asset pricing provides a framework to characterize this relation of interest. This framework considers that the observed returns balance between exogenous and firms intrinsic determinants. The nature of the relation may differ given that technical efficiency mirrors either exposition to systematic market factors, or contains information about the specific attributes of the firm. According to Roll (1988), the stock prices reaction to systematic factors and specific attributes correspond to trades based on public and private information respectively. Regarding its construction, we suggest that technical efficiency encompasses both types of information. Indeed, the change in technical efficiency contains information about the productivity gains of the firm and about the productivity gains of the best competitors in the industry. Given that changes in technical efficiency are mainly due to pure managerial quality, we guess technical efficiency conveys more private information. Consequently, given the underlying drivers of the changes in technical efficiency, we expect a different impact on stock returns.

The analysis in Chapter 4, based on the review of 67 empirical contributions about the relation between frontiers based efficiency measures and stockholder value creation, provides additional insights about the nature of the relation. The analysis provides the following conclusions:

- The empirical evidence confirms general equilibrium theory. Stock returns contributes to drive the internal allocation of resources. In addition, the improvements in profitability associated with the changes in efficiency are integrated into stock prices. Moreover, the level of efficiency, which reflects the competitive advantage of the firm, is also strongly related to stock prices.
- Tests on the relation between lagged efficiency measures and stock returns reveal that the relation is persistent over time.
- Contributions also provide evidence that the sign of the relation between efficiency and stock returns may change across industries, countries and given the time window. Indeed, some studies demonstrate that the efficiency can be negatively related to stock returns.
- Value relevance analysis shows that efficiency information beats accounting ratios in the explanation of stock returns or valuation.
- There is evidence that listed firms are more efficient than private companies. This tends to confirm the role of control of the stock market.
- DEA, which is the method most employed in the literature, seems more appropriate to predict stock returns than stochastic frontier analysis.

In the light of these results and based on the typologies of the nature of the information set provided by the Efficient Market Hypothesis, the investigation defends that technical

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efficiency contains two kinds of information. On the one hand, technical efficiency mirrors information about the exposure of the firm to the systematic risks measured by assets pricing models. On the other hand, technical efficiency conveys information about the firms-specific performance captured by the idiosyncratic risk component. Regarding the EMH of Fama (1970) and the works of Roll (1988), it implies that technical efficiency contains public and private information. In addition, the thesis investigates the advantages of using technical efficiency in the financial analysis when the accounting is incomplete to report the dynamic and troublesome evolution of the industry.

Turning to the second part, this study investigates these issues through an application on the U.S. airlines industry. The unbalanced sample constructed consists in quarterly production and financial data about 28 major carriers over the period 1990-2012. Production data are extracted from the official reports of the U.S. Department of Transportation disclosed by the Bureau of Transportation Statistics. They provide technical information about the carriers such as the quantities employed and the characteristics of the equipments. Non-consolidated financial statements are also provided by the Bureau of Transportation Statistics. By contrast, the consolidated financial statements and the time series of stock prices are extracted from Bloomberg. The premia employed to perform multi-factors asset pricing models are taken from the Kenneth French's website.

The results provided by the applications constitute contributions for the financial theory and the frontier framework as well. The first part of the results focus on the value relevance of non-financial information, especially technical efficiency and related technical items, to explain stock valuation. The second part of the analysis is concerned with the relation between each technical efficiency component and stock returns. The decomposition provided in this second part contributes to the development of the frontier framework.

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Part II

Empirical Analysis: Relation between Technical Efficiency and Total Factor Productivity with Stock Returns in the US Airline Industry

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Introduction

A core issue in the measurement of technical efficiency is the data availability. Fair computation of technical efficiency requires the use of quantities consumed and produced usually not disclosed in official reports. Because of the lack of availability of micro-level data about physical quantities, most of contributions about technical efficiency focus on data collected at the industry level or on the banking sector. Others employ industry price indices to proxy the quantities employed in the production processes. Nevertheless, such procedure is accurate only if the price dispersion for each production factor is low. To overcome these limitations, we investigate the relation between technical efficiency and stock returns in the US airline industry.

The interest of the US airline industry is the existence of strict fillings requirements about the activity of the firm that satisfy the data requirements for a fair computation of technical efficiency. Indeed, the official reports, released by the US Department of Transportation (DOT), include non-consolidated information about the physical quantities and characteristics of the production possibility set.

Only Alam and Sickles (1998) provide an analysis of the relation between technical efficiency and stock returns in the US airline industry prior to 1991. No other attempts have been made to deepen the relation by the decomposition of sources of efficiency nor to investigate it in the recent period featured by industry structural changes. In contrast, literature in finance and accounting provides recent empirical contributions about the worthiness of DOT reports for fundamental financial analysis. Moreover, the particular treatment of information provided by Bloomberg and Reuters is oriented towards technical information. This suggests that traders' decisions are based on technical information instead of accounting. It then is expected that the DEA based computation of technical efficiency - that simultaneously handle a large number of technical variables - would be of interest in this sector for financial analysis purposes. This part is divided in three chapters:

- The first empirical chapter describes the characteristics and the recent evolution of the US airline industry. The investigation of the information content of technical efficiency for financial analysis requires to interpret efficiency scores with regard to the production conditions of the firm. Differences in the exploitation conditions of the firms are key information to discuss the meaning, the differences in efficiency patterns, and the relation with stock returns. In addition, the methodology is sensitive to the modification of the concentration of the industry as well as the presence of extraordinary events. Then the functioning and the evolution of the industry deserves to be reviewed for the reliability of the statistical measures implemented. This chapter deals with the industry overall performance and details its factors mentioned in the literature. We explain the main costs drivers, operating constraints

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mirrored in the cost structure, and the important events that may affect the relevance of efficiency measures. Finally, we describe the sample employed to perform our investigation. The sample is an unbalanced panel data set of the 28 US major air carriers over the period 1990-2012. The data set consists of non-consolidated production and financial statements, on consolidated financial statements and on market data especially stock prices time series and risks premia.

- The second chapter concerns the value relevance of technical efficiency and related non-financial information for the explanation of stock prices. The US airline industry is characterized by important troubles over the sample period. The sector destroyed 25.35 $ billions in net income since 1990. In addition, the occurrence of adverse events, such as the 11^{th} September 2001, the SARS epidemic or the dramatic increases in main costs drivers, considerably affected the production conditions of the carriers. In such circumstances, accounting may suffer some lacks of reliability to report the exploitation cycle and to permit comparison of operating performance over time. This chapter provides evidence of the complementary role of non-financial information in the explanation of stock prices. It demonstrates that DEA and SFA based technical efficiency measures summarize more technical information than other non-financial indicators and are reliable to report the evolution of industry performance.

- The last chapter focuses on the core issue of this study, that is to say, the investigation of the information content of technical efficiency. The hypothesis we maintain is that the relation between technical efficiency and stock returns may be characterized by the proportion of public and private information it conveys. According to Roll (1988), the degree of synchronicity of stock returns depends on the intensity of trades on public information, while the specific component of the returns corresponds with trades on private information. The purpose of this chapter is to decompose the TFP changes into the changes in pure technical efficiency and the technological changes. The changes in pure technical efficiency corresponds with productivity gains attributable to the improvements of managerial practices. By contrast, the technological changes catch the changes in the benchmark of best practices, which correspond to the changes in production conditions. In that sense, the decomposition of performance provided by the frontier framework is in line with the decomposition of returns established by the CAPM paradigm. Hence, we expect that the technological changes reflect the exposure to systematic factors of risks, while the pure efficiency changes better explain the specific components of returns. The decomposition is performed with the complete Hicks-Moorsteen with variable basis and the Färe-Primont with fixed basis. The results are twofold. First, we obtain a persistent negative relation between changes in pure technical efficiency and stock returns. This result holds for the Hicks-Moorsteen and the Färe-Primont decompositions. It suggests that the persistent improvements in efficiency are rewarded by the stock market with a reduction in the required rate of returns. In addition, we observe that the technological change is positively related to systematic factors of risk and negatively related with the specific components of returns. The reversed pattern is observable for the changes in pure technical efficiency. This latter result confirms that technical efficiency conveys information about the exposure of the firm to systematic risks and about the firms-specific performance. In addition, it provides evidence of the ability of complete TFP indices to disentangle

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the effect on the performance of exogenous and firms-specific factors in line with the CAPM paradigm.

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Chapter 5

The US Airlines Industry Since 1978

"It's been a death trap for investors"

Warren Buffet

The US airline industry did not create value since the Deregulation Act of 1978. The US airline industry faced important structural changes that may explain these losses. These changes fastened during the last twenty years. This chapter reports the evolution of the sector and describes its functioning. The first section positions the airline industry in the US economy and in the worldwide sector. The second section is concerned with the chronological evolution of the sector since the Airline Deregulation Acts. It describes the evolution of the network organization of the carriers and the changes in the market competitiveness. The third section focuses on the performance of the last twenty years that correspond to the sample period. Finally, the last section presents the sets of causes that may explain the poor financial performance.

5.1 Position of the US Air Carriers in the US Economy and Traffic

5.1.1 Air Carriers in the US Economy

The US airline industry provides domestic and international transportation services for passengers and freight. This industry accounts directly for 0.4% of the US GDP. It also represents 0.4% of the total US employment in full time equivalent according to the US Department of Commerce. For comparison, the Transportation and Warehousing sector accounts for about 3% in the US GDP and employment. During the last decade, the US airlines represented 14% of the value creation in the Transportation and Warehousing sector and 12.02% of employment (see the US Bureau of Census). Until the subprime crisis, the contribution of its US airlines was constantly increasing +0.042 points over the period 1998-2008 except for the downside shocks related to 11^{th} September 2001. In

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2010, it was the fifth employer of the Transportation and Warehousing sector, while it was the second in 1990.

5.1.2 The US Air Carriers in Worldwide Traffic

The US airlines industry is the first air carrier of the world. In 2010, 31.82% of all take-offs in the world have been performed by the US carriers and about one quarter in the US domestic market according to the World Bank and the US Department of Transportation. Figure 5.1 depicts a world map with the number of system take-offs (domestic and abroad) given the country of registration for the period 2008-2012. However, the proportion of

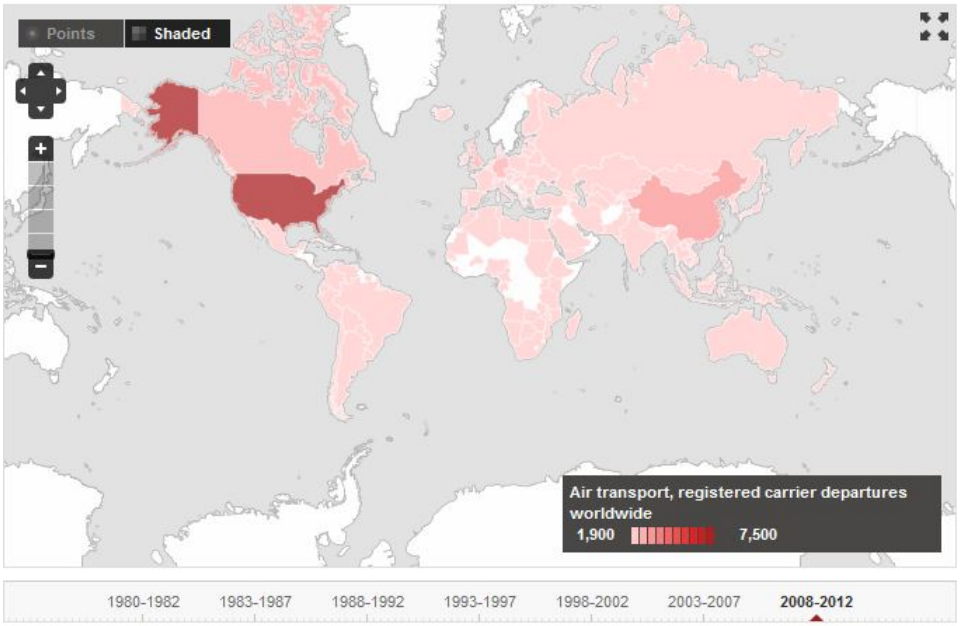

Figure 5.1: Air Transport, Registered Carrier Departures Worldwide in Number of Take-offs for 2008-2012 *(Source: World Bank)*

the US air carriers in worldwide traffic tends to decrease over the years. Figures 5.2 and 5.3 depict the evolution of the worldwide traffic of freight and passenger given carriers' registration origin.

Although the US carriers remain leader in the worldwide traffic, their proportion in passenger transportation passed from 43% in 1993 to less than 27% in 2010. This decrease is due to structural catching-up effect and nonstructural shocks. Indeed, worldwide domestic markets expand, while the US domestic market is mature. Indeed, 68% of their revenue in 2012, which corresponds with 58% of the revenue ton miles (RTM), has been realized by the US carriers on the domestic market. Proportions of domestic operation were 77% of their revenues and 62% of RTM in the early nineties. In addition, the 09/11/2001 terrorist attack and subprime crisis had downside impacts on demand for domestic flights (see also Figure 5.9). Regarding freight, the proportion of the US carriers in worldwide traffic slightly increased over the period 1993-2010.

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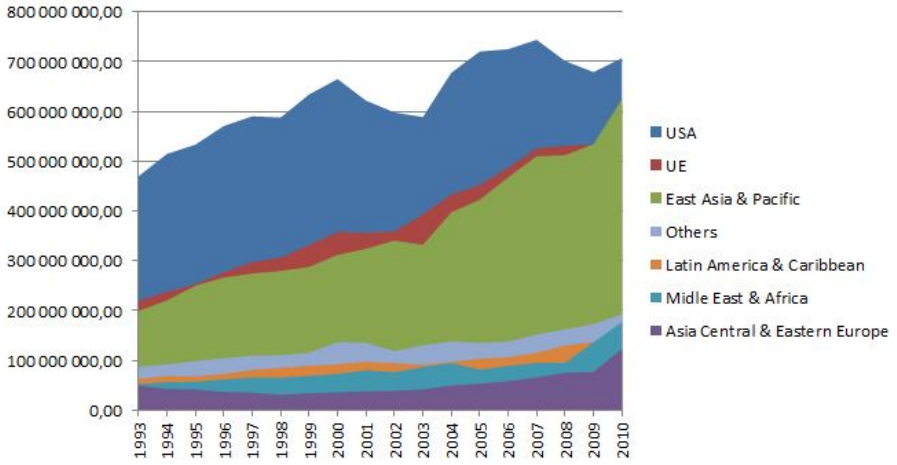

Figure 5.2: Evolution of Worldwide Passenger Traffic in Number of Passenger Emplanned

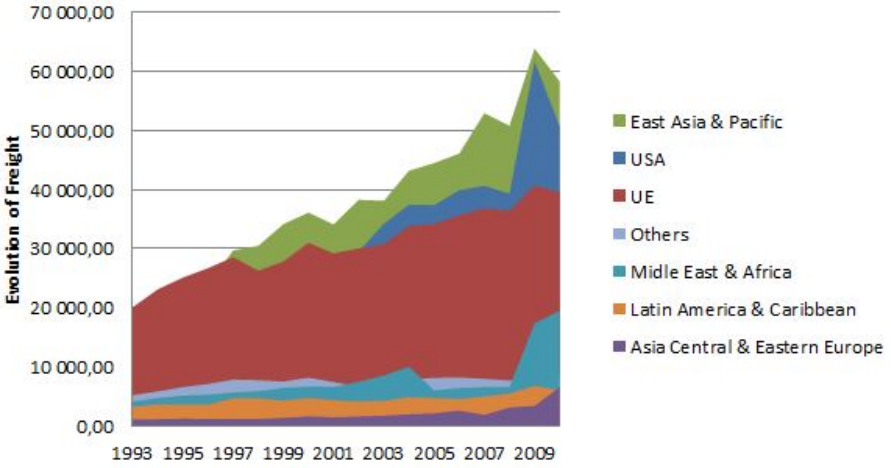

Figure 5.3: Evolution of Worldwide Cargo and Mail Traffic in Tons

5.2 The US Airline Evolution since ADA (1978)

The US airline industry faced important structural changes since the Airline Deregulation Act of 1978. The deregulation aimed at removing barriers to entry in point to point markets and to make price determination free. Before 1978, the US airline industry was governed by the Civil Aeronautic Board (CAB) which provided authorization for flight operations and fixed prices since 1938. CAB delivered a monopoly on routes to existing carriers and authorized the entry of competitors only if they provided a differentiated service and not a substitute. Indeed, the entry had not to harm the incumbent carriers. Regarding fares, CAB imposed prices based on the Standard Industry Fare Level (SIFL). This formula computed prices under the assumption of non-linear relation between cost and revenue ton miles, a 12% target returns for carriers and a target load factors of 55%. Finally, CAB was entitled to allocate subsidies to carriers operating on less profitable routes as reward for the public services. We detail below the main effect provoked by the deregulation on the industry and on the market structure that we are studying.

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5.2.1 Changes in Market Structure

The changes in market structure concern the nature of the competition, due to the transformation of a point-to-point network into a hub and spoke configuration, and the concentration of the industry.

Changes in Nature of Competition

Deregulation changed the nature of the competition into mutli-markets competition. Before the ADA (1978), carriers competed in city pair markets within the frame provided by CAB. With the deregulation, carriers restructured their network following a hub and spoke system. In a hub and spoke system, the airport is a node connected with other airports. The stake for carriers is to set up a local dominant position on airports so as to occupy as much routes as possible. Such strategy confers the advantage of a local monopoly. The number of gates and slots available in the airport determines the number of non-stop connections feasible and thus the range of a carrier's offer. It also implies cost advantages associated with the exploitation of returns to density and high load factors. In addition, a dominant position favors obtaining new routes out of the hub (Borenstein (2011a); Gimeno (1999)). The target for carriers is consequently to extend their sphere of influence on airports to favour their access to city pair markets and to lock access to competitors. Indeed, dominant position is used to deter entry through footholds in carriers' important markets.

Changes in Market Concentration

Deregulation also favored the entry of new competitors in the industry. The intense competition implied dramatic market selection. Whereas 47 new carriers entered the industry in the period 1978-1984, 48 exited between 1984 and 1988. Figure 5.4 depicts the number of entries, exits and bankruptcies in the US airline industry since 1978. In response to the rise of competition, carriers modify their organizational forms through merger and code-sharing agreements. Code-sharing is a partnership that allow one counterpart to sell tickets for trips on the flight of the second partner. Code-sharing concerns both domestic and international services. It permits for a partner to enlarge their offer and to overcome the pitfalls of fixed capacities inherent to airline industry. In addition, we note that most of the firms passed under Chapter 11 during the last two decades.

The consequence of this market selection is an increase of the market concentration. Figure 5.5 reports the normalized Herfindahl-Hirschman index (HHI) for the overall US airlines industry over the period 1974-2012. The normalized Herfindahl index is a measure of the market concentration computed by the sum of squares of firms' market shares. The result is bounded by 0 and 1. Low HHI indicates a competitive market. It is obtained by the following equations:

$$HHI = \sum_i s_i^2 \tag{5.1}$$

where s_i is the market share of the firm i. It is normalized by:

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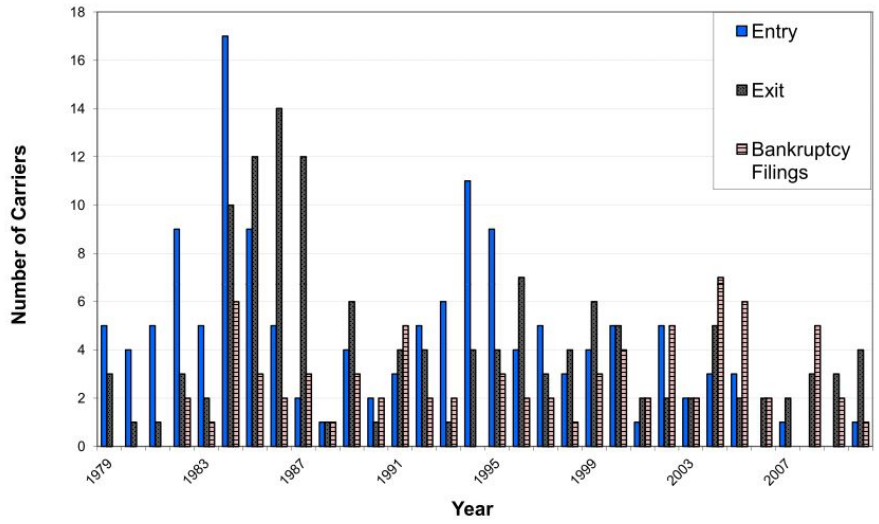

Figure 5.4: Entry, Exit and Bankruptcy Filings: 1979-2011 *(Source: Borenstein (2011b, Figure 8 p. 93))*

$$NHHI = \frac{(HHI - 1/N)}{(1 - 1/N)} \tag{5.2}$$

The results of NHHI provided in Figure 5.5 are based on the relative Revenue Ton Miles (RTM) as measure for market shares. The HHI encompasses all scheduled and non-scheduled services for passengers and freights and all regions of operation. In addition, we do not control here for the carriers which belong to the same holdings. Thus results are underestimated.

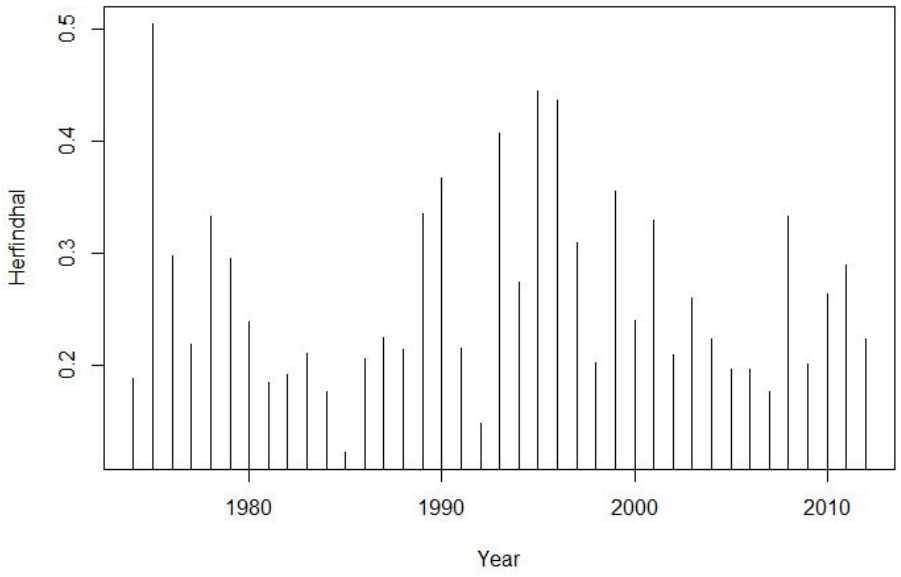

Figure 5.5: Herfindahl Index: 1974-2012

We observe the HHI is high on average (above 30%). This indicates that the market is highly concentrated. It is important to note that during the last decade, the HHI seems

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to reduce comparing with the nineties. This trend is artificial if we take into account the ownership structure of capital. Indeed, over the last decade, the US airline industry faced an important stream of mergers and acquisitions. In most cases, multiple major carriers belong to the same quoted holding as described in the data generating process.

5.2.2 Demand and Fares

It was expected that the deregulation would reduce concentration and provide increase in traffic and reduction in fares. Figure 5.6 from Borenstein (2011b) depicts the evolution of demand and fares from 1938 to 2011. Dashed line depicts variation in fare per revenue generating passenger miles for domestic market, while the solid line proxies demand with the load factor.

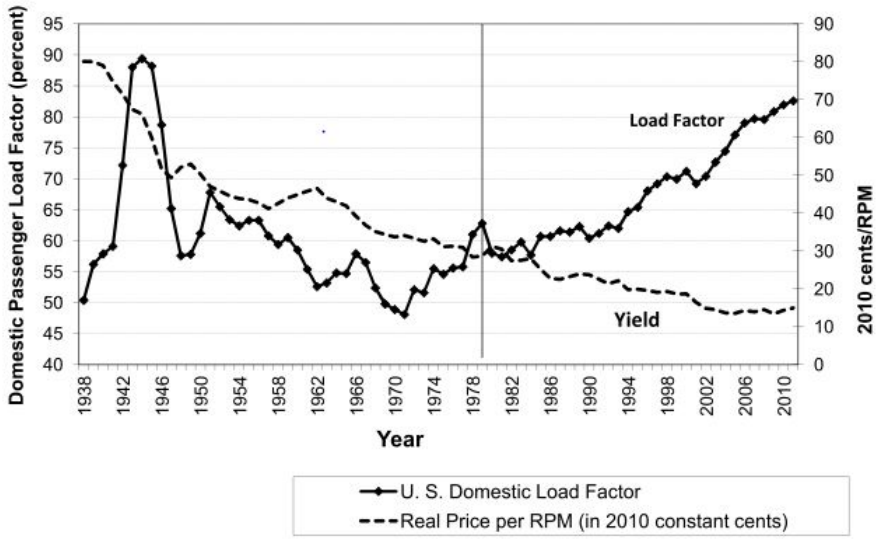

Figure 5.6: Airline Industry Average Domestic Load Factors and Real Yield for Passenger Service, 1938 – 2011 *(Source: Borenstein (2011b, Figure 3 p. 88))*

Figure 5.6 shows demand has been multiplied by 1.5, while fares have been divided by 2 since ADA. This is consistent with expectations attributed to the deregulation. However, this result must be taken with caution. These trends started the decade before the deregulation with -2.1% and +7.6% mean yearly variation for fare and load factor respectively. Such rates have never been improved even during the deregulated period. Hence, these trends are not only attributable to market discipline. The reduction in yield is inseparable from technological improvement (e.g. internet reservation system), while demand - proxied with load factor - must be viewed in comparison with the US GDP. In addition, the relation of high load factor to fares is pro-cyclical since high aircraft payload is a fundamental determinant of low unit costs. In addition, it is important to note that, to a certain extent, load factors maximization implies reduction in service quality. In addition, evidence suggest the SIFL would have provided lower fare than the the fares offered by legacy carriers.

It is of interest to note that the yield reduction is not uniform. Entry of carriers with new business models, new organization forms and price determination systems led to

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great dispersion in fares. First, the average yield reduction concerned mainly long stages whereas short stages fares increased. Second, the entry of low-cost carriers alike Southwest Airline in the middle of the 1980's introduced differentiated services. In addition, fares differ considerably even on the same flight. Airline industry is featured by *predictable and stochastic demand, fixed capacity and non storable products*. Hence, prices are established intertemporally as the demand is realized. Nevertheless, the introduction of Frequent Flyer Programs (FFP) rewarding frequent travelers and leisure agents for their loyalty as well as the first development of computing reservation system by American Airlines relatively reduced fares for customers. This enhanced high load factors and hub occupation that procures the costs advantages of a local dominant position.

5.2.3 Service Quality

The effect of deregulation on service quality is mitigated. On the one hand, the development of the hub and spoke system implied more connections. Carriers then have been able to propose more destinations and a differentiated range of services. Moreover, the introduction of small jets intensified the offer of regional flights and constituted a considerable gain of time travel. Lastly, the development of internet booking systems permits customers to book flights with a wide range of options.

On the other hand, the maximization of the occupancy of routes and load factors in line with cost minimization targets had negative impacts on service quality. The maximization of load factors reduces the quality in several ways:

- Gains in load factors are usually achieved with the minimization of the area available for each passenger in the cabin and the reduction of the cosiness of the equipment.
- Customers willing to book flights are more likely to face scarcity and risk to be forced to book flights at a different point in time.
- The load factor maximization target stimulates carriers at overselling tickets assuming a percentage of customer will cancel their trips. The negative externality is that travelers are sometimes denied boarding. Even they are systematically compensated, in 10% of cases travelers require to be reboarded in the order of check-in time what implies extra compensations.

The second source of quality decrease is the maximization of route occupation. This implies to minimize time between each landing. When a carrier misses its slot, it causes important delays and increases time travel. This problem worsened by the fact that the airport facilities did not grow in proportion of carriers' capacity.

5.3 The US Air Carriers Performance over the Last Two Decades

Since the Airline Deregulation Act in 1978, the US airline industry destroyed more than $35 billion in net income. According to Borenstein (2011b) the total loss for scheduled domestic market from 1979-2009 equals 69$ billions. Table 5.1 presents aggregated

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industry net income for all carriers, all regions of operation, and all services. Except the period 1979-1989, all data are extracted from Form 41 - P12 income statement released by the US DOT. Table 5.1 indicates airline industry destroyed $10 billion in net income during 1979-1989[1], created $10.5 billion during 1990-1999, lost 42.5 billions during 2000's decade and earned 6.6 billion during the last three years.

Table 5.1: Industry Net Income from 1979 to 2012

Period	Cumulated Net Income in thousand dollars
1979-1989	- 10 000 000
1990-1999	10 479 705
2000-2009	- 42 451 283
2010-2012	6 618 448
Total loss	- 35 353 131

In addition to important losses, the industry returns exhibit a high volatility. Figure 5.7 depicts the variation of the returns provided by the industry value weighted portfolio from 1978-2012. It suggests a great variability in earnings and a very low average return.

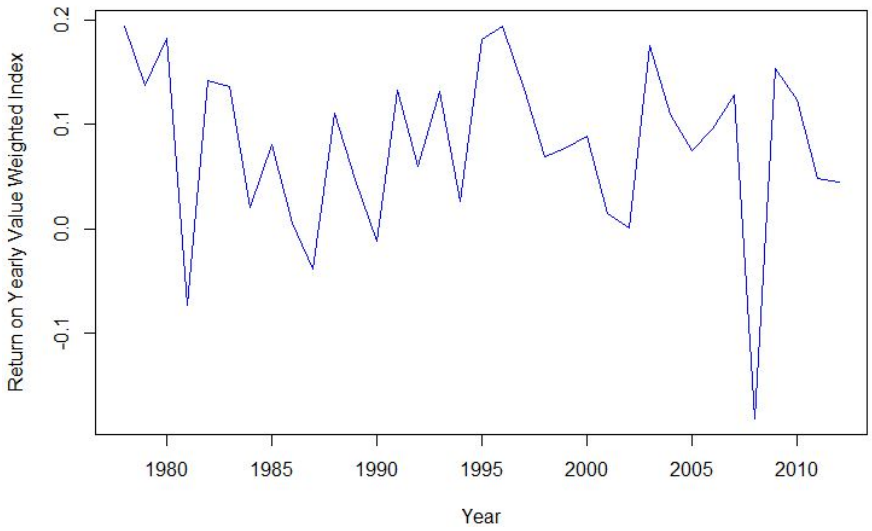

Figure 5.7: Yearly Cumulated Returns of the US Airline Value Weighted Index

Table 5.2 provides financial performance measures of the US airlines index. Two stock market performance measures are employed. The Sharpe ratio measures the unitary risk premium by dividing the excess returns to standard deviation:

$$\text{Sharpe ratio} = \frac{E(R_I) - R_f}{\sigma(R_I)} \tag{5.3}$$

where R_I is the returns on the weighted industry portfolio I, $\sigma(R_I)$ its standard deviation and R_f is the riskless rate. The second measure of the US airline index is the Treynor

[1]Data from 1979-1989 are taken from Borenstein (2011b). It includes only domestic carriers for passenger services. The data for period 1990-2012 are coming from the Form-41-P12 disclosed by the US Bureau of Transportation Statistics.

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ratio based on a partial measure of risk. This ratio measures the returns relative to the systematic risk that corresponds with the US airline index relation to the market portfolio.

$$\text{Treynor ratio} = \frac{E(R_I) - R_f}{\beta_I} \tag{5.4}$$

where β_I corresponds with the correlation coefficient between the industry index I and the market portfolio M divided by the variance of M.

Sharpe ratio provides a result below one. This means the index exhibited less returns given the risk incurred. Negative Treynor ratio confirms previous results. Treynor ratio indicates that, given the relation of the industry index with market index, the US airline industry created less wealth than the riskless asset.

Table 5.2: Financial Performance of the Weighted US Airline Industry Portfolio XAL Listed on NYSE from 1980-2010

Indicators	Scores
Mean returns	0.11
Standard deviation	1.41
Sharpe ratio	0.78
Treynor ratio	-1.26

Switching from financial market data to accounting based performance allows an analysis per category of services and region of operation. Table lists 5.3 sums up returns on capital employed (ROCE) over the period 1990-2012 for all carriers' scheduled and non-scheduled services. ROCE is adapted for firms with recurrent negative income as specified in Vernimmen, Quiry, Dallocchio, Lefur, and Salvi (2005, p. 243):

$$ROCE = \frac{(EBITDA + \text{Financial Income}) \times (1 - Taxes)}{(\text{Shareholder equity} + \text{short term investment})} \tag{5.5}$$

The tax rate employed is 40%. Table 5.3 the ROCE of carriers given their characteristics. The left part distinguishes domestic and trunk carriers, while the right part focuses on the kind of services provided. The last column provides the yearly mean ROCE score. Table 5.3 indicates that during 10 years industry provided negative income. The abnormal profit in 2006 may be partly due to the sudden economic upturn after the 2001-2002 period featured by dramatic loss in shareholder equity and due to balance sheet data unreliability. Results reveal international activities are less profitable than domestic activities. This results is no surprise since international services are likely to be less risky than domestic because of the geographic diversification. However, international activities seem more exposed to economic recession. In the early 90's as well as during the subprime crisis in 2008, international services are more affected than domestic carriers. The comparison of freight versus passenger specialized carriers indicates that the former have less volatile performance suggesting demand is more stable. Moreover, they do not have negative performance over the sample period and are not as broadly impacted by 09/11/2001 than passenger or diversified carriers. We also note that diversified carriers exhibit worse performance than specialized carriers. This may be explained by the business model of each activity. Passenger specialized carriers are mostly low costs carriers which have

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provided best performance in the industry over the sample period, while legacy carriers suffered more (with 14 periods of negative income). It is important to note that balance sheet data was incomplete. We cannot report performance of low costs carriers (LCC) because of their data unreliability. Information for LCC is only reliable for 2001 and 2012 where the ROCE scores were 2.43% and 3.08%: these are the best scores of the industry over this period.

Table 5.3: Returns On Capital Employed (ROCE)

Year	Domestic	International	Freight	Passenger	Diversified	All carriers
1990	-1,21%	-4,00%	1,06%	-1,51%	-1,96%	-1,87%
1991	-0,87%	-3,50%	0,00%	-1,35%	-1,17%	-1,64%
1992	-1,73%	-4,93%	0,01%	-2,00%	-2,62%	-3,04%
1993	-0,13%	-2,55%	1,59%	0,18%	-2,59%	-0,95%
1994	0,63%	0,09%	1,86%	0,60%	-1,02%	0,65%
1995	3,09%	1,28%	1,58%	1,85%	2,10%	3,61%
1996	3,28%	1,18%	1,92%	2,18%	1,81%	3,70%
1997	3,81%	3,20%	1,84%	2,91%	3,13%	4,87%
1998	3,91%	1,03%	1,57%	2,06%	3,98%	4,28%
1999	3,36%	1,68%	1,65%	2,19%	3,25%	4,04%
2000	1,91%	1,17%	1,57%	1,28%	1,53%	2,40%
2001	-3,68%	-1,79%	0,67%	-2,22%	-4,67%	-4,50%
2002	-4,69%	-1,94%	0,98%	-2,34%	-6,11%	-5,96%
2003	0,19%	0,18%	0,85%	0,82%	-2,97%	0,32%
2004	-2,62%	1,45%	1,35%	-0,65%	-4,44%	-1,87%
2005	-0,80%	0,05%	1,50%	-0,09%	-3,66%	-0,78%
2006	7,48%	12,05%	1,71%	15,41%	-1,53%	11,40%
2007	2,05%	12,34%	1,58%	3,15%	1,38%	4,07%
2008	-2,33%	-9,73%	1,54%	-2,59%	-6,87%	-4,33%
2009	-0,13%	0,14%	0,55%	0,89%	-1,53%	-0,09%
2010	1,43%	6,65%	1,58%	3,19%	0,60%	2,79%
2011	1,29%	-1,16%	1,24%	1,48%	-0,46%	1,15%
2012	2,08%	-1,50%	1,10%	1,72%	0,52%	1,86%

5.4 Factors of Poor Performance over the Last Two Decades

Borenstein (2011a) identifies two sets of causes explaining the recurrent losses in the US airlines industry. The first set of causes is related to market fundamentals, that is to say, the demand and constraints inherent to the airline industry. The other set of causes is more specific and concerns the business model of carriers and their innovations.

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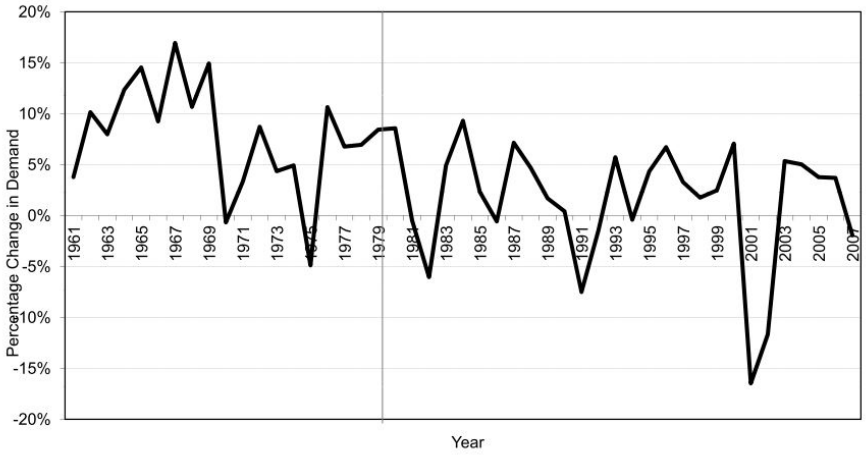

Figure 5.8: Year-to-Year Changes in Implied Demand for Air Travel, 1961-2007 *(Source: Borenstein (2011a, Figure 14 p. 99))*

5.4.1 Market Fundamentals

High-Cyclical Demand and Exogenous shocks

Demand for passenger traffic was particularly volatile and suffered important exogenous shocks over the last twenty years. Figure 5.8 depicts changes in demand for domestic passenger traffic from 1961 to 2007. Figure 5.8 reveals that demand became more volatile in the post deregulation period. Although it is likely investors forecast demand changes, four unexpected shocks are observable. The shocks of the early 80's and 90's reflect economic downturns, while the two important shocks in 2001 and 2007 report the effect of the 09/11/2001 attack and of the subprime crisis on demand.

The effect of the last two demand shocks are well depicted in Figure 5.9 as well. It represents changes in demand compared with the change in the US GDP from 1979 to 2009. We observe that demand increased faster than GDP growth. Indeed, it increased 110% over the period 1979-2000. However, the 09/11/2001 attack reduced demand at its level in 1995. The same pattern is observable for the subprime crisis shock.

However, the comparison of Figures 5.9 and 5.10 shows that even though over the period 1990-2009 we observe downside demand trends over 6 years, the industry reported a negative net income over 11 periods. This suggests causes of the poor performance are not imputable to demand only.

5.4.2 Margin Analysis

Operating Leverage and Dramatic Increase in Cost Drivers

High volatility of demand may not be a problem if the producer is able to adjust its scale of production. The cost structure of the airline does not allow for such adjustments. Each flight implies costs that are not proportional to its load factor. Hence, if many costs are proportional to the number of departures, they are not a function of the number of

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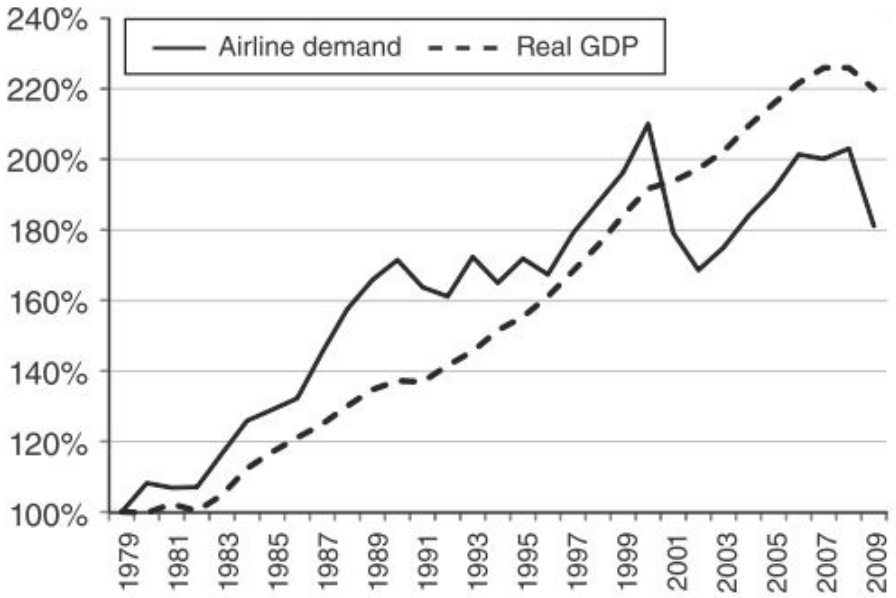

Figure 5.9: Airline Domestic Demand and Real GDP, Relative to 1979 *(Source: Borenstein (2011a, Figure 1 p. 254))*

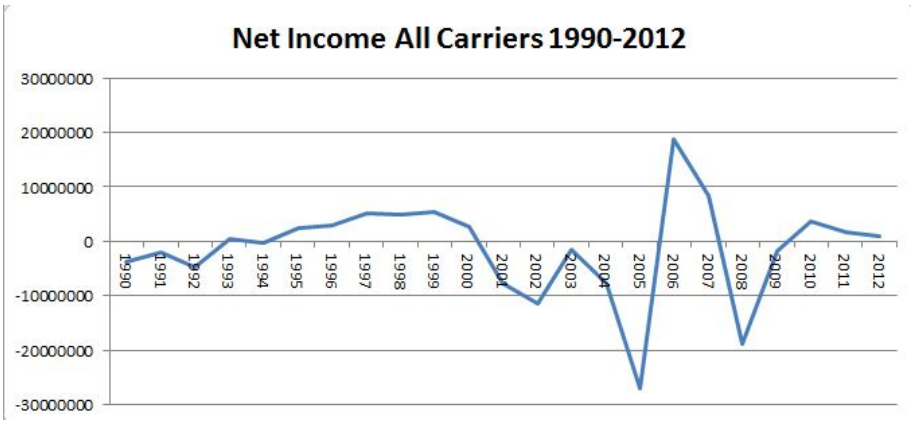

Figure 5.10: Evolution of Net Income of the US Carriers Since 1990

output produced. Such costs, including fuel costs, are assimilated to semi-fixed costs. In addition, the specificity of skills required for labor makes wages and the related expenses fixed too.

The importance of fixed costs increased with the dramatic increase in fuel cost over the decade 2000-2005. The US Bureau of Census reveals that fuel price per gallon increased about 206.6% between 1990 and 2009 for all services. Fuel costs reached 31% in the total operating costs in 2008, while it represented only 12% during the decade 1990-2000. Figures 5.11 and 5.12 depict the evolution in total consumption in the US airline industry over the period 2000-2012 and the price per gallon over the deregulated period respectively. Figure 5.12 shows the cost per gallon was the highest historically recorded since the deregulation. Figure 5.11 reports the high volatility of fuel prices that is a source of operating risk for carriers.

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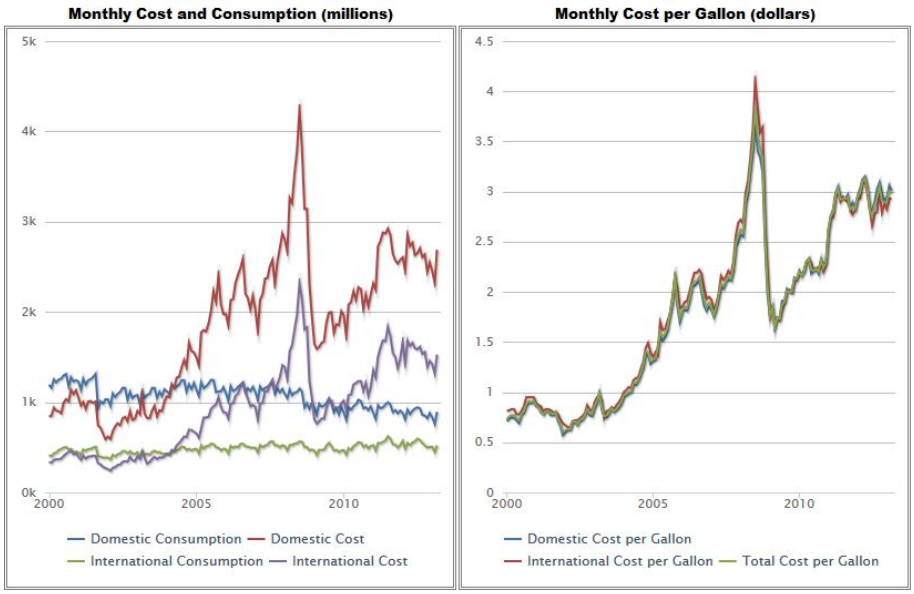

Figure 5.11: Evolution of Fuel Costs and Consumption 2000-2012 *(Source: US Bureau of Transportation Statistics)*

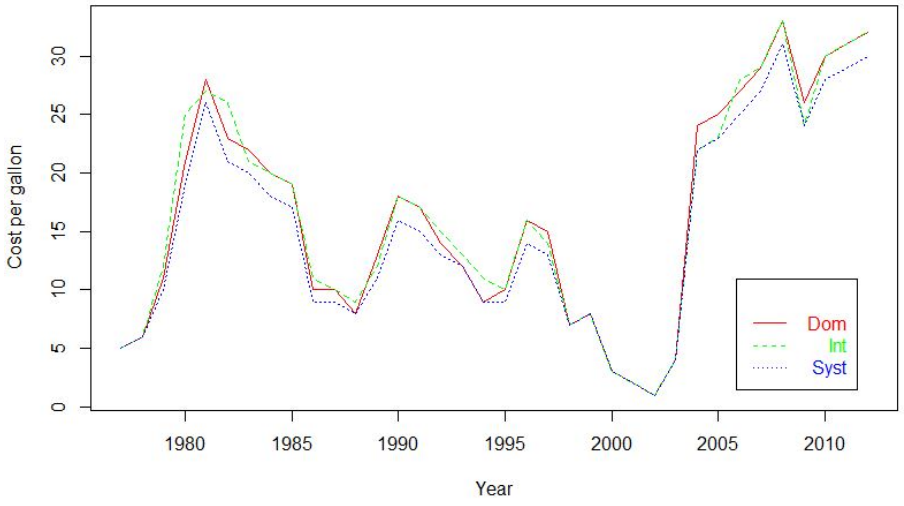

Figure 5.12: Cost Per Gallon over Deregulated Period

In addition, over the same period labor costs increased by 174.3%. In 2012 labor costs and fuel costs together accounted for 52% of total operating expenses. The cost structure associated with the dramatic increase in cost drivers largely explains high operating leverage and negative profits. The operating leverage measures the elasticity of operating profit for changes in sales. A high operating leverage means the presence of high fixed costs. The average operating leverage over the last two decades was 9.2: this is particularly high and confirms these observations.

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Incremental Increase in Taxation

Borenstein (2011a) reports that the second important source of fixity of charges is the modification of the tax system over the last twenty years. During the 80's, taxes were a percentage of the entire ticket value and thus proportional to revenues generated. Nowadays, about half of the ticket tax entails fixed charges. Since 1992, carriers are forced to pay passenger facility charges (PCF) of 4.5$ per passenger. Borenstein observes that the federal taxes and PCF is now twice as high as compared to the 80's. In 1997, the segment tax was added, while since 2002 carriers must pay the 09/11/2001 security fee. All new taxes are a function of the number of passengers carried regardless of the price paid. Now, the taxes implied in tickets' prices contain $ 10.70 fixed taxes per passenger boarded and 7.5 percent of variable taxes based on the value of the ticket. The fact that the domestic passenger tickets price has fallen towards 28% since 1992 indicates this cost has not been included in fares, but has been more likely absorbed in network economies.

Absence of Competitive Secondary Market for Aircrafts and Spare Parts

In addition to the fixity of operating expenses, carriers face issues for adjusting capacity when demand collapses because of the specificity of assets. Figure 5.4 shows that 39 carriers passed under chapter 11 during the period 2000-2010. It is as important as in the period 1979-1999. In such circumstances, firms are generally forced to sell out their assets to redeem their liabilities. The abundance of supply of assets in the small secondary market due to concentration prevents firms to reduce their operating fleet.

Adjustment of Fares in Response to Demand Variations

Regarding the important fixity of charges, the adjustment to demand variations cannot be performed by the reduction of the quantities of input. Evidence suggests that in most cases, carriers tried to reduced the downturn in demand through adjustment in fares.

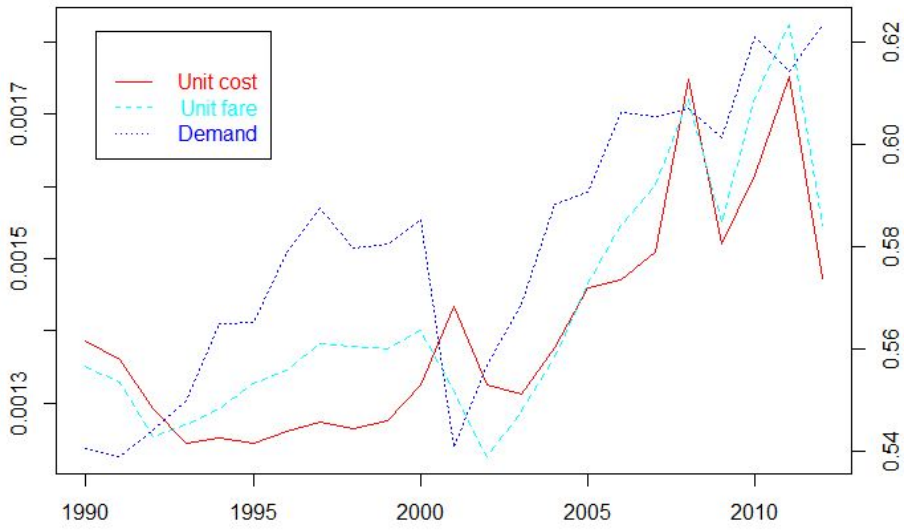

Figure 5.13: Yearly Average Fares and Demand for 1990-2012

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Figure 5.13 provides evidence of the fare adjustment relative to demand variations. The cyan dashed line and the red solid line depict the average unit fares and cost respectively. Both are scaled on the left hand side axis and are computed by the ratio of total revenue to total RTM (ratio of total costs to total RTM). Load factors depicted by the blue dotted line scaled on the right hand axis providing an estimation of the demand. It includes the effect of demand variation and capacity adjustment. Figure 5.13 shows when demand falls, fares decline too suggesting carriers attempt to sustain demand through more attractive prices. This is confirmed by the average elasticity of demand given prices over the period which is -0.115. We observe that during the troublesome decade 2000-2010, load factor increased faster than average revenue per unit carried. This suggests carriers sustain demand through fare reduction against exogenous shocks. Another explanation is the behavior of firms under bankruptcy fillings over the period 2000-2010. According to (Borenstein, 2011a), firms under Chapter 11 tend to reduce their fares to become more attractive.

In addition, we note that costs do not decrease proportionally with unit fares. This trend is particularly true during the nineties. Moreover, we observe that the cost of excess capacities was particularly high during the 11/09/2001 period. In contrast, we note that, during the period 2005-2012, carriers managed their capacity more efficiently. We believe that, following Borenstein (2011a), it corresponds with the reduction of capacity over this period. This has been enhanced by the implementation of codeshares agreements and the restructuration of the biggest carriers which have redeployed their network.

5.4.3 Evolution of Business Models

The US airline industry has implemented important process innovations. These led to important changes in the post regulation environment, but it is also source of pitfalls.

Hub and Spoke Configuration

The hub and spoke configuration and the local market power strategy enhances the maximization of the occupation of gates to benefit returns to density and demand advantages. Nevertheless, this configuration may raise more important costs when carriers manage their network *tightly-banked*, that is to say coordinate flights so as to minimize the interval between each landing and take-off. Any incident on the schedule of landings raises issue of congestion implying delays, cancellation costs and penalties. Moreover, observers note that the most successful low costs carriers like Southwest Airlines are not organized following a hub and spoke system and exhibit better performance. This may be partly explained by the over-investment in capacity spurred by a hub and spoke network.

Pricing and Reservation Systems

Complexity at defining a fair price and segmentation introduces a wide range of prices even in the route for the same carriers. This may be first explained by the specificity of the transportation services. Carriers face highly variable demand and fixed capacity, while services cannot be stored. Carriers then developed a pricing system that establishes prices

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as demand is realized. These sophisticated systems make price determination opaque and sometimes disconnected from operating costs.

One of the most important innovations of the US airline industry was the computer reservation system developed by American Airlines during the eighties. Computer reservation system aims at providing information about the availability and the fares for a given segment. Most of them were developed and owned by airlines. The innovation was twofold. First, it makes the reservation process for carriers more efficient. Next, bookings performed by travel agencies, the customers of computer reservation system, were biased by the underlying system towards the reservation of the flights of the developers.

With the implementation of internet, airlines were able to skirt travel agency commissions by providing directly online computer reservation system. However, alternative computer reservation system freely available on the internet enable customers to have access to all fares for any trip and to book tickets at the cheapest price. This increase in transparency increased consumer surplus to the detriment of carriers.

Code-Sharing Agreements

A surprising response to the fixed capacity associated with highly variable demand was to soften competition through the introduction of code-sharing agreements. A code-sharing agreement is a partnership which frames the extent of cooperation among competitors. This coopetition consists of selling tickets for flights carried by competitors. Antitrust authorized such agreement since they provide differentiation of services, promote inter-airline connections what *a priori* create more value to customers. The advantage of such an organization is both to extend the offer to new routes without investing in new capacities and to maximize the load factor of each flight. The drawback of existing code-sharing agreements is their complexity and opacity. It is difficult to know which carriers really benefit from the code-sharing alliances.

Entry and Success of Low-Cost Carriers

The entry of Low-Cost Carriers (LCC) and their networks expansion have considerably depressed fares in the US airline industry. Contrasting with what some observers argued, LCC entrenched markets of other carriers. In 1995, major LCC represented less than 4% of domestic transportation, while they accounted for about 20% of the traffic in 2012. Moreover, one quarter of the registered major carriers are low-costs today, while there was only Southwest Airline before 1995.

The erosion of legacy carriers' market shares has been incremental because of barriers to entry in their local markets. The first barrier is associated with marketing strategies. Legacy carriers used to lock their market by the use of frequent flyer programms (FFP) and corporate discounts that reward customers loyalty. These programs considerably reduce fares for frequent flyers and permit to carriers to have a more intensive occupation of their routes to benefit from economies related to network density and high load factors. The second locking mechanism is the use of carriers sphere of influence to deter competitors to entrench their markets. Their local market power with airports and local governments make them able to restrict available resources for competitors through restrictions on gates and slots. In addition, the hub and spoke network configuration favors

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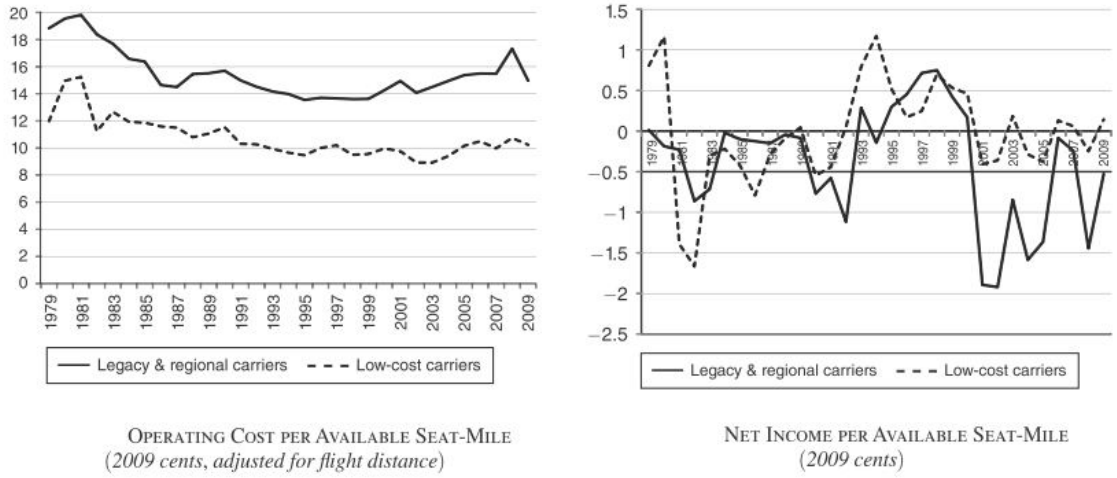
retaliation through footholds on the competitors local market power (Gimeno, 1999).

Nevertheless, the network configuration of LCC make them less sensitive to retaliations and favors a better cost structure. Indeed, the point to point market organization of LCC make the retaliations trough footholds from competitors more difficult and less severe for the LCC performance than in the hub and spoke configuration. In this latter case, footholds reduce returns to density and high load factors that are key determinants of the profitability. In addition, the organization of the point to point market makes the management of capacity less complex.

As a response to the rise of LCC, other carriers have considerably reduced their fares although their costs remain more important. Figure 5.14 compares the cost and the fare evolution of LCC and legacy carriers. The left part illustrates the unit operating costs for legacy and LCC from 1978 to 2009, while the right part focuses on the unitary net income in the same period.



OPERATING COST PER AVAILABLE SEAT-MILE
(*2009 cents, adjusted for flight distance*)

NET INCOME PER AVAILABLE SEAT-MILE
(*2009 cents*)

Figure 5.14: Evolution of Cost and Profit per Seat Miles for LCC and Legacy Carriers since ADA *(Source: Borenstein (2011a, Figure 3 and 5 p.236)*)

We observe that the spread remains constant over time. However, the profit per available seat miles (ASM) depicted by the right part of Figure 5.14 exhibits a greater volatility and a decreasing trend of profit per ASM of legacy carriers over the last decade. This suggests legacy carriers reduced their fares in response to LCC competition. Moreover, we note that LCC remain more profitable than legacy carriers since the beginning of the nineties.

5.5 Sample Construction

The sample collected encompasses the 28 major carriers of the US airlines industry, alternatively called the Group III carriers, over the period 1990-2011. Group III refers to the large certificated US air carriers with annual operating revenues over $1 billion. Since major carriers are the oldest and the biggest firms in the industry, their data availability and reliability is greater since these firms have to fill out DOT reports. Moreover, Group III carriers are entitled to release more specific information about the characteristics of their assets. On average, majors account for more than 88% in the total market share

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between 1990-2012. Consequently, conclusions about the relation of efficiency to stock returns in the US airline industry can be made without loss of generality.

5.5.1 Sample Sources

The sample relies on secondary data. It consists of quarterly official reports provided by the US DOT and the carriers' official reports. The detailed data generating process is providing in Appendix A. The sample has been constructed with multiple sources:

- Production and non-consolidated financial data have been downloaded from the DOT Bureau of Transportation Statistics (RITA), especially Form-41, Form-T1 and Form-T100.
- The consolidated data have been extracted from Bloomberg and from Edgar SEC.
- The time series of stock prices have been downloaded from Bloomberg.

5.5.2 Structure of Sample

Table 5.4 provides the identity of each carrier included in the sample, the category of services it provides and the number of periods it spans. The abbreviation used corresponds to the DOT classification code for the carrier regardless for all activities and regions of operation. The sample contains 5 LCC: Southwest Ailrines, Frontier Airlines, Aitran Airways Corporation, American Trans Air Inc. and JetBlue Airways. Southwest is the greatest LCC. It accounted for 60% in the LCC market share in 2011.

Table 5.4 also reports the cargo carriers. The sample contains 5 cargo carriers: Airborne Express Inc. (ABX), DHL Airways (ER), Federal Express (FX), United Parcel Services (5X) and Atlas Inc. (5Y). Despite differences in the services provided, the technical constraints are homogenous with passenger services. Moreover, DOT provides an aggregate measure based on ton miles carried to describe the activity of carriers regardless of the specificity of services. Only 9 carriers span the entire sample period. As depicted in Table 5.4, the sample period is characterized by a lot of entries, exits and bankruptcy fillings.

5.5.3 Evolution of the Holdings

Most of the carriers are listed or belong to a quoted holding. In most cases, the holdings have several carriers. Figure 5.15 records the ticker of the major carriers over the period 1990-2011. It reports that carriers changed ticker codes during the sample period. When a carrier is delisted due to Chapter 11 fillings or merger and acquisition reasons, Figure 5.15 reports a blank cell for the delisted period. When a carrier is fully consolidated due to merger or absorption, that is to say it stops operations under its IATA code, it is reported by blank cells. By contrast, for carriers involved in mergers, but still having a distinct legal existence, we maintain its observation in the sample. For instance, TWA (ticker TWAIQ) has been fully acquired and consolidated by American Airlines (AA,

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Table 5.4: List of Airlines Observations

Airline	Abbreviation	Observation period	Category
United Parcel Service	5X	1990-2011	Legacy-cargo
Alaska Airlines Inc.	AS	1990-2011	Legacy
American Airlines Inc.	AA	1990-2011	Legacy
Continental Air Lines Inc.	CO	1990-2011	Legacy
Delta Air Lines Inc.	DL	1990-2011	Legacy
Eastern Air Lines Inc.	EA	1990	Legacy
Federal Express Corporation	FX	1990-2011	Legacy-cargo
America West Airlines Inc.	HP	1990-2007	Legacy
Northwest Airlines Inc.	NW	1990-2009	Legacy
Pan American World Airways	PA (1)	1990-1991	Legacy
Trans World Airlines Inc.	TW	1990-2001	Legacy
United Air Lines Inc.	UA	1990-2011	Legacy
US Airways Inc.	US	1990-2011	Legacy
Southwest Airlines Co.	WN	1990-2011	LCC
DHL Airways	ER	1992-2002	Legacy-cargo
American Eagle Airlines Inc.	MQ	2000-2011	Legacy
American Trans Air Inc.	TZ	2000-2006	LCC
Expressjet Airlines Inc.	XE	2004-2009	Legacy
Airborne Express Inc.	ABX	2005-2011	Legacy-cargo
JetBlue Airways	B6	2005-2011	LCC
Comair Inc.	OH	2005-2011	Legacy
Atlantic Southeast Airlines	EV	2006-2010	Legacy
AirTran Airways Corporation	FL	2006-2011	LCC
SkyWest Airlines Inc.	OO	2006-2011	Legacy
Frontier Airlines Inc.	F9	2007-2011	LCC
Mesa Airlines Inc.	YV	2007-2009	Legacy
Atlas Air Inc.	5Y	2008-2011	Legacy-cargo
Hawaiian Airlines Inc.	HA	2010-2011	Legacy

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ticker AAMR) and ceased operations. Hence, we stop to report TW since 2001 that is the year of the acquisition. By contrast, Continental Airlines (CO, ticker CAL-US Equity) merged with United Airline (UA, ticker-UAL), but continued operations as a subsidiary under its initial DOT and IATA code as a legal distinct carrier. Hence, we report it in Figure 5.15. HA, ER and EA are private companies and are not reported in Figure 5.15.

The troubles in the quotation of the holdings reflect the stream of bankruptcies and restructurings over the sample period. Table 5.5 records every carrier involved in Chapter 11 fillings. It indicates that 14 of the 28 carriers went to bankruptcy mainly during the last ten years.

Table 5.5: Chapter 11 - Bankruptcy Fillings of US Major Air Carriers

Carrier	Year
EA	1990
PA	1991
HP	1991
CO	1993
TW	2001
UA	2002 - 2004 - 2008
US	2002-2006
DL	2005
NW	2005
TZ	2006
F9	2008
YV	2009
EV	2010
AA	2011

In addition, Tables 5.6 and 5.7 report the mergers and acquisitions (M&A) between major carriers. Even though, most of the carriers in the sample were involved in M&A with medium and regional carriers, we only report the operations that concern major carriers. Table 5.6 reports four important mergers, while Table 5.7 records 8 acquisitions. Except for XE, FL, OO and WN, all carriers involved in M&A faced a bankruptcy. Consequently, 18 carriers among the 28 faced at least one important change in their capital structure. The changes in the carriers' capital structures prevented the automation of the consolidated financial data collection.

Table 5.6: Mergers of US Air Major Carriers

Carrier A	Carrier B	Year
UA	HP	2005
CAL	UAL	2008
DL	NW	2008
LCC	AA-MQ	2011

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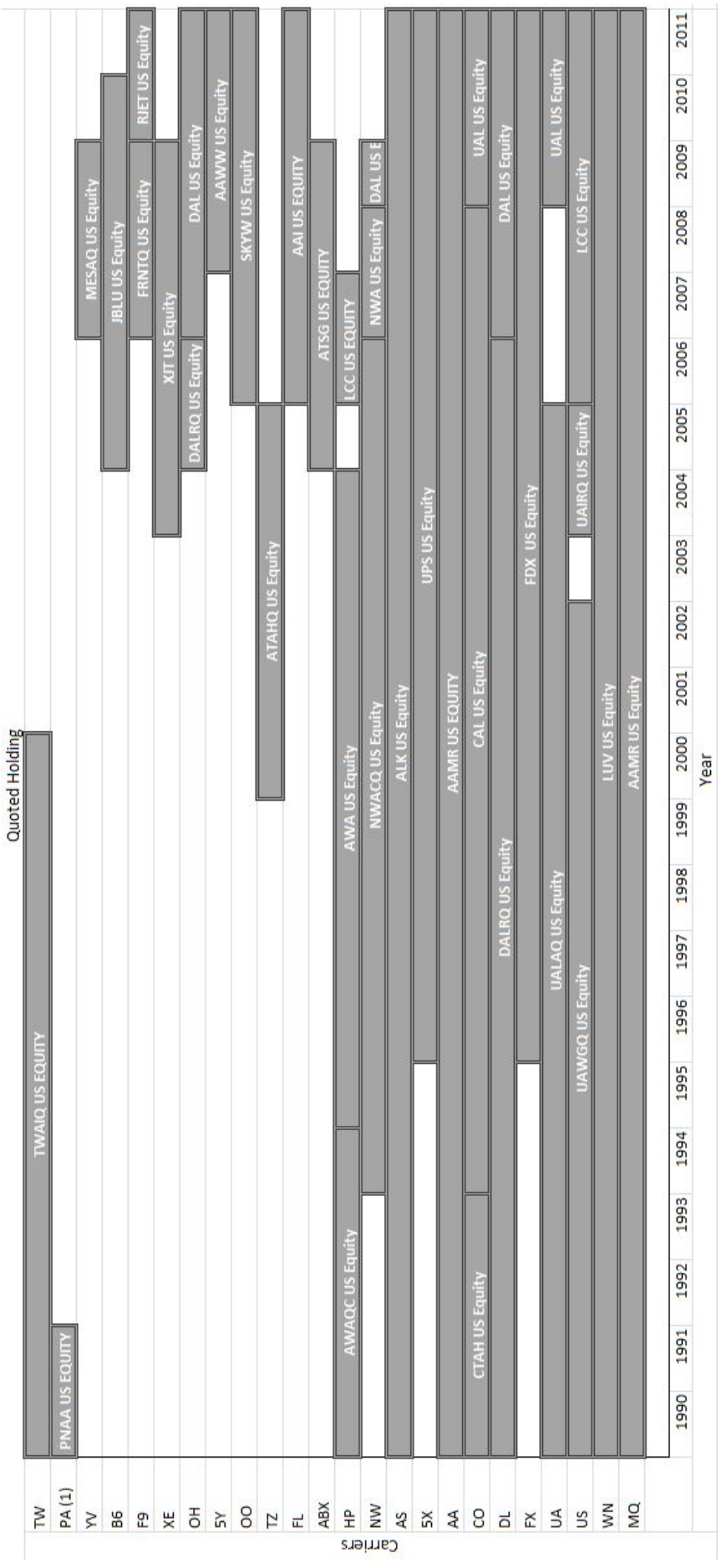

Figure 5.15: Evolution of Listed Holdings and Carriers

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Table 5.7: Acquisitions Operations of US Major Air Carriers

Target	Bidder	Year
PA (1) European routes	DL	1991
PA (1) UK routes	UA	1991
TW	AA-MQ	2001
EV	OO	2005
TZ	WN	2008
F9	Republic Airways Holding	2009
FL	WN	2010
XE	OO	2010

Conclusions

This chapter aims at reporting the evolution of the US airline industry. Since the Deregulation Act, the industry faced important structural changes. The changes concern the market concentration, the carriers' network organization, the yield management and the entry of low-costs carriers. The adaptation of carriers to these changes partly explains the poor financial performance of the carriers. A second set of reasons for poor performance is the high fixed costs featured by the airline operations combined with the dramatic increase in fundamental costs drivers and a highly volatile demand. This latter set of causes has a direct implication on the specification of the production technology and the DEA and SFA constraints imposed. Finally, the industry faced various unfortunate events as well as the first Gulf War, the terrorist attack of the 09/11/2001, the SARS crisis and the economic recessions that need to be taken into account to discuss variation of technical efficiency over time. This context determines the information content of technical efficiency.

In addition, this chapter describes the sample employed for the investigation of the relation between technical efficiency and stock returns. The sample consists of 28 US major air carriers over the period 1990-2011. The 28 major air carriers belong to 24 quoted holdings. The stream of restructurings faced by the industry over the last twenty years is detailed in Table 5.5 for Chapter 11, Table 5.6 for mergers and Table 5.7 for acquisitions. 18 carriers among the 28 were involved in one of the restructurings reviewed. The detailed data generating process is provided in Appendix A.

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Thèse de Matthieu Belarouci, Lille 1, 2013

Chapter 6

Relation between Technical Efficiency and Stock Prices

Introduction

The analysis of operating performance based on non-financial information is a core issue in stock valuation. Since the last fifteen years, the literature about the value relevance of operating performance based on frontier optimization techniques has been emerging. These techniques consist of reporting the operating performance relative to a benchmark of best comparable firms. Most of the contributions focus on accounting-based information. Only few are focusing on the use of technical reports. In addition, most of the contributions have been dedicated to the banking sector.

The purpose of this chapter is to analyze the relation between the level of technical efficiency and stock prices in the US airlines industry from 1990 to 2010. Technical efficiency is a measure of operational performance derived from productivity analysis. We assess the technical efficiency of the firm on the basis of technical information released in the US Department of Transportation's quarterly reports. This tool aims at measuring firm's performance, while taking into account the effect of competition. Referring to fundamental analysis as a theoretical framework, we expect that technically efficient firms exhibit profits above the normal as reward for their effectiveness in competition. Considering stock prices result from the sum of expected future cash-flows discounted at the risk-adjusted hurdle rate, technically efficient firms should exhibit greater market capitalization than the less efficient firms.

Describing and analyzing this relation is motivated by the potential use of technical efficiency in fundamental analysis for assets valuation. Indeed, technical efficiency has worthy properties: (i) it accounts for the effect of size on performance, (ii) it is free of price distortion effects on performance, and (iii) it summarizes into a single number several relevant dimensions simultaneously. We refer to frontier methodology (especially data envelopment analysis (DEA)) to solve the technical efficiency scores and we discuss the issue of technical efficiency measurement in a non-parametric setting. The non-parametric framework is a set of methodologies developed for the measurement of productive performance. It allows for great flexibility in modeling due to its minimal assumptions. Cross-checking performed with stochastic frontier (SFA) confirms the DEA results. In

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order to test for the relation between technical efficiency and stock prices, we attempt to renew the specification of the production technology of the US airlines industry. We provide an extension of the analysis of Alam and Sickles (1998) who are focusing on the period 1970-1990. We find a statistical relation of technical efficiency level to stock market prices for both DEA and SFA. This relation is significant for the two months after the end of the quarter. This result indicates that financial information is inferred from technical information.

This chapter is organized as follow. First, we present the theoretical relation of the link between technical efficiency and stock valuation. The next section develops the methodology in two stages. In the first stage, we propose two alternative methods of technical efficiency computation. In the second stage, we develop the method of estimation of the relation. The last section reports the results. We emphasize the structure of the data set and we describe the evolution of technical efficiency. At last, we provide evidence of the value relevance of technical efficiency patterns.

6.1 Technical Efficiency Analysis in Capital Market Research in Accounting

Since the seminal contributions of Beaver (1968) and Ball and Brown (1968), the value relevance literature has been mainly oriented to the analysis of the information content of accounting numbers. The main focus of the value relevance studies is to identify accounting items, and other variables that enable to predict the magnitude of the change, the timing and the uncertainty on stock prices (Kothari, 2001). Even though early contributions focused on earnings as key accounting numbers, the decrease in relevance of earnings and the inadequacy of accounting based measures at describing performance in dynamic and constantly changing businesses has given raise to the analysis of non-financial items (Amir and Lev (1996), Francis and Schipper (1999)). In addition, Low and Siesfeld (1998) report that major investors decisions are in fact significantly influenced by non-financial performance rather than financial items to assess future profitability. Amir and Lev (1996) highlight the complementarity of financial and technical information in the analysis of firm's performance. They provide evidence of the superior relative value relevance of non-financial indicators, such as market penetration and physical growth potential in wireless companies.

Despite the fact that the investigation of the value relevance of technical information constitutes just a minor part of the literature, several authors have provided evidence for the US airline industry. Schefczyk (1993) insists on the inadequacy of accounting to report air carriers performances because of their international diversification and the importance of leased assets. His results reveal a strong relation between operating efficiency and profitability. He summarizes into operating efficiency, computed with data envelopment analysis, financial and non-financial variables as well as capacity and revenue ton miles. Behn and Riley Jr. (1999), Suzuki (2000) and Suzuki, Tyworth, and Novack (2001) provide evidence of the relevance of on time performance statistics and consumers' complaints for stock returns forecasts. In addition, Riley, Pearson, and Trompeter (2003) demonstrate the superior incremental value relevance of physical capacity of aircraft, market share and customer satisfaction in stock returns explanation. Leidtka (2002) tests the information content of technical information relative to a set of eighteen financial

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measures. She confirms that technical performances capture information not integrated into financial ratios. Alam and Sickles (1998) report on a relation between changes in technical efficiency, computed with data envelopment analysis, and security returns in the US airline industry from 1970 to 1990. They reveal that a buy and hold portfolio strategy based on changes in technical efficiency extracted from technical reports permits to catch abnormal returns.

No other contribution has attempted to deepen the value relevance of technical efficiency in the US airlines industry, while it is expected to be particularly valuable to assess stock market performance. Basically, technical efficiency evaluates the ability of the firm at avoiding waste in its operations. Formally speaking, it reports the deviation of the firm's production from the best productive combination achievable in its industry. The information provided by technical efficiency is twofold: it ranks firms given their efficiency level and quantifies the potential gains associated with the rationalization of their production processes. In addition, technical efficiency has two interesting attributes for financial analysis. On the one hand, it summarizes into a single number the main variables that reflect production constraints faced by the firm. The underlying computation processes provide a benchmarked measure of operating performance, while taking into account the firm's size effect. On the other hand, its computation requires physical input and output instead of prices. It reports relative efficiency of the firm based on quantities without including price distortion effects likely to hide production inefficiencies. This deep anchorage in the real sphere explains the broad appeal of technical efficiency in regulatory analysis (Bauer, Berger, Ferrier, and Humphrey, 1998). Technical efficiency is in most cases computed from technical reports instead of accounting statements. That's why it is free of accounting rules distortions.

It is important to note that the information content of technical efficiency is inseparable of the underlying computation techniques. Indeed, its determination implies to handle simultaneously a large number of variables to compare firms' production with the production of their peers in the industry. This process leads to a benchmarked determination/estimation of the firms operating performance. Hence, technical efficiency contextualizes the outcome of the firm in its industry or within its strategic group (Coelli, 1998). It encompasses industry factors as well as idiosyncratic firm's attributes in performance determination. The underlying dimension of technical efficiency is the way the firm deals with the industry structure, especially technology and competitors. It provides an indication about how the firm combines its skills and resources so as to develop a sustainable competitive advantage centered on the effectiveness of production processes (McWilliams and Smart (1993), Leibenstein (1966), Barney (1991)). Technical efficiency provides evidence of the existence of competitive advantage and quantifies its effect: the relative gain it raises for the firm under evaluation over time. Consequently technical efficiency informs about the value potential of the firm, i.e. its ability at rising returns above the normal one in the industry. Such ability has been early identified as a fundamental determinant of the market valuation (Collins and Kothari, 1989). Likewise, the relation between the potential of the firm at earning economic rent, its cost structure and competition is well documented (Kothari, 2001).

Only few contributions are discussing the effect of technical efficiency on stockholder value creation. Articles about the value relevance of technical efficiency are mostly dedicated to the analysis of the banking sector and are focusing on the changes rather than the level of technical efficiency. Fernandez, Fernando, and Gonzalez (2002) provide evidence of the relation of changes in technical efficiency to security returns in the European,

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Japanese and the US banking sector. Pasiouras, Liadaki, and Zopounidis (2008) confirm that units facing changes in technical efficiency exhibit yearly abnormal returns in the Greek banking sector. The same is documented by Sufian and Majid (2009) for Chinese banks. Fioderlisi and Molyneux (2010b) and Haddad, Hall, Kenjegalieva, Santoso, and Simper (2010) analyze the effect of changes in technical efficiency on returns in the case of a decomposition of total factor productivity of banks. Wu and Ray (2005) employ the level of technical efficiency as a predictor of abnormal yields in the case of mergers and acquisitions in the manufacturing sector. Amess and Girma (2009) provide evidence of correlations between changes in technical efficiency and market capitalization through a comparison between the UK manufacturing and services sectors.

In line with Alam and Sickles (1998), this contribution is the first at investigating the value relevance of technical efficiency and related technical information, as well as aircrafts' characteristics, in the US airline industry. We test whether the information provided by technical reports significantly explains a portion of stock prices not captured by accounting information. Tests also aim at investigating the incremental value relevance of the firm's technical efficiency assessed from technical information compared with alternative technical information and accounting numbers over the period 1990-2010. It is important to note that this period is characterized by extraordinary adverse events, deterioration of carriers' financial positions and value destruction (Borenstein, 2011a). In such circumstances, it is likely that operating earnings information is not as relevant as it normally should be (see Patel (1989), Riley, Pearson, and Trompeter (2003)). Consequently, we expect technical efficiency to be particularly relevant relative to accounting.

6.2 Methodology

6.2.1 Efficiency Measurement

Formally, output-oriented technical efficiency of the firm is defined as the maximization of output quantities produced given the amount of input consumed for a given state of the technology. Technology refers to the set of the feasible production factor combinations managers can implement. The most productive known combinations correspond to the frontier of the technology. The frontier constitutes the benchmark for relative operating performance evaluation. This state of technical knowledge is grounded on past and current observations of competitors and on the firm's own experience and consequently it evolves over time. Technical efficiency contrasts with productivity, which is simply a ratio of output to input, because it is measured relative to the performance of competitors.

Computation of technical efficiency is a two steps procedure. In a first step, it draws a reference set of best practices with best performers in the sample. In the second step, it measures the inefficiency as any deviation from this frontier. The way the benchmark must be constructed and the way firms must be compared with it has given rise to a methodological debate between deterministic and stochastic paradigms. We measure output-oriented technical efficiency with two techniques from both paradigms: the data envelopment analysis (DEA) with constant returns to scale and the stochastic frontier analysis (SFA). We illustrate the differences between both methods in the following simple example. The single input (X) - single output (Y) technology in Figure 6.1 depicts differences in benchmark construction for both paradigms. The stochastic frontier pictured

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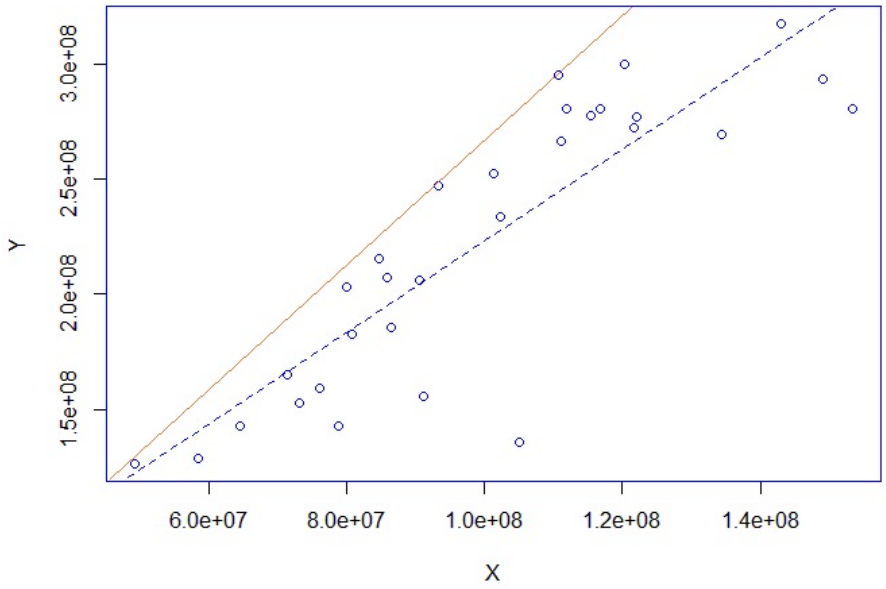

Figure 6.1: Benchmark Construction under DEA and SFA Approaches

by the blue dashed line reports the estimated relation between output and input inferred from the sample. The DEA based construction contrasts in focusing on the best relation established with the best observed production combination.

In both cases, output-oriented technical inefficiency corresponds with the vertical negative deviation from the frontier. In SFA estimation, residuals are split up into a IID random error with zero mean that is separated from the negative deviation to assess technical inefficiency. Consequently, for the same panel data treatment, DEA is likely to provide greater inefficiency than SFA. The purpose of our study is not to compare the relative strength of one method over another, but to provide cross-checking confirmation.

Data Envelopment Analysis

DEA has been introduced by Charnes, Cooper, and Rhodes (1978) based on the seminal contribution of Farrell (1957). The DEA Model with constant returns to scale and strong disposability, so-called CCR Model, is given by the following linear programming Model (6.1):

$$\begin{aligned} max_{u,v}\theta &= uy_0 \\ st\ ux_0 &= 1 \\ -vX + uY &\leq 0 \\ u \geq 0, v &\geq 0 \end{aligned} \tag{6.1}$$

where X and Y are the matrix of input and the matrix of output of the firms under evaluation and u and v are vectors of non-negative weights respectively. Weights are employed to maximize the value of the output subject to the normalization constraint $ux_0 = 1$.

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They enable to construct a convex benchmark with local linearity. Convexity implies the benchmark of best practices is at any point constructed with the linear combination of other observed points. Thus, the performance of each firm is evaluated through its comparison with its virtual optimal peer projected on the frontier. A firm is said efficient when $\theta = 1$ that means the productivity score of the firm under evaluation equals the highest feasible productivity computed, while keeping input levels fixed.

Since the frontier is inferred from the sample, the way the panel data is treated matters crucially (Tulkens and Vanden Eeckaut, 1995). We determine the frontier of best practices with an unbalanced panel data set with quarterly frequency pooled by year. Each year corresponds with a point in time t=1,...,T where there are n=1,...,N firms. Firms are consuming an amount j=1,...,J of four input to produce one output. We construct the benchmark for evaluation of the firms with a three periods based window analysis (Charnes, Clark, Cooper, and Golany, 1985). It consists of computing efficiency scores at point t with periods t-2 to t. Only technical efficiency scores of the last period added are employed to estimate the relation of technical efficiency to stock market valuation. In the following application, each window encompasses 3 years (12 periods). This approach enables the construction of a benchmark that is consistent with the contemporaneous constraints faced by firms. Hence, it allows for both technological progress and regress.

There are several advantages of using DEA. It can handle simultaneously large number of information, when comparing firms. It does not require any behavioral assumption or specification of a functional form contrasting with parametric estimations. In addition, it does not need the use of prices. However, DEA has some drawbacks too. It does not permit to distinguish inefficiencies and random noise. Technical efficiency scores are solved with the FEAR package developed by Wilson (2008) for the R software.

Stochastic Frontier Analysis

Stochastic frontier analysis has been introduced by Aigner, Lovell., and Schmidt (1977) and Meeusen and Van Den Broeck (1977). The regression model tested here is the log linear Model (6.2). Technical efficiency is estimated with the Battese and Coelli (1992) time varying technical efficiency Model[1]

$$\begin{aligned} ln(Y)_{i,t} &= \beta_0 + \sum \beta_n ln(X)_{nit} + \epsilon_{it} \\ \epsilon_{it} &= v_{it} + u_{it} \\ TE &= e\{-\hat{u}\} \end{aligned} \tag{6.2}$$

where Y is the output set and X is the input set. SFA model consists of separating technical inefficiency component u from idd random noise v with $E(v) = 0$. We assume left skewed half normal distribution of technical inefficiencies. The transformation $TE = e\{-\hat{u}\}$ provides efficiency scores (Battese and Coelli, 1992). Contrasting with DEA window analysis approach, we employ in the SFA analysis the whole sample and we include time effects to obtain a time varying technical efficiency.

[1]In addition to the linear production functional form, the translog functional form with instrumental variables introduced by Battese and Coelli (1995) has been tested. Resulting scores for market value explanation were significant, but less explicative.

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The main advantage of SFA is to provide information about the industry as well as elasticity substitution even if every DMU was efficient. It also accounts for random error. Nevertheless, this latter advantage comes at the cost of a very strong assumption about the distribution of technical efficiency scores. In addition, SFA requires to specify a parametric form of the production function and is likely to provide unreliable results when the sample size is small.

6.2.2 Relation between Technical Efficiency and Stock Prices

The empirical foundation of this study is based on the relation between stock valuation and financial information inferred from technical reports in the US airlines industry. The methodological approach aims to determine whether the most technically efficient carriers are likely to generate greater market valuations than less efficient units. This hypothesis implies that poorest technically efficient carriers are value destroying projects.

Like Amir and Lev (1996), we estimate the relation between the monthly end stock prices of the second month after the end of the quarter to quarterly technical efficiency with ordinary least squares (OLS) time and random effects regressions. The second month after the end of the quarter corresponds with the disclosure of non-official information, such as Aviation Daily, about the performance of the carriers (Alam and Sickles, 1998). More detailed DOT reports which contain technical information used to compute technical efficiency is available three or four months after the end of the quarter.

The regression is performed over 84 periods and a total of 1115 unbalanced observations after removing unlisted companies. The empirical regression model is detailed in Equation (6.3):

$$SP_{i,q+2} = \alpha_0 + \beta TE_{i,q,k} + \beta Nodes_{i,q} + \beta Jets_{i,q} + \beta NI_{i,q} + \beta SE_{i,q} + \epsilon_{i,q,k} \qquad (6.3)$$

where the dependent variable SP represents the shareholders' wealth and TE is technical efficiency, the variable of interest. The regression estimates the relation between the monthly end stock price of the second month after the end of the quarter q to the quarterly technical efficiency of the i^{th} firm solved with the k^{th} method: DEA or SFA. $Nodes$ is the number of airports in city pair markets. $Nodes$ proxy the effect of returns to density on stock prices. Economies of density corresponds with the savings resulting from the degree of intensity of operation in a route. It is intrinsically related to returns to scale since the latter depends on the network's size (Sickles, Good, and Getachew, 2002). $Jets$ is the portion of jet engines in the carriers' fleet. This variable provides information about equipment and service quality. Jets are three times faster than turboprops and require less crew (Alam and Sickles, 1998). In contrast, Jets consume more fuel. The value relevance of each technical item is compared with the two accounting numbers: net income NI and accounting value of shareholder equity SE. The final component ϵ refers to the error term.

Holthausen and Watts (2001) define three designs in the value relevance framework: incremental value relevance, relative value relevance, and marginal value relevance. (i) The incremental value relevance investigates whether the variable of interest enables the explanation of stock prices or returns given the other specified variables. The accounting

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number is viewed as incremental value relevant if its coefficient is significantly different from zero. (ii) The relative value relevance studies compare the relation of security price or returns to alternative company items such as performance measures. The relative value relevance of accounting numbers is assessed with the comparison of the adjusted R-squared. (iii) The marginal value relevance aims to test whether an increase of the investors' information set depends on the disclosure of a particular number. To investigate the first two aspects of the value relevance of technical efficiency, we test three reduced forms of (6.3) described in Table 6.1.

Table 6.1: Regression Models Tested

	Dependent variable:			
	SP_{m+2}			
	(1)	(2)	(3)	(4)
Financial Variables				
Net income	X			X
Shareholder equity	X			X
Non-Financial Variables				
Technical efficiency		X	X	X
Number of nodes			X	X
Percentage of jets			X	X
Instrumental variables				
Load factor		X		
Average stage length		X		

Table 6.1 summarizes the four Models that are estimated based on the general specification (6.3) above. To assess the relative value relevance of technical information we compare results with Model (1) focusing only on accounting information. We compare the accounting based Model (1) with two technical information based Model (2) and (3). The first technical based Models (2) tests the relation of technical efficiency to stock price, while taking into account two instrumental variables: load factor and average stage length. The former variable provides information about the capacity utilization as well as service quality. Average stage length provides information about the time spent in an efficient altitude. Finally, Model (3) aims at controlling the information content of additional technical information. Incremental value relevance of technical indicators against net income and shareholder equity is analyzed with the complete Equation (6.3) that corresponds to Model (4).

6.3 Data and Results

6.3.1 Data Description

Production Data

The unbalanced panel data set contains 27 US trunk and local air carriers over 20 years from 1990 to 2010 on a quarterly basis. This is a total of 1286 observations over

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84 periods. The study is focusing on the major carriers. Major carriers also called Group III carriers exhibit annual revenues that exceed $1 billion. Except DHL Airways, Fed Ex and United Parcel Service specialized in cargo services, all carriers are providing cargo and passenger services. Their activities differ depending on the proportion of cargo and passenger services and the regions of operation.

Only 9 carriers span the entire period. The number of observations passes from 13 decision making units (DMU) in 1990-2000 towards 19 in 2010. Except Eastern Airlines, DHL Airways and Hawaiian Airlines Inc., every DMU is quoted or belongs to a quoted holding on the US stock exchange. Carriers or holdings are not listed during the entire period. Most of them passed under the Chapter 11 procedures. Continental Airlines is unlisted in 1991 and 1993. Delta Air Group is unlisted during the first two quarters of 2008 and has changed ticker code the first quarter of 2007. It acquired Comair in November 2000 and merged with Northwest Airlines in November 2008. Northwest Airlines is listed from 1994 to 2007 under NWACQ ticker and from 2007 to its acquisition by Delta Air Group under NWA. US Airways Group was not delisted, but changed three times ticker codes due to Chapter 11. It acquired America West Holding in July 2005 and since 100% owns America West Airlines. Since America West Airlines disappeared into the acquirer.

We have controlled for DOT consolidations. America West Holding changed in ticker too in the third quarter of 1994. United Airlines changed ticker three times. The stock prices of United Parcel Service are available over the period 1999-2010. ATA Holding, whose American Trans Air is the main subsidiary, is listed from 2000-2006. ATA passed under Chapter 11 in 2004 and was excluded from major classification in 2006. It went bankrupt in 2008. Trans World Airways went bankrupt at the end of 2001 and is consequently only listed over the period 1995-2001. Express Jet is listed from 2004 to the beginning of 2009. At the end of the first quarter 2009, Express Jet is unlisted for Chapter 11 purpose until its merger with Skywest Holding in November 2010. This latter holding encompasses two 100% owned majors: Skywest Airlines and Atlantic Southeast Airlines. Frontier Airlines is acquired at the end of the second quarter 2009 by Republic Airways, but continues its operations under the Frontier Airlines name.

Each time a holding changes ticker code, it is unlisted during weeks and the market valuations prior and post changes are extremely low. Except for the acquisition of America West Airlines, the changes in capital structures due to merger and acquisitions do not affect carriers' reporting in the sense that it does not lead to the creation or the disappearance of a new operating entity. Yet, it affects the cooperation, alliances and local market power strategies. It is important to note that we describe only the subsidiaries ranked majors by the US DOT, but every holding also owns medium, regional carriers and/or firms providing services related to their activities such as insurances, booking systems, commuters etc. All information related to holdings as well as monthly stock prices have been collected from Bloomberg for the US stock exchange.

Production Possibility Set

The production data have been provided by the Form-41 released by the US Bureau of Transportation Statistics that belongs to the US DOT. It provides quarterly detailed information about technical and financial carriers' activities. Even though the US DOT releases information on other carrier groups, we focusing on Major certificated carriers for the sake of consistency with Alam and Sickles (1998) who provide a similar study over

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the period 1970-1990. In addition, the reporting requirements for major carriers ensure better data availability and accuracy.

There exist several descriptions of airlines production possibility set. Atkinston and Cornwell (1998) focusing on aircraft capacity as a measure of the output's quality. *"Capacity output measures seats flown whether or not they are occupied by a passenger. The capacity output measure describes the potential output of the airline and provides an important measure of service quality. A carrier offering a lot of flights (and consequently having a large capacity output) will be more likely to have a seat available when a passenger wants it"* (Sickles, Good, and Getachew, 2002). They measure technical efficiency with capital, labor and gallons of aircraft fuel as inputs and available seat miles as output.

Furthermore, Ray and Hu (1997) and Caves, Christensen, and Tretheway (1984) are referring to a revenue approach of the technology. They select as inputs the materials, labor, gallons of aircraft fuel, flight equipment and ground property and their output are an aggregate of revenue passenger miles scheduled and non-scheduled, revenue ton miles for freight and other.

Sickles, Good, and Getachew (2002) combine these two approaches with a two outputs technology: revenue ton miles and available ton miles. Alam and Sickles (2000) and Alam and Sickles (1998) are combining these two approaches too in a two steps procedure. In a first stage, they compute technical efficiency with gallons of fuel, number of aircrafts, number of employees and materials as inputs and revenue ton miles as output. They define materials as an aggregate of supplies, outside services and non-flight capitals. In a second stage, they normalize the technical efficiency scores with a set of control variables including capacity utilization estimates such as load factor and average cabin size. It is important to note that all of these contributions are working on samples that end at the latest in 1990.

In this chapter, we propose a new specification of the technology. We consider four inputs: available ton miles (X1), fuel gallons (X2), maintenance (X3) and number of employees (X4). This information is also available in the consolidated quarterly reports of the quoted holdings. The fuel gallon data differs between the periods 1990-1999 and 2000-2010. During the first part of the sample fuel gallons is decomposed from the income statement Form-41 P-6 accounts with the industry domestic and international yearly fuel indices disclosed by the US Bureau of Census, while, during the second period, it is extracted from the Form-41 P-12A accounts. Labor consists of an aggregate of 15 jobs categories converted into full time equivalent. Contrasting with the previous approaches, we analyze available ton miles as an input. This measure of capacity describes the ton available for each flight. The available ton miles seems a good substitute for aircraft fleet since it better reflects the flexibility in capacity utilization resulting from recent evolutions such as alliances and code-shares. Finally, we use revenue ton miles as output (consisting of scheduled and non-scheduled freight and passenger revenues). The four other variables employed in regressions Models (2-4) in Table 6.1 are computed from different sources. Load factor is computed as the ratio of RTM to ATM downloaded from Form-T1. Average stage length, percentage of jets and number of nodes are aggregated from the US Market Air Statistics Form-T100.

Table 6.2 provides descriptive statistics of the production technology in thousands of units. It exhibits a large dispersion in input and output. This dispersion reflects the differences among carriers in size and services. Indeed, the data set contains trunk and local carriers. Trunk carriers are the biggest since they operate all over the world, while locals operate only in the domestic market. The equipment of trunk carriers is adapted

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for long stages such as trans-Atlantic routes. Equipments differ considerably for short stages.

Table 6.2: Descriptive Statistics (N=1286)

Variables	Label	Mean	Standard deviation	Min	Max
Output					
Y	Revenue ton miles	450602	385361	10057	1824160
Inputs					
X1	Available ton miles	770982	657458	18620	2805694
X2	Fuel (gallons)	267471	231743	24	927597
X3	Maintenance	69779245	65648142	966265	364560800
X4	Employees (full time equivalent)	33944	31710	466	121367

6.3.2 Empirical Results

Technical Efficiency of the US Airline Industry

Figure 6.2 depicts yearly mean technical efficiency for each specification under stochastic frontier and window analysis based DEA frontier. The comparison of the two lines provides information about the evolution of the productivity of the industry over the period 1990-2010. Table 6.3 provides descriptive statistics about the efficiency scores for SFA and DEA Models. Differences between DEA and SFA based technical efficiency scores are partly resulting from differences in the treatment of panel data. The SFA encompasses all the sample to construct the benchmark of best practices. Hence, first periods are compared with technologies that do not exist. This explains why SFA inefficiencies are on average greater than DEA inefficiencies, while SFA generally provides lowest estimation. However, the continuous improvement on average SFA based technical efficiency suggests technological progress over time. Focusing on the average DEA based technical efficiency

Table 6.3: Technical Efficiency Scores: Descriptive Statistics

	CCR	SFA
Mean	0,84	0,68
Std	0,11	0,06
Min	0,37	0,51
Max	1	0,80

in Figure 6.2, one can observe two distinct sub-periods: 1990-2000 and 2000-2010. The sub-period 1990-2000 is characterized by increase on average technical efficiency due to the bankruptcy of the most inefficient DMU and to the implementation of innovation. Two clear shocks depicted by all curves over the period 2000-2010 characterized by more inefficiencies. The shock in 2001-2002 reflects the effect of the terrorist attacks on the 09/11/2001. The second shock corresponds mainly with the effects of the dramatic fuel price increases over the years 2004-2008. Nevertheless, it is important to note that the sample size increases over the period 2000-2010, that is likely to artificially magnify DEA

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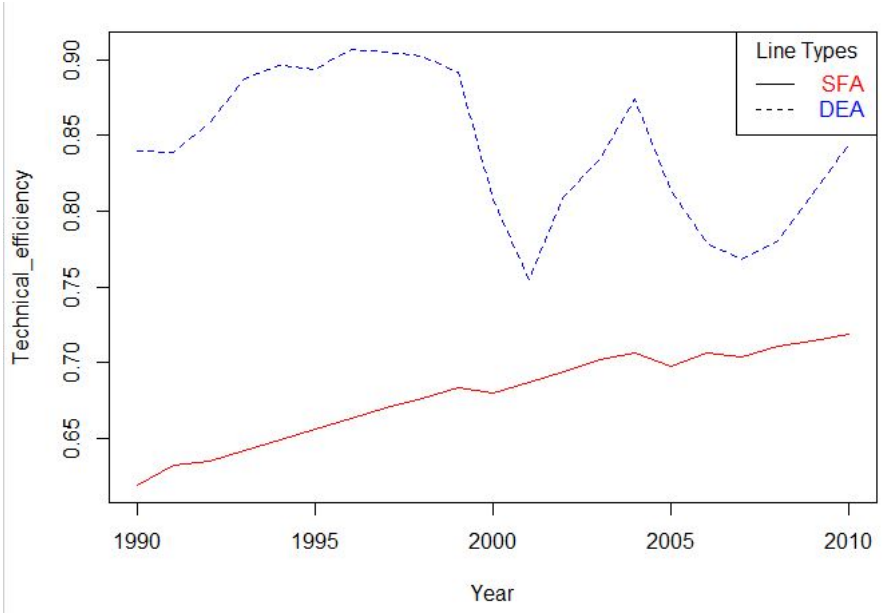

Figure 6.2: Yearly Mean Technical Efficiency

window analysis based technical inefficiency. Comparing these two lines in Figure 6.2 tells us that, even though the US airlines industry improved technical efficiency, differences between carriers were magnified too. Shocks are less noticeable in the SFA case. Due to its construction, the SFA benchmark is likely to consider shocks as random noise.

More detailed statistics provide evidence of the suitability of efficiency results. Table 6.4 reports DEA and SFA based mean technical efficiency of firms involved in merger and acquisition or passed under Chapter 11. The average is computed three years before the events occurred. The lower part of Table 6.4 provides the mean technical efficiency for the overall sample. It reveals that firms passed under Chapter 11 have lower average technical efficiency. Likewise, target firms involved in an acquisition have lower technical efficiency than bidders. These descriptive results are consistent with the ability of technical efficiency scores at providing information about firms' financial performances.

Table 6.4: Average Technical Efficiency Scores

	CCR	SFA
Chapter 11	0,79	0,70
Bidder	0,81	0,68
Target	0,77	0,71
Merger	0,81	0,76
Overall sample	0,84	0,68

Relation of Stock Prices to Technical Efficiency

Tables 6.5 and 6.6 report regressions results for DEA and SFA based computations of technical efficiency respectively. Each table reports results for Models (1) to (4) with fixed effects and random effects regressions. Coefficients and their significance levels are

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reported. The number on the second line between brackets refers to the standard error.

Model (2) consists of regressing technical efficiency scores against stock prices. Two instrumental variables are added: load factor and average stage length. Results reveal that in both cases SFA and DEA based technical efficiency significantly explains the stock valuation. The explanatory power of DEA based technical efficiency is adjusted R^2 of 16%, while it is 10.3% with SFA estimation.

Model (3) corresponds to the first Model with the addition of two technical information: the number of nodes and the percentage of jets. The additional variables improve the Model. DEA based computation beats SFA estimation with an adjusted R^2 of 28.7% and 21% respectively. We observe that in both cases, technical efficiency is the most incrementally relevant variable. The percentage of jets in the fleet is negatively related to stock valuation. We assume this trend is related to the cost associated with fuel consumption involved by jets. In addition, the use of turboprop fleet instead of jets increases for short stages to counter the recent dramatic fuel increase.

Model (4) explains almost half of the stock prices. Despite its explanatory power, the comparison with Model (1) and Model (3) illustrates that, even though technical information is complementary with accounting information, the most part of the information content is captured by net income and shareholder value variables. In addition, each technical component is of greater incremental value relevance than accounting numbers in line with Riley, Pearson, and Trompeter (2003) and Leidtka (2002). Again, Model (4_{DEA}) as well as Model (4_{SFA}), technical efficiency exhibits the highest coefficient. This confirms the hypothesis that technical efficiency is of greater information content than any other technical information.

Finally, the comparison of Model (4_{DEA}) and Model (4_{SFA}) with Model (3_{DEA}) and Model (3_{SFA}) suggests that when it is included with an accounting based model, technical efficiency scores based on DEA and SFA converge. Indeed, Model (4_{DEA}) outperformed Model (4_{SFA}) with +2 points of adjusted R^2, while the difference was +7.7 points. These results support the hypothesis that technical information is of relevance to predict firm's future performance. In addition, it confirms that technical efficiency significantly explains stock value. Cross-checking enhances the robustness of the results.

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Table 6.5: OLS Time and Random Effects Regressions Results: CCR Model

	Dependent variable:							
	SP_{m+2}							
	Fixed Effects				Random Effects			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Net income	0.007***			0.008***	0.009***			0.008***
	(0.001)			(0.001)	(0.001)			(0.001)
Shareholder equity	0.003***			0.002***	0.003***			0.002***
	(0.0002)			(0.0002)	(0.0002)			(0.0002)
Technical efficiency		61.039***	98.470***	63.188***		58.452***	85.699***	57.989***
		(9.750)	(6.506)	(5.755)		(9.293)	(5.895)	(5.264)
Nodes			0.015***	0.010***			0.015***	0.010***
			(0.001)	(0.001)			(0.001)	(0.001)
Percentage of jets			−40.495***	−18.864***			−43.535***	−20.205***
			(4.788)	(4.235)			(4.783)	(4.233)
Constant					18.763***	−24.368***	−16.268**	−15.739**
					(0.788)	(7.789)	(7.165)	(6.189)
Observations	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009
R^2	0.429	0.193	0.320	0.522	0.404	0.164	0.291	0.499
Adjusted R^2	0.392	0.176	0.293	0.476	0.403	0.163	0.290	0.497
F statistic	346.051***	175.879***	144.717***	200.614***	341.244***	490,989.700***	137.331***	200.161***
	($df = 2; 923$)	($df = 1; 924$)	($df = 3; 922$)	($df = 5; 920$)	($df = 2; 1006$)	($df = 1; 1007$)	($df = 3; 1005$)	($df = 5; 1003$)

Note: *p<0.1; **p<0.05; ***p<0.01

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Table 6.6: OLS Time and Random Effects Regressions Results: SFA Model

	Dependent variable:							
	SP_{m+2}							
	Fixed Effects				Random Effects			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Net income	0.007***			0.009***	0.009***			0.010***
	(0.001)			(0.001)	(0.001)			(0.001)
Shareholder equity	0.003***			0.003***	0.003***			0.002***
	(0.0002)			(0.0002)	(0.0002)			(0.0002)
Technical efficiency		97.540***	120.384***	82.789***		81.350***	104.595***	76.161***
		(16.397)	(11.384)	(9.414)		(14.236)	(10.368)	(8.688)
Nodes			0.011***	0.006***			0.011***	0.007***
			(0.002)	(0.001)			(0.002)	(0.001)
Percentage of jets			−47.080***	−20.882***			−47.069***	−21.296***
			(5.012)	(4.319)			(5.002)	(4.321)
Constant					18.763***	−30.986***	−9.735	−16.023**
					(0.788)	(9.716)	(8.713)	(7.197)
Observations	1,009	1,009	1,009	1,009	1,009	1,009	1,009	1,009
R^2	0.429	0.140	0.243	0.501	0.404	0.126	0.221	0.478
Adjusted R^2	0.392	0.128	0.222	0.457	0.403	0.126	0.220	0.475
F statistic	346.051***	132.493***	98.661***	184.641***	341.244***	487,618.100***	94.745***	183.892***
	($df = 2; 923$)	($df = 1; 924$)	($df = 3; 922$)	($df = 5; 920$)	($df = 2; 1006$)	($df = 1; 1007$)	($df = 3; 1005$)	($df = 5; 1003$)

Note: *p<0.1; **p<0.05; ***p<0.01

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Conclusion

The purpose of this chapter is to provide evidence that technical efficiency is a driver of the firm's fundamental value. Technical efficiency informs about the value potential of the firm, that is its ability at generating returns above the normal one in the industry. The empirical foundation of this study is based on the relation between stock valuation and financial information inferred from technical reports in the US airlines industry.

This chapter provides evidence of the value relevance of technical efficiency in an application for the US airlines industry over the period 1990-2010. The relation is investigated with two models: data envelopment analysis with constant returns to scale and strong disposability and a log linear stochastic frontier over an unbalanced sample of 27 carriers. Descriptive statistics reveal technical efficiency scores that are consistent with both firms-specific situations (bankruptcy or position in merger and acquisition) and industry events.

The value relevance analysis is based on the comparison of four models. The first Model focuses on net income and book value of shareholder equity, while the second and third Models focus only on the technical information including technical efficiency. The last Model involves both accounting and technical items. Results confirm that both specifications of technical efficiency are positively related to stock value. Consistently with literature, it also reveals the superior relative and incremental value relevance of the technical information over accounting numbers. Technical efficiency is the most incrementally and relative value relevant variable to explain stock valuation given technical information. Compared with accounting numbers, results denote the complementary role of technical information in stock price explanation. Despite most of the information content of technical efficiency is captured in accounting items, technical efficiency improves the results.

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Chapter 7

Relation between Total Factor Productivity Changes with Expected Stock Returns

Introduction

Stock market is a mechanism by which ownership and control is allocated and investment and production decisions are determined. This allocation process relies on the aggregation of investors decisions. Based on the information set available, investors draw expectations about the future performance of the firms and of the economy to take decisions in a way that will maximize their future wealth with respect to their preferences for risk and time. Since the information set is at the heart of this process, the need for reliable measures of the performance of firms is crucial for stock market to react efficiently. It means to provide a fair allocation of financial resources among securities and the appropriate signals to guide internal firms' investment and production decisions.

Foundations of the linkage between the cost of equity and the performance of the firms under uncertainty have been laid by Modigliani and Miller (1958) and Sharpe (1964). Both approaches share a common view on the performance of the firm. They consider that firms achieve positive performance as soon as they exhibit a rate of returns above the one provided by the corresponding category of assets. The definition of the category of assets resulted in an extensive literature. We retain here the implicit definition in factor based models. These consider that firms belong to the same category when they share the exposition to the same systematic factors. The exposure to systematic data can be measured macroeconomic data, as in (Chen, Roll, and Ross, 1986), or including fundamental data as provided by Fama and French (1995). Firms sharing the same exposition to systematic factors are supposed to share similar underlying characteristics including the same correlations with market indices, but also similar operating costs structures and constraints. As evidence, King (1966) demonstrates the importance of industry membership in the pattern of returns.

Financial theory, based on perfect correlation and pure competition assumptions, usually considers stock price formation responds mainly to external forces (Chen, Roll, and Ross, 1986). However, the real world, featured by technological restrictions and in-

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complete contracts, implies firms' cash-flows balance between exogenous and endogenous determinants. In addition, manager's discretion about the implementation, the riskiness and the time pattern of production and investment decisions have a central effect on firm's cash-flows. Consequently, the empirical assessment of a fair measure of the firms' financial performance requires to disentangle exogenous versus endogenous sources of cash-flows.

Given the financial definition of the performance of the firm, the better the management the larger the portion of positive semi-variance of returns unexplained by pervasive common factors. It ensues that, according to the law of one price, difference in market valuation of two firms facing the same investment opportunity set and the same production possibility set is expected to reflect differences in managerial quality. The purpose of this chapter is precisely to catch this market value shortfall by distinguishing exogenous from endogenous sources of firm's operating efficiency based on index methodology.

Based on a sample of the major US airline carriers over the period 1990-2011, this chapter provides an analysis of the productivity of the sector. In addition, tests of the relation between productivity components and stock returns are tested. Results reveal a statistical relation between stock returns and productivity components computed with Hicks-Moorsteen and Färe-Primont indices. We observe a different relation when productivity arises from improvement in management practices rather than changes in production conditions. The relation is negative in the first case and positive in the second one. This results are consistent with Lin (2010) and Nguyen and Swanson (2009). We consider that, regarding the persistent trend of efficiency, this relation mirrors the reduction in the hurdle rate of the firm. In contrast, changes in production conditions is a factor of risk. However, the assumption of data biases cannot be rejected.

The first section is dedicated to the review of the decompositions provided by the productivity indices in the analysis of their relation with stock returns. The second section introduces the Hicks-Moorsteen and the Färe-Primont indices. Both have desirable properties for an unbiased decomposition of productivity. This section focuses on the benchmarking techniques employed to decompose productivity and on the presentation on the Fama-French-Carhart Model. Sections III and IV present and discuss main results respectively.

7.1 Tests of Relation between Malmquist Components and Stock Returns: A State of the Art

Despite many contributions providing evidence of the relation of operating efficiency to stock market returns, the relation of TFP components to valuation and returns remains relatively unexplored. The survey reviews 5 articles providing such evidence. Except Kumar and Charles (2009) and Thore, Phillips, Ruefli, and Yue (1996), all of the contributions focus on the banking sector and investigate the relation of TFP components within the value relevance framework.

Table 7.1 summarizes evidence of the relation of changes in TFP components to value creation assessed with financial market data. Table 7.1 reports the articles, the Malmquist specification, the regression models employed to assess the relation and estimation methods. Each item is marked with "V" for validation, with "R" for refuted or is blank if not tested. The second number refers to the rank in incremental value relevance. Since results provided by Lin (2010) differs given periods and countries, incremental value relevance is

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not reported.

Fernandez, Fernando, and Gonzalez (2002) provide evidence of the superior incremental value relevance of pure technical efficiency changes over technological changes in Malmquist based comparison of the North American, Japanese and European banking sector. Their output-oriented Zofio and Lovell (1998) specification explains 40% of the yearly cumulated return. However, scale of technological change and changes in scale efficiency are not related. Based on the same specification and a similar regression techniques in the Eastern Asiatic countries, Lin (2010) indicates that the relation of TFP components to year end returns differ depending on countries. Based on the similar regression specification, Fioderlisi and Molyneux (2010a) demonstrate that all changes and level in FGNZ TFP components are significantly related to changes on average market adjusted returns in an application on the banking sector of four European countries. Pure technical efficiency changes appears as the most incremental value relevant component. Models explain at most 44.2% of the returns' variance. Kumar and Charles (2009) provide a statistical relation between shareholder efficiency technical change component and change in market value in the Indian food processing industry. Changes in returns to scale and pure technical efficiency change are not significantly related to value creation. We note that these contributions refer only on fundamental models focusing only on TFP components. Finally, Thore, Phillips, Ruefli, and Yue (1996) include market value as an output in efficiency determination in the US computer industry. This study is not reported in Table 7.1 since we are only focusing on regressions tests to assess the relations of interest.

7.2 Methodology

This section focuses on the evaluation of the TFP and on the estimation of the relation between TFP components and stock returns. The first subsection proposes alternative benchmark selection for the Hicks-Moorsteen and Färe-Primont TFP evaluation. The second section presents the implementation of the Fama-French-Carhart model for the estimation of the relation between TFP components and stock returns.

7.2.1 Benchmark Determination

Decomposing TFP indices into measures of technological change and efficiency change involves estimating the benchmark. The benchmark is the base observation used to perform comparison and decomposition of the performance of the DMU of interest. The choice of the benchmark in efficiency measurement and decomposition raises two subissues. The first issue is: Which evaluation techniques should we use to construct the reference set? As most of contributions about index based decomposition, we refer to linear programming techniques to construct the production frontier. The second issue is: Which observation should we choose as a basis to perform the TFP decomposition? This subsection is concerned with this second issue. Three benchmarks are employed to solve and decompose Färe-Primont TFP (FPTFP) components and one for Hicks-Moorsteen TFP (HMTFP).

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Table 7.1: Contributions Focusing on Relation between Malmquist Components and Stock Returns

Year	2002	2009	2010	2010
Article	Fernandez, Gazcon & Gonzales	Kumar & Charles	Fiorderlisi & Molyneux	Lin
Period	1989-1998	1992-2006	1995-2002	1993-2002
Geo	North America, Japan, Europe	India	Europe	Eastern Asia
Industry	Banking	Food processing industry	Banking	Banking
Specification	Simar & Wilson (1998)	Ray & Desli 1997	FGNZ	Zofio & Lovell 1998
Orientation	Output	Output	Input	Output
Determination	Intertemporal	Intertemporal	Multilateral	Multilateral
TFP changes			V (2)	V
Changes in PTE	V (1)	R	V (1)	V
Changes in SCALE EFF	R		V (4)	V
Changes in RTS		R		
TECH Changes	V (2)	V	V (3)	V
Changes in SCALE TECH	R			V
Dependent variable	Yearly cumulated returns	Change in Market Value	Expected returns	Yearly end returns
Model	dPTE+dScale eff+dTech+dScaleTech	Dpte+dScale+dTech	Tech+PTE+SE	dPTE+dScale eff+dTech+dScaleTech
Estimation method	OLS Fixed and Random Effects	OLS Fixed Effects	OLS Fixed Effects	OLS Fixed Effects

Note: Europe: France,germany,Italia and UK
Eastern Asia: Japan, Taiwan, Indonesia, Hong Kong, Thailand, Malaysia, Philippines, Singapore, and Korea

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Adjacent Years

The first decomposition is done by comparison of the same DMU's within two adjacent years. This computation is performed for the Hicks-Moorsteen and the Färe-Primont decompositions. Since the panel data set is unbalanced, the level of TFP for each firm is obtained by the geometric mean of the two adjacent years. The Hicks-Moorsteen decomposition TFP index is measured over two adjacent years with Equation (2.32). The purpose of this analysis is to report the evolution of the firm's productivity over time.

For the Färe-Primont, that is not designed for this specification, the index is given by the following equation:

$$FPTFP(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D_I^t(x^{i,t}, y^{i,t})}{D_I^t(x^{i,t-1}, y^{i,t})} \times \frac{D_O^t(x^{i,t}, y^{i,t-1})}{D_O^t(x^{i,t}, y^i, t)} \tag{7.1}$$

where x^i and y^i are input and output of the i^{th} individual respectively. The change of FPTFP then is obtained with:

$$dTFP_{t,t+1} = \frac{TFP_{i,t+1}}{TFP_{i,t}} \tag{7.2}$$

Fixed basis Färe-Primont TFP: Southwest Airlines 1990

The standard Färe-Primont consists of evaluating TFP with respect to a specified benchmark as given by Equation (2.33). We have chosen the production of Southwest airlines in 1990 as reference unit for two reasons. First, Southwest Airlines spans the entire sample period. Second, Southwest Airlines is a low-cost carrier characterized by a particular business model. Its network is not designed in a hub and spoke configuration contrasting with majors and legacy carriers. It is important to note that Southwest Airlines constantly increased its market share and profits over the sample period. In addition, it has outperformed other carriers especially during troublesome periods. This decomposition aims at differentiating business model of the low-cost carriers from others and describing alternatively the evolution of the productivity of the industry.

Variable basis Färe-Primont TFP: Contemporaneous Best Performer

Frontier determination is done with respect to the best performers in the cross-section. The best performer is determined with the geometric average of HMTFP efficiency - that is equivalent to CCR-efficiency with the specification of ODonnell (2012a)- over two adjacent years. We refer to the best performer of the year, the DMU that exhibits the highest TFPE level in the year of interest. The FPTFP then is given by the following equation:

$$FPTFP = \frac{D_O(x^{t+1,i}, y^{t+1,i})}{D_I(x^{t+1,l}, y^{t+1,l})} \times \frac{D_I(x^{t,l}, y^{t,l})}{D_O(x^{t,i}, y^{t,i})} \tag{7.3}$$

where the superscripts i and l refer to the individual i^{th} and the reference set l. Change in TFP expresses the change in TFP of the DMU i relative to the change of TFP of the best performer from year t to $t+1$:

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$$dTFP_{i,l,t,t+1} = \frac{TFP_{i,t}}{TFP_{l,t}} \times \frac{TFP_{l,t+1}}{TFP_{i,t+1}} \tag{7.4}$$

where the reference unit l is not the same firm over two years except if it remains the most efficient unit over the two adjacent years. In other words, the measure takes into account the change in TFP of the firm and the change in the best performer over two years. The measure provided by FPTFP differs from HMTFP because it focuses on the most efficient firm an not the most productive to construct the reference set. Since changes in TFP may be driven by technological change and efficiency change, nothing tells whether the premium associated with TFP improvements is assessed with respect to the TFP changes or efficiency changes of the comparable unit.

7.2.2 Relation between Stock Returns and TFP Components

The model estimates the relation of yearly changes in TFP components to yearly cumulated excess returns following the Fama French Carhart Model.

$$CER_{i,t} = \beta(Rm_t - Rf_t) + SMB_t + HML_t + MOM_t + dTFP_{i,k,t} + \epsilon_{i,k,t} \tag{7.5}$$

Variables:

- $CER = \sum Ri - Rf$ where Ri is the returns on the stock i and Rf the Risk-free rate provided by the Kenneth French's data base
- SMB = Sum of daily Small Market Value portfolio premia provided by Kenneth French
- HML = Sum of daily High Market Value portfolio premia provided by Kenneth French
- MOM = Sum of daily momentum effects provided by Kenneth French
- $dTFP_k$ is the TFP component tested detailed in Table 7.2 below.

Before analyzing the relation between TFP and stock returns, the extremes TFP observations are removed manually. The list of the 10 outliers is provided in Table C.1 (see Appendix). They correspond to observation with changes in HMTFP greater than 3. It is important to note that the sign of the relation between HMTFP components and stock returns do not change even though outliers are taken into account in the regression.

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Table 7.2: TFP Components Tested

Label	Score
dY	Change in output
dX	Change in input
dTFP	Change in TFP
dTech	Technological change
dTFPE	Changes TFP Efficiency
dRME	Changes in Residual Mix Efficiency
	Output-oriented
dOTE	Change in pure technical efficiency
dOSE	Change in scale efficiency
dOME	Change in mix efficiency
dROSE	Change in residual scale efficiency
dOSME	Change in scale mix efficiency
	Input-oriented
dITE	Change in pure technical efficiency
dISE	Change in scale efficiency
dIME	Change in mix efficiency
dRISE	Change in residual scale efficiency
dISME	Change in scale mix efficiency

7.3 Results

7.3.1 Data

Production Data

The sample contains 337 observations over the period 1990-2011. Only 8 DMU's over the 28 carriers span the entire period. Different kind of services are provided by DMU's in the sample. 13 are specialized in passengers, while 5 in cargo services. We note that 5 operate only on the domestic market (including 2 low-costs carriers). Nevertheless, the services provided and the constraints faced by carriers are homogeneous. The specification of the 1 output / 3 inputs is akin to the production set of Kumbhakar (1990) to compute comparable productivity scores. The output is the revenue ton miles (Y). The three inputs are the available ton miles (X1), the number of employees (X2) and the gallons of fuel consumed (X3). Their descriptive statistics are provided in Table 7.3.

The output is expressed in revenue ton miles (RTM). Revenue ton miles corresponds with one revenue ton (about 2,000 pounds) transported one mile. It encompasses cargo as well as passenger services for charters and regular flights. The output is an aggregate of scheduled and non-scheduled passenger and cargo services for domestic and international flights[1]. The information about this output has been extracted from the Form 41-T1 statement disclosed by the US Department of Transportation. Likewise, the input available to miles involves all category of services and has been downloaded from T1

[1]A passengers is assumed equivalent with 200 pounds according to the US DOT.

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Table 7.3: Production Possibility Set: Descriptive Statistics

	Fuel gallons	Employee FTE	RTM	ATM
10 %	144047.77	5215.80	574561591	982339843.80
25 %	296386.08	8267	1215114001	2255330843
Median	746685	24308	4139071938	7502560837
75%	1514362.32	49910	9060269909	14585058248
90%	2541199.87	83225.40	12336336716.20	21967925052
Mean	609488.87	19948.66	3179271143.63	5491959871.53
sd	899727.72	32895.57	4610944693.32	7947252727.54

statement. Because of the lack of reliability of operating fleet information for the period 1990-1999, we prefer available ton miles as a measure of capacity. Contrasting with previous contributions focusing on an aggregate of equipment and property ground divided by a multilateral index, we refer here to physical quantities released by carriers. Labor is an aggregate of all labor categories expressed in full time equivalent for all region of operation. Data is provided by the Form 41-P10. Finally, fuel gallons is disclosed in the Form 41 - P12(a). Data have been rescaled to perform TFP computations.

Market Data

The 28 carriers belong to 22 quoted holdings. Over the period 1990-2012, 16 firms passed under Chapter 11 and 17 firms merged. After Hicks-Moorsteen computations, 36 observations are removed as they are not listed on stock market. Table 7.4 provides descriptive statistics about the yearly total of the financial market data. $Mkt.Rf$ stands for the value weighted US market portfolio. Excess returns is the result of the difference between *return* and the riskless rate Rf, SMB, HML and UMD refer to the small cap premia, the high cap premia and the momentum factor of the Fama French Carhart Model. We note that the dependent variable *Excess return* is negative. This means that over the sample period, the US airline industry destroyed value. All financial data are

Table 7.4: Descriptive Statistics: Financial Data

	Mkt.RF	returns	Rf	Excess returns	SMB	HML	UMD
10%	7.58	-1.13	0.08	-5.34	-8.10	-11.97	-13.75
25%	17.05	-0.44	1.18	-4.82	-2.83	-1.12	0.26
Median	31.95	-0.01	3.41	-3.53	2.64	2.40	9.98
75%	41.27	0.28	4.70	-1.36	6.98	11.57	17.83
90%	49.87	0.67	5.39	-0.14	11.80	16.21	23.67
Mean	27.18	-0.12	3.01	-3.13	2.38	3.55	6.17
sd	24.32	0.99	1.95	2.07	9.03	12.59	20.92

downloaded on daily basis and aggregated to obtain the yearly total value. Returns are extracted from Bloomberg, while other data are provided by Kenneth French website.

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Table 7.5: HMTFP Level Geometric Mean

	Nb. obs.	Y	X	TFP	TFP*	TFPE	OTE	OSE	OME	ROSE	OSME	ITE	ISE	IME	RISE	ISME	RME
1990	12	0.95	1.05	0.91	1.11	0.81	0.95	0.93	1.00	0.85	0.85	0.95	0.94	1.00	0.86	0.86	0.91
1991	12	0.96	1.03	0.93	1.19	0.78	0.97	0.95	1.00	0.81	0.81	0.96	0.96	1.00	0.82	0.81	0.85
1992	12	0.97	1.03	0.94	1.24	0.76	0.97	0.96	1.00	0.78	0.78	0.97	0.96	1.00	0.78	0.78	0.81
1993	13	0.95	1.03	0.92	1.38	0.67	0.95	0.97	1.00	0.70	0.70	0.96	0.97	0.99	0.70	0.70	0.72
1994	13	0.96	1.02	0.94	1.47	0.63	0.96	0.98	1.00	0.66	0.66	0.96	0.98	1.00	0.66	0.66	0.67
1995	13	0.96	1.04	0.93	1.49	0.62	0.96	0.98	1.00	0.65	0.65	0.96	0.98	1.00	0.65	0.65	0.66
1996	13	0.96	1.04	0.92	1.38	0.67	0.95	0.99	1.00	0.70	0.70	0.95	0.99	1.00	0.70	0.70	0.71
1997	13	0.96	1.04	0.92	1.31	0.71	0.96	0.98	1.00	0.74	0.74	0.96	0.98	1.00	0.74	0.74	0.75
1998	13	0.96	1.03	0.93	1.28	0.72	0.96	0.97	1.00	0.75	0.75	0.96	0.97	1.00	0.75	0.75	0.78
1999	13	0.96	1.04	0.92	1.30	0.71	0.96	0.96	1.00	0.74	0.74	0.96	0.96	1.00	0.74	0.74	0.77
2000	14	0.95	1.05	0.90	1.63	0.55	0.95	0.93	1.00	0.59	0.59	0.94	0.93	0.99	0.59	0.59	0.63
2001	15	0.95	1.04	0.91	1.77	0.52	0.95	0.94	1.00	0.54	0.54	0.95	0.94	0.99	0.55	0.54	0.58
2002	14	0.95	0.98	0.97	1.93	0.50	0.95	0.94	1.00	0.53	0.53	0.95	0.94	0.96	0.55	0.53	0.56
2003	13	0.96	1.03	0.93	1.54	0.60	0.96	0.94	1.00	0.63	0.63	0.96	0.94	1.00	0.63	0.63	0.67
2004	14	0.96	1.03	0.93	1.52	0.61	0.96	0.95	1.00	0.64	0.64	0.96	0.95	0.99	0.64	0.64	0.68
2005	16	0.96	1.03	0.93	1.45	0.64	0.96	0.91	1.00	0.67	0.67	0.96	0.91	0.98	0.68	0.67	0.74
2006	18	0.94	1.05	0.90	1.45	0.62	0.94	0.89	1.00	0.66	0.66	0.94	0.88	0.99	0.66	0.66	0.75
2007	20	0.93	1.06	0.87	1.35	0.64	0.93	0.90	1.00	0.70	0.70	0.93	0.90	1.00	0.70	0.69	0.77
2008	21	0.95	1.05	0.90	1.38	0.66	0.96	0.90	1.00	0.69	0.69	0.95	0.90	1.00	0.69	0.69	0.77
2009	20	0.97	0.97	1.00	1.92	0.52	0.97	0.95	1.00	0.54	0.54	0.97	0.95	0.91	0.59	0.54	0.56
2010	19	0.96	0.95	1.01	2.08	0.49	0.96	0.98	1.00	0.51	0.51	0.96	0.98	0.99	0.51	0.51	0.52
2011	18	0.96	0.88	1.08	4.27	0.25	0.96	0.93	1.00	0.26	0.26	0.96	0.93	0.98	0.27	0.26	0.29
10%		0.86	0.97	0.74	0.90	0.21	0.86	0.84	1.00	0.21	0.21	0.86	0.84	0.98	0.22	0.21	0.24
25%		0.92	1.00	0.85	1.00	0.61	0.92	0.91	1.00	0.62	0.62	0.92	0.91	1.00	0.66	0.62	0.69
Median		1.00	1.00	1.00	1.09	0.83	1.00	0.98	1.00	0.89	0.89	1.00	0.98	1.00	0.90	0.89	0.93
75%		1.00	1.09	1.00	1.56	0.90	1.00	1.00	1.00	0.97	0.97	1.00	1.00	1.00	0.97	0.97	0.98
90%		1.00	1.16	1.03	4.87	0.98	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.99	0.99	1.00
Geo Mean		0.95	1.02	0.93	1.54	0.61	0.96	0.94	1.00	0.63	0.63	0.96	0.94	0.99	0.64	0.63	0.67
sd		0.06	0.11	0.63	519.99	0.27	0.06	0.07	0.00	0.29	0.29	0.06	0.07	0.05	0.29	0.29	0.29

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7.3.2 TFP Analysis

Detailed descriptive statistics about the level of TFP for each year is given by Table 7.6. Since the data set is unbalanced, TFP is obtained by the geometric mean of the HMTFP of two adjacent years. Descriptive statistics in Table 7.6 show that the geometric mean of HMTFP increased by 8.7% between 1990 and 2011. The increase is not constant and is attributed to the performance of the last 3 sample periods 2009-2011. Indeed, in 2006-2008, the TFP was below its level of 1990. In addition, the last 3 years are characterized by high dispersion. Results indicate a fall in the industry TFP in 2007. This reflects the impact of the dramatic fuel cost per gallon increase on carriers productivity. The normal standard deviation with regard to the sample pattern confirms it impacted all carriers. We note that this is not the case for the 11^{th} September effect on 2002 carriers' accounts. Indeed, if TFP seems relatively high over the adjacent periods, the dispersion is high too and left skewed suggesting carriers have not been equally affected by the demand shock.

Table 7.6: TFP Descriptive Statistics

Year	HMTFP Percentiles					Geom. Mean	SD
	10%	25%	median	75%	90%		
1990	0.75	0.82	1.00	1.00	1.00	0.91	0.12
1991	0.79	0.85	1.00	1.01	1.03	0.93	0.11
1992	0.81	0.89	1.00	1.00	1.02	0.94	0.10
1993	0.78	0.85	0.96	1.00	1.02	0.92	0.11
1994	0.82	0.85	0.95	1.00	1.03	0.94	0.15
1995	0.76	0.85	0.99	1.00	1.00	0.93	0.11
1996	0.76	0.83	0.98	1.00	1.01	0.92	0.11
1997	0.79	0.81	0.98	1.00	1.01	0.92	0.12
1998	0.81	0.84	0.98	1.00	1.02	0.93	0.10
1999	0.78	0.84	0.97	1.00	1.01	0.92	0.10
2000	0.72	0.80	0.98	1.00	1.01	0.90	0.12
2001	0.71	0.81	1.00	1.00	1.04	0.91	0.14
2002	0.70	0.87	1.00	1.02	1.07	0.97	0.72
2003	0.72	0.88	1.00	1.01	1.05	0.93	0.13
2004	0.74	0.89	1.00	1.01	1.05	0.93	0.12
2005	0.73	0.90	1.00	1.00	1.03	0.93	0.12
2006	0.70	0.80	1.00	1.00	1.03	0.90	0.14
2007	0.65	0.78	0.96	1.00	1.01	0.87	0.15
2008	0.70	0.88	1.00	1.00	1.02	0.90	0.14
2009	0.82	0.94	1.00	1.01	1.06	1.00	0.57
2010	0.79	0.90	1.00	1.00	1.06	1.01	0.76
2011	0.79	0.91	0.97	1.02	1.10	1.08	3.26

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TFP Components

Figure 7.1 depicts the evolution of TFP changes compared with aggregate output and input changes. The blue dotted line is the change in the yearly geometric mean of TFP sample (dTFP), while the red solid line and the green dashed line refer to the yearly geometric average changes of aggregated output (dY) and input (dX) respectively.

The period 1990-2000 features a high volatility in TFP related to important demand variations. The decreasing trend in TFP results from the excess input. Borenstein (2011a) notes that the period 1990-2000 is featured by over-investment in capacity from non-low costs carriers. The second conspicuous shock is the 09/11/2001 that makes the demand fall over the period 2001-2002. TFP reduced by 25% between 2000 and 2001. However, the catching-up effect in demand from 2003 to 2004 permitted the use of excess capacity and an increase in TFP. Contrasting with the nineties, the last decade is characterized by better adjustment of input to output variations. This result is consistent with the reduction of excess capacities and a better management of the network through increases in carriers size and code-shares. Despite two shocks in 2005-2006 and 2008, the quasi proportional variation in the aggregate input left TFP almost unchanged. The first shock 2004-2006 corresponds with the increase in the fuel price per gallon, while the second shock reflects the combined effects of fuel price increase with the subprime crisis. Nevertheless, we observe input tend to converge with output since 2008. This latter trend implies a slight decrease in TFP.

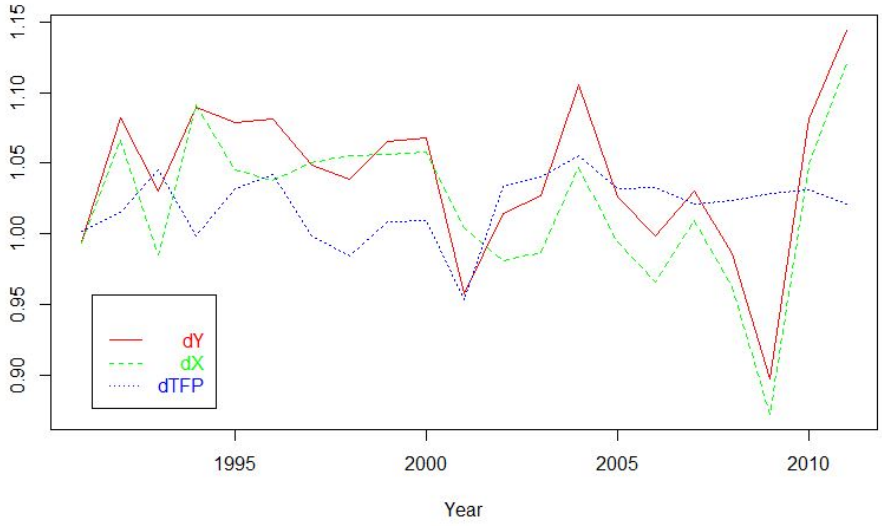

Figure 7.1: Changes in HMTFP

Figure 7.2 illustrates the variation of the sources in TFP changes. It depicts the evolution of TFP changes (dTFP) relative to the technological change (dTech) and efficiency changes (dTFPE) components. At first sight, three shocks featured by high and symmetric technological and efficiency changes can be observed. The first two shocks correspond with the economic recession of 1993 and the terrorist attacks of 2001. In both cases, the TFP is driven by technological regress. This regress artificially increases technical efficiency, but it does not compensate the fall in TFP. The last shock in 2007-2009 corresponds with technological improvements compensated by a fall in efficiencies letting the TFP almost unchanged. This latter movement is more difficult to interpret. This

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period is featured by a dramatic fall in demand related to the subprime crisis. It seems that the improvement in capacity management, which was a great concern for carriers, enables to adjust input quantities. Nevertheless, this interpretation must be taken with caution. The sample size passed from 13 to 20 observations between 2000 and 2008, while 3 observations disappeared in 2009-2010. Increases/decreases in sample size tend to decrease/increase efficiency scores.

After removing these 3 shocks, TFP changes resulted mostly from technological change that reflects changes in capacity utilization and network expansion. The symmetry between technological change and efficiency change suggests technological change is not neutral. This is consistent with the formalization of the technological change provided by ODonnell (2012a) who reports only changes at the MPSS. We observe an interesting relation between changes in TFPE and technological change in the period 2003-2004. We note that each period in which TFP is driven by technological change is followed by an increase in efficiency. This lagged response indicates carriers attempt to adapt their structure to changes in production conditions and sustain TFP against technological regress.

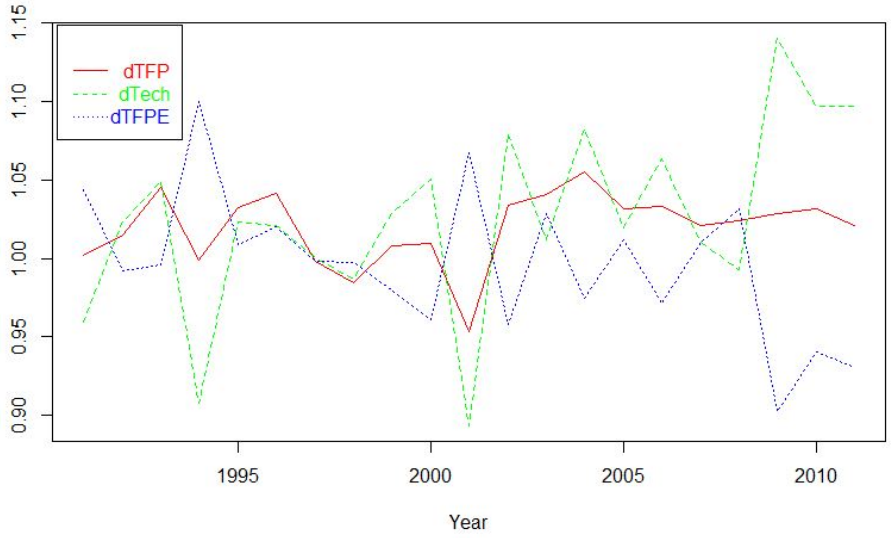

Figure 7.2: Changes in HMTFP Components

Figure 7.3 isolates sources of output-oriented efficiency changes. The solid line represents changes in TFPE. TFPE is the product of output technical efficiency (dashed line) to output scale mix efficiency. Since we specify a single output technology, output mix efficiency equals 1 and is not relevant for the analysis. Hence, output scale mix efficiency equal to residual scale efficiency. In addition, output technical efficiency is not mix restricted and must be interpreted as the deviation from the best practices given the input scale as provided by the BCC Model. Figure 7.3 reveals changes in TFPE arise mostly from changes in output residual scale efficiency. We note that OSE that encompasses input mix effect is irrelevant except in 2000-2002.

The input-oriented determinants of efficiency depicted in Figure 7.4 confirm the conclusions from Figure 7.3. TFPE has been mainly driven by changes in scale efficiency except during the period after the 11^{th} September. During this period, the fall in TFPE is caused by an important input mix inefficiency. This inefficiency is due to the excess capacity with regard to the demand. This leads to a lower load factor. In the other years, IME is quite high suggesting carriers optimize operating load (non-revenue load).

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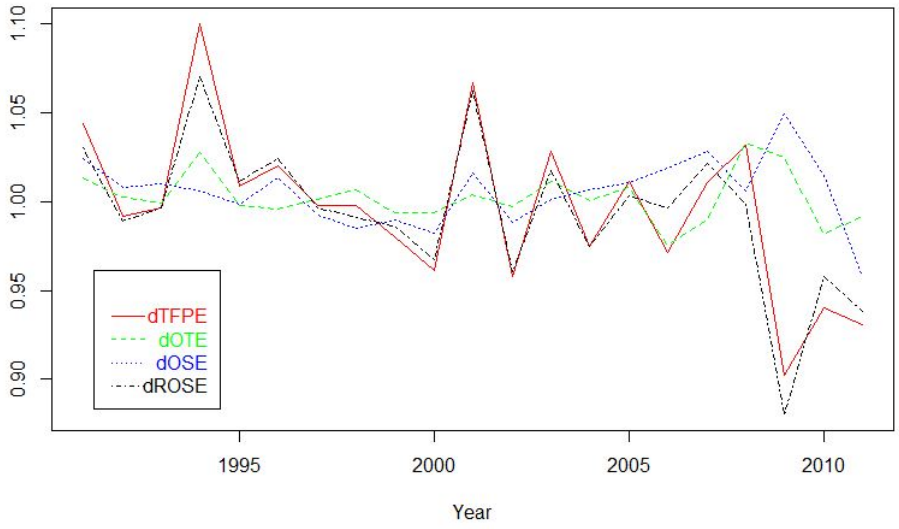

Figure 7.3: Changes in Output-Oriented HMTFP Efficiency Components

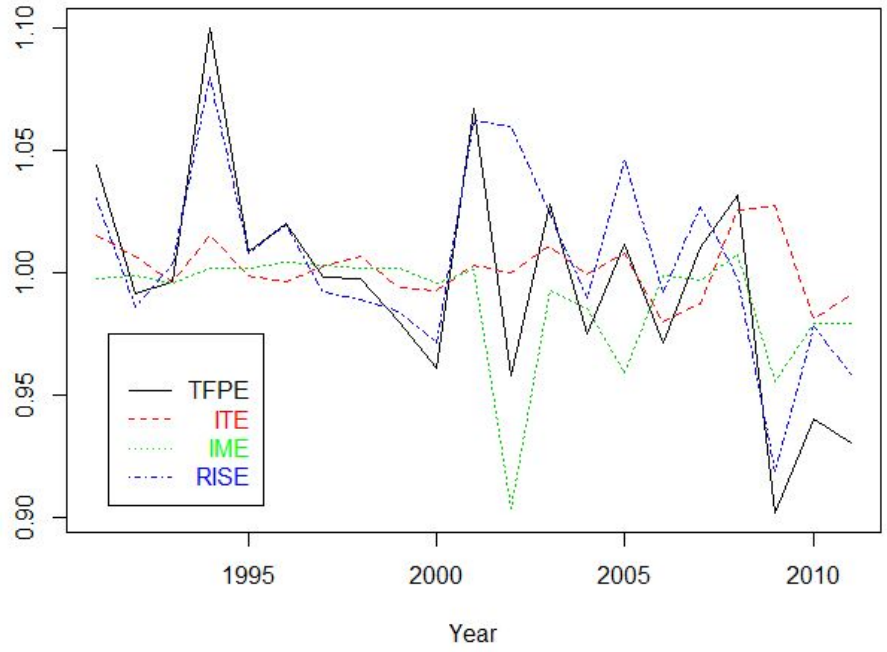

Figure 7.4: Changes in Input-Oriented HMTFP Efficiency Components

The importance of scale component in TFPE determination is no surprise. RTS plays a particular role in transportation services since it involves returns to density (RTD). RTD corresponds with the gain associated with the intensity of the hub and spoke network utilization.

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Domestic versus System Carriers

Table 7.7 provides geometric average change in TFP in the industry according to the region of operation. System refers to carriers providing services worldwide, while domestic carriers focus only on the USA including Alaska and Hawaii.

Table 7.7: Changes in TFP Descriptive Statistics: Domestic vs System Services

Year	Geometric mean		dHMTFP Percentiles All					geo mean	sd
	Domestic	Trunk	10%	25%	median	75%	90%		
1990-1991	0.98	1.00	0.94	0.98	1.00	1.02	1.06	1.00	0.04
1991-1992	1.04	1.01	1.00	1.01	1.02	1.03	1.03	1.01	0.02
1992-1993	1.06	1.04	1.00	1.00	1.05	1.06	1.09	1.04	0.07
1993-1994	1.00	1.00	0.92	1.00	1.03	1.06	1.10	1.00	0.13
1994-1995	0.97	1.04	0.99	1.00	1.02	1.03	1.05	1.03	0.08
1995-1996	1.03	1.04	1.01	1.01	1.03	1.05	1.06	1.04	0.05
1996-1997	0.96	1.00	0.96	0.99	1.01	1.02	1.04	1.00	0.06
1997-1998	1.06	0.98	0.94	0.96	0.99	1.00	1.01	0.98	0.03
1998-1999	1.05	1.00	0.98	0.99	1.00	1.03	1.05	1.01	0.03
1999-2000	1.03	1.01	0.99	0.99	1.00	1.03	1.04	1.01	0.02
2000-2001	0.92	0.96	0.91	0.93	0.96	0.98	1.00	0.95	0.04
2001-2002	0.96	1.04	1.00	1.02	1.02	1.06	1.10	1.03	0.04
2002-2003	1.02	1.04	1.02	1.02	1.02	1.04	1.09	1.04	0.03
2003-2004	1.06	1.05	1.01	1.03	1.05	1.08	1.10	1.05	0.04
2004-2005	1.02	1.03	0.99	1.00	1.03	1.05	1.08	1.03	0.04
2005-2006	1.05	1.03	0.98	1.02	1.03	1.05	1.07	1.03	0.05
2006-2007	1.04	1.01	0.98	0.99	1.01	1.03	1.10	1.02	0.06
2007-2008	1.01	1.03	0.98	0.98	1.00	1.03	1.12	1.02	0.08
2008-2009	1.20	0.99	0.95	0.99	1.00	1.04	1.07	1.03	0.14
2009-2010	1.06	1.03	1.00	1.02	1.04	1.05	1.05	1.03	0.03
2010-2011	1.13	1.00	0.97	0.99	1.01	1.02	1.10	1.02	0.08

Over the sample period geographically diversified carriers provided better performance than domestic carriers. Differences between domestic carriers and trunk carriers are depicted in Figure 7.5. The red solid line depicts changes in TFP of domestic, while the green dashed line and the blue dotted line refer to system carriers and the overall sample respectively. As expected, diversified carriers were less impacted by the 11^{th} September. This trend is not only due to diversification, but is also related to the kind of activity. Indeed, domestic carriers are in many cases specialized in passenger services. Hence, their TFP reflects the effect of demand for passenger services which is particularly volatile.

Passenger vs Cargo Services

Detailed descriptive statistics in Table 7.8 provide information about TFP change given carriers' specialized in cargo or passengers. Figure 7.6 provides geometric average of change in TFP by comparing specialized carriers in cargo or passengers with diversified carriers.

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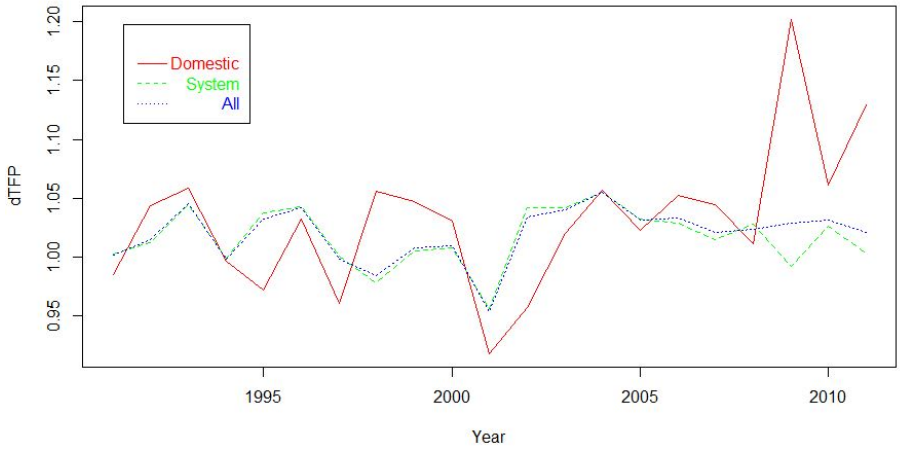

Figure 7.5: Evolution of HMTFP per Geographical Diversification

Table 7.8: Changes in TFP Descriptive Statistics: Passenger, Cargo and Trunk

Year	Passenger	Cargo	Both	dHMTFP Percentiles All					geo mean	sd
				10%	25%	median	75%	90%		
1990-1991	1.01	0.98	1.01	0.94	0.98	1.00	1.02	1.06	1.00	0.04
1991-1992	1.01	1.02	1.03	1.00	1.01	1.02	1.03	1.03	1.01	0.02
1992-1993	1.03	1.11	1.05	1.00	1.00	1.05	1.06	1.09	1.04	0.07
1993-1994	1.03	0.86	1.10	0.92	1.00	1.03	1.06	1.10	1.00	0.13
1994-1995	1.01	1.10	1.02	0.99	1.00	1.02	1.03	1.05	1.03	0.08
1995-1996	1.04	1.08	1.02	1.01	1.01	1.03	1.05	1.06	1.04	0.05
1996-1997	1.01	0.95	1.03	0.96	0.99	1.01	1.02	1.04	1.00	0.06
1997-1998	1.00	0.97	0.96	0.94	0.96	0.99	1.00	1.01	0.98	0.03
1998-1999	1.00	1.02	1.01	0.98	0.99	1.00	1.03	1.05	1.01	0.03
1999-2000	1.01	1.01	1.01	0.99	0.99	1.00	1.03	1.04	1.01	0.02
2000-2001	0.95	0.95	0.95	0.91	0.93	0.96	0.98	1.00	0.95	0.04
2001-2002	1.02	1.05	1.06	1.00	1.02	1.02	1.06	1.10	1.03	0.04
2002-2003	1.04	1.02	1.05	1.02	1.02	1.02	1.04	1.09	1.04	0.03
2003-2004	1.06	1.06	1.05	1.01	1.03	1.05	1.08	1.10	1.05	0.04
2004-2005	1.03	1.01	1.04	0.99	1.00	1.03	1.05	1.08	1.03	0.04
2005-2006	1.03	1.04	1.03	0.98	1.02	1.03	1.05	1.07	1.03	0.05
2006-2007	1.02	1.04	1.00	0.98	0.99	1.01	1.03	1.10	1.02	0.06
2007-2008	1.03	1.00	1.00	0.98	0.98	1.00	1.03	1.12	1.02	0.08
2008-2009	1.04	1.09	1.01	0.95	0.99	1.00	1.04	1.07	1.03	0.14
2009-2010	1.04	1.04	1.05	1.00	1.02	1.04	1.05	1.05	1.03	0.03
2010-2011	1.03	0.98	1.00	0.97	0.99	1.01	1.02	1.10	1.02	0.08

Results indicate diversified carriers outperform specialized carriers in 9 periods. It is important to note that carriers diversified in services are in many cases also geographically diversified. We observe that the increase in TFP of cargo specialized carriers is particularly high during economic growth as well as during the periods 1995-2000 or 2004-2007. They are also the most affected during economic recession, as in 1993 and during last two years.

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In contrast, cargo services were as much impacted by the 2001-2002 events as passenger services.

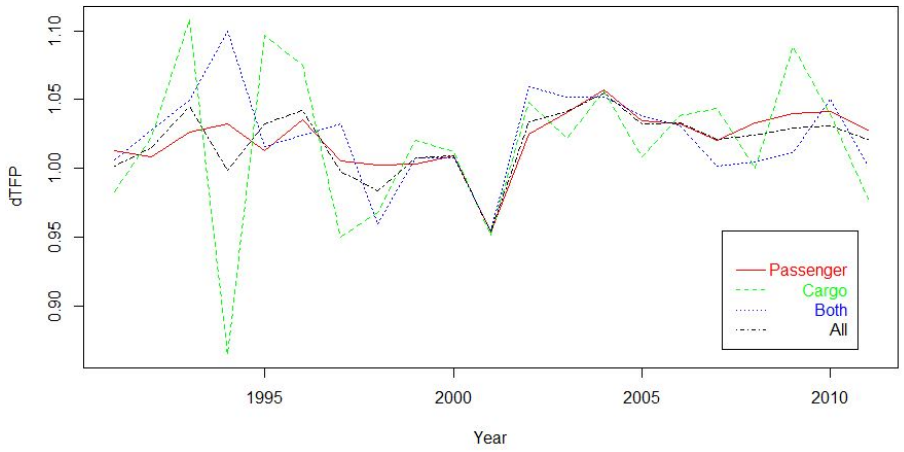

Figure 7.6: Evolution of HMTFP per Services Diversification

LCC vs Legacy Carriers

The entry and the rise of low-costs carriers (LCC) significantly modified the nature of the competition in the US passenger services. The LCC outperformed other carriers over the sample period. While the industry destroyed $ 25.35 billions over the period 1990-2012, LCC created $ 7.6 billions during the same period. The decomposition of the TFP of LCC permits on the one hand to verify whether the competitive advantage of LCC is associated with higher productivity and on the other hand, to understand the specificity and the advantage of their business model. Table 7.9 compares TFP level of LCC with the rest of the passenger services.

We note that on average, LCC were less productive than other carriers. Thus, LCC performance results from something else than pure productivity. LCC provides passenger services in point to point market instead of hub and spoke configuration. The gain associated with network utilization is then less important. Nevertheless, their network configuration implies a more flexible cost structure suitable with the highly volatile demand. Table 7.9 shows that during the period 2004-2007 the LCC productivity fell dramatically behind non-LCC carriers. This is enhanced by the distress of ATA Airlines. Its operation has been divided by two in 2005 and 2006. Southwest Airlines acquired it in 2010. By contrast, the period 2010-2011 is featured by high performance of LCC carriers. This seems to correspond to the entry and the success in the sample of Frontier Airlines and JetBlue Airways.

Figure 7.7 compares the variations of TFP of LCC, including input and output variations, with the TFP variation of domestic activities of other majors carriers specialized in passenger services. We focus only on Southwest Airlines to measure LCC performance because it accounts for more than half of the LCC market share and it is the oldest LCC major carriers spanning the entire sample period. The red solid line represents variations in input, while the green dashed line indicates output variation. The blue dotted line

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Table 7.9: TFP Descriptive Statistics: Low costs carriers versus legacy

Year	LCC	Other Pass.	dHMTFP Percentiles All					geo mean	sd
			10%	25%	median	75%	90%		
1990	1.00	0.82	0.75	0.82	1.00	1.00	1.00	0.91	0.12
1991	1.00	0.96	0.80	0.86	1.00	1.01	1.02	0.94	0.11
1992	0.97	0.93	0.81	0.93	1.00	1.01	1.01	0.94	0.10
1993	0.88	0.94	0.84	0.88	0.93	1.01	1.02	0.93	0.09
1994	0.82	0.97	0.82	0.85	0.96	1.00	1.03	0.94	0.13
1995	0.76	0.92	0.78	0.85	0.99	1.00	1.00	0.93	0.11
1996	0.75	0.95	0.77	0.86	0.98	1.00	1.02	0.92	0.11
1997	0.70	0.95	0.80	0.82	0.98	1.00	1.03	0.92	0.12
1998	0.73	0.92	0.81	0.84	0.98	1.01	1.02	0.93	0.10
1999	0.77	0.99	0.78	0.84	0.97	1.00	1.01	0.92	0.10
2000	0.88	0.98	0.77	0.81	1.00	1.01	1.02	0.91	0.12
2001	0.89	0.92	0.71	0.79	1.00	1.02	1.04	0.90	0.14
2002	0.81	0.96	0.73	0.88	1.01	1.03	1.04	1.03	1.00
2003	0.80	0.95	0.75	0.89	1.01	1.02	1.03	0.93	0.13
2004	0.83	0.98	0.78	0.90	1.01	1.02	1.04	0.94	0.12
2005	0.90	0.94	0.78	0.88	1.00	1.01	1.02	0.94	0.11
2006	0.88	0.89	0.75	0.84	0.97	1.01	1.03	0.90	0.14
2007	0.77	0.89	0.68	0.79	0.93	1.00	1.02	0.87	0.15
2008	0.82	0.91	0.72	0.89	1.00	1.01	1.01	0.91	0.13
2009	0.90	1.12	0.82	0.94	1.00	1.01	1.14	1.03	0.75
2010	0.93	1.01	0.80	0.92	1.00	1.02	1.29	1.04	0.57
2011	0.94	0.92	0.79	0.91	0.97	1.02	1.10	1.08	3.26

depicts the TFP changes of diversified carriers, while the black solid line represents the TFP changes of the overall sample. Figure 7.7 underlines the volume of output of LCC decreases over time. This is concomitant with the entry of new competitors during the last decade. In addition, the reduction of the fare spread between LCC and non-LCC engaged during the early nineties permitted to slow down the increase in LCC market shares. It is of interest to note that aggregated input exceed the output four times in 1995, 1997, 2001 and 2006 whereas Figure 7.1 shows it happens only twice in 1993 and 2002 for the overall industry. This means that LCC met difficulties at adjusting to the high volatile domestic demand. Contrasting with legacy carriers, LCC are less engaged in frequent flyer programs. One can imagine that passenger services provided is less oriented to business class that is a less volatile.

By comparing TFP changes of LCC and non-LCC, we note that during the period 1993-1997, changes in TFP of non-LCC carriers were higher than those performed by LCC. This period corresponds with the highest reduction of the spread between LCC and non-LCC airfares and the exploitation of RTD implied by the rise of demand. However, the following period 1997-2001, when non-LCC over-investment in capacity has reached its highest magnitude, the TFP of LCC and non-LCC reversed. In addition, the catching-up of demand for LCC takes double the time than for legacy carriers. Finally, despite noticeable effort of network restructuring through mergers, acquisitions and code-shares, the TFP growth of LCC remains, in most cases, greater than legacy carriers.

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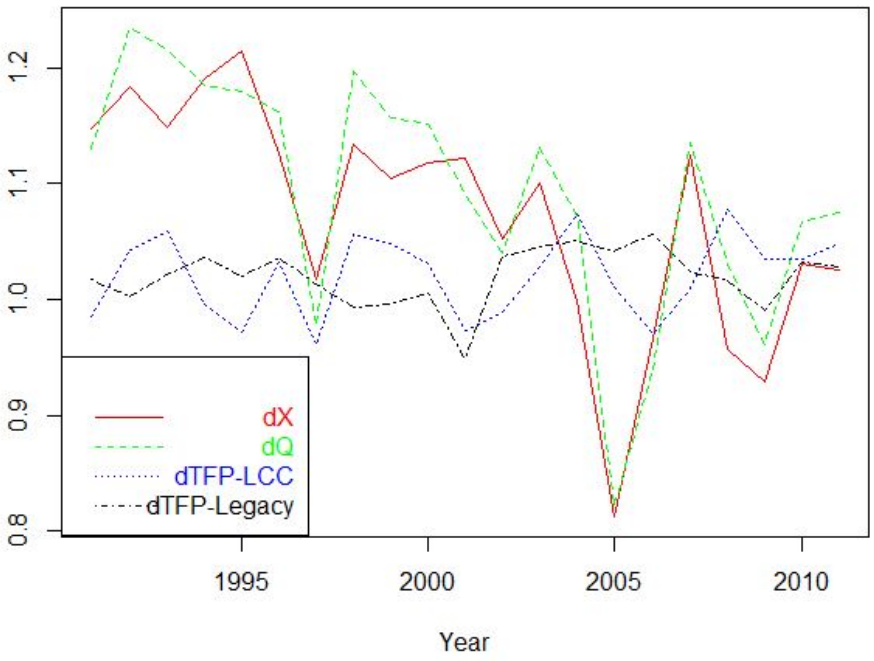

Figure 7.7: Southwest Airlines HMTFP Changes versus Non Legacy Carriers

Despite lower TFP level, LCC were more efficient. Figure 7.8 confirms that LCC had a greater geometric average of TFPE level. The black solid line represents the evolution of LCC TFPE, while the red dashed line depicts the evolution of the TFPE level of other majors specialized in passenger services over the sample period. This difference is confirmed in Figure 7.9, that compares the changes in TFP sources of Southwest Airlines with other majors carriers. It highlights that TFPE were the main driver of TFP changes.

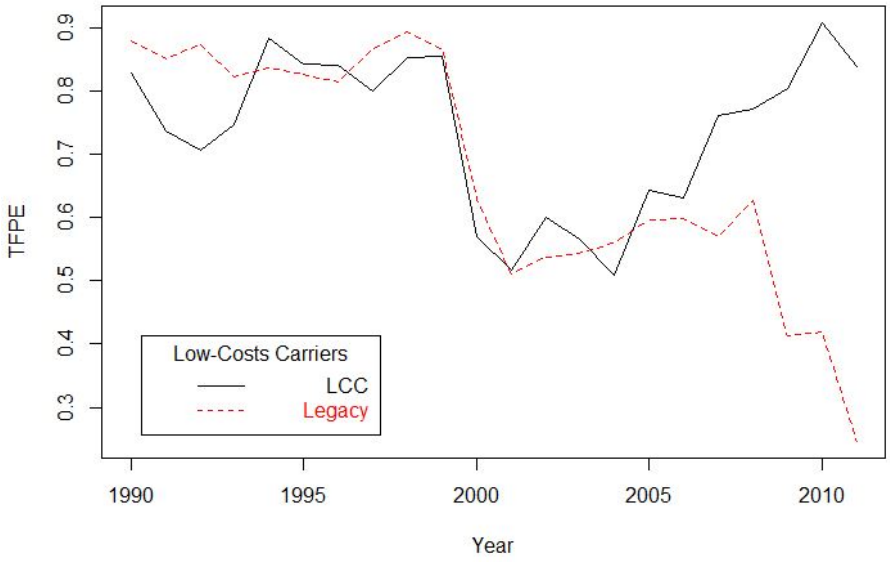

Figure 7.8: HMTFP Efficiency Level: LCC versus Legacy Passenger Services

This difference in TFPE is not only attributable to the success of the differentiated offer provided by LCC, but also to differences in network configuration. LCC are not

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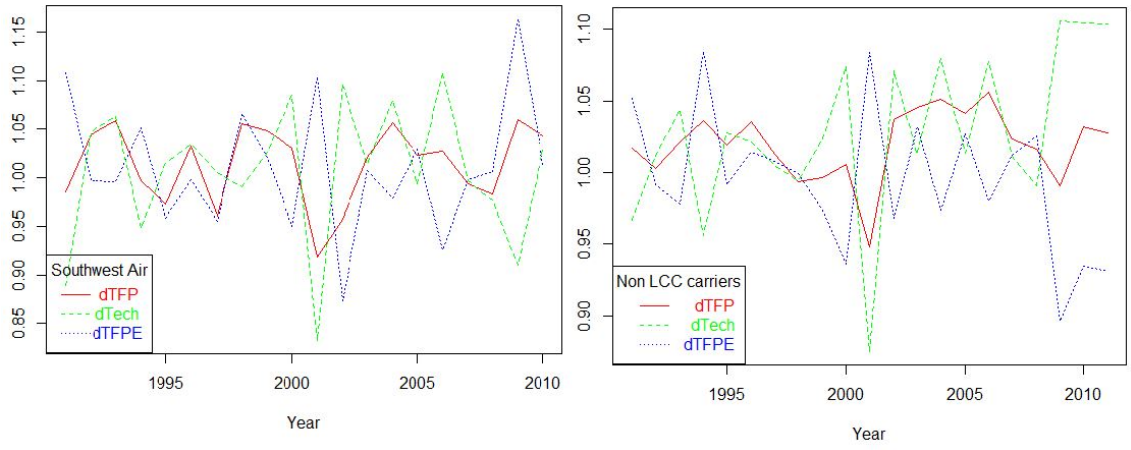

Figure 7.9: Sources HMTFP Changes

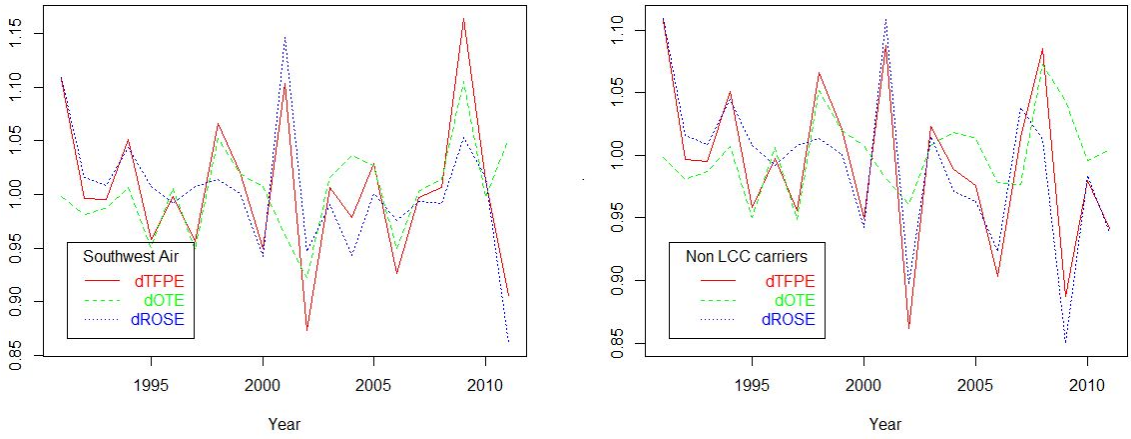

Figure 7.10: Sources of Output HMTFP Efficiency Changes: Southwest versus Non-LCC Passenger Services

structured as a hub and spoke system contrasting with other majors. The hub and spoke configuration aims at establishing a local market power on a hub airport to maximize inter-airport connections to take profit from returns to density. Nevertheless, this enhanced the development of excess capacity by legacy carriers and high fixed costs. This difference is captured by Figures 7.10 and 7.11 which compare changes in efficiency sources in both orientations. If, during the first decade, TFPE patterns are similar and mainly driven by changes in ROSE, Southwest Airline TFPE is more driven by output technical efficiency than scale components during the last decade. The effect of output technical efficiency improvement provides higher increase in TFPE in 2008. If this pattern is not unique to Southwest airlines during 2007-2008, it is more marked for the LCC.

This observation is confirmed when focusing on the input-oriented components of TFPE for Southwest Airlines and non-LCC in Figure 7.11. Input-oriented measures of efficiency confirm that the TFPE of Southwest Airlines was mainly driven by technical efficiency and partly by residual scale efficiency, while this latter component was the only driver of non-LCC performance. The fact that TFPE were driven by mix restricted efficiency components reflects that LCC network configuration is more suitable for the

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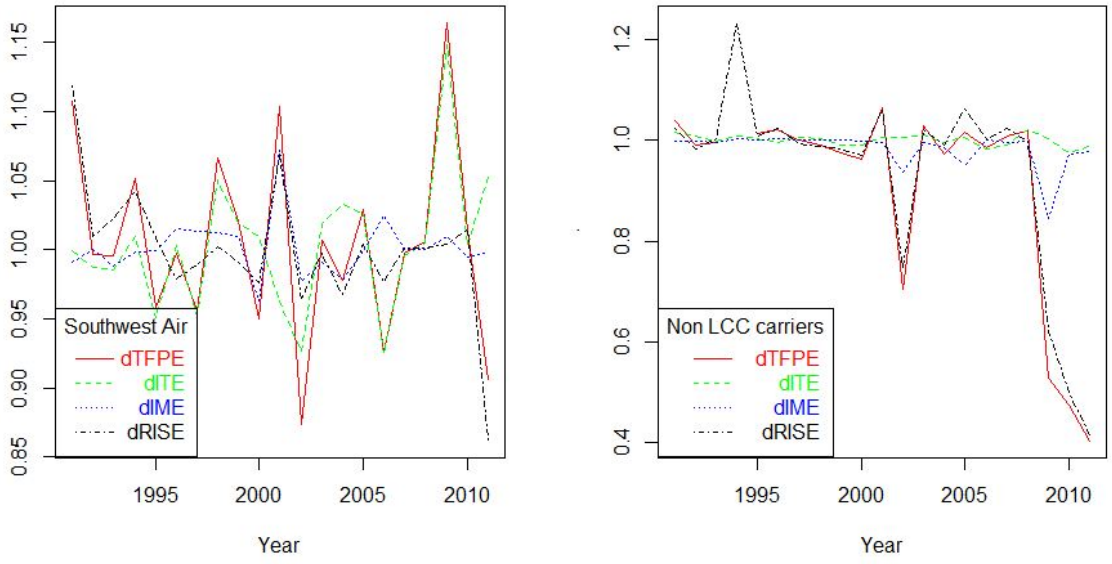

Figure 7.11: Sources of Input HMTFP Efficiency Changes: Southwest versus Non-LCC Passenger Services

management of capacity.

7.3.3 Benchmarks Comparison

Adjacent Years

Descriptive statistics about the yearly geometric means of levels of HMTFP and FPTFP for adjacent years are described in Tables 7.6 and 7.10 respectively. Contrasting with the HMTFP, the FPTFP is highly concentrated with an average TFP equal to unity and no improvement over the sample period. These results are no surprise since the informational power of the data set for the adjacent benchmark TFP determination is weak. In addition, FPTFP components are all equal to unity. The projection of HMTFP and FPTFP level in Figure 7.12 suggests convergence between FPTFP and HMTFP adjacent base periods.

FPTFP Fixed and Variable Bases

Table 7.11 reports yearly geometric mean of FPTFP levels on variable and fixed bases. The left hand side of Table 7.11 is concerned with the contemporaneous benchmark. Level and changes in TFP are computed relatively to the best performer within the cross-section. The best performer is the performer that exhibited the highest average CCR-efficiency over two adjacent years. The right hand side of Table 7.11 depicts descriptive statistics for the FPTFP fixed basis solved through comparison of each DMU with the input and output sets of the base unit Southwest Airlines in the base year 1990.

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Table 7.10: Descriptive Statistics of Level of Adjacent Years FPTFP

Year	FPTFP Percentiles					geo mean	sd
	10%	25%	median	75%	90%		
1990	0.97	0.98	0.99	1.00	1.01	0.99	0.02
1991	0.97	0.99	1.00	1.01	1.02	1.00	0.02
1992	0.98	0.99	1.00	1.01	1.03	1.00	0.02
1993	0.96	0.98	1.00	1.01	1.02	0.99	0.02
1994	0.98	1.00	1.00	1.01	1.02	1.00	0.03
1995	0.98	0.98	0.99	1.00	1.01	1.00	0.03
1996	0.98	0.99	1.00	1.01	1.02	1.00	0.02
1997	0.99	0.99	1.00	1.02	1.02	1.00	0.02
1998	0.98	0.99	1.00	1.00	1.01	1.00	0.02
1999	0.98	0.99	1.00	1.00	1.02	1.00	0.02
2000	1.00	1.00	1.01	1.02	1.02	1.01	0.02
2001	0.97	0.98	0.99	1.00	1.00	0.99	0.02
2002	0.98	0.98	1.00	1.01	1.02	1.00	0.02
2003	0.97	0.97	1.00	1.02	1.02	0.99	0.02
2004	0.96	0.98	1.01	1.03	1.03	1.00	0.03
2005	0.97	0.99	1.00	1.01	1.02	1.00	0.02
2006	0.99	1.00	1.00	1.01	1.02	1.00	0.02
2007	0.98	1.00	1.00	1.00	1.02	1.00	0.02
2008	0.99	0.99	1.00	1.00	1.02	0.99	0.03
2009	0.98	0.98	0.99	1.00	1.01	1.00	0.10
2010	0.98	1.00	1.00	1.02	1.02	1.00	0.03
2011	1.00	1.00	1.00	1.01	1.04	1.01	0.02

Cross-Benchmarks TFP Comparison

Figure 7.12 depicts the changes in FPTFP for fixed and variable bases and HMTFP. The black solid line represents HMTFP changes, while the blue dotted line is the corresponding FPTFP changes. The red dashed line and the green dotted lines refer to the changes in FPTFP for variable basis related to the contemporaneous most efficient peer and the fixed basis respectively. This comparison shows that the adjacent year benchmarks provide the least dispersed changes in TFP than the fixed and best peer variable bases FPTFP. Similar to HMTFP, FPTFP reports the exogenous shocks the industry suffered over the sample period. As can be reasonably expected, adjacent years based benchmark provide a higher TFP change than those computed with reference to the most efficient peers. The variable basis FPTFP depicted by the red dashed line reflects more the effect of adverse events in the sample period especially during the 2007-2008 period. The fixed basis 1990 FPTFP is constantly increasing except during the period 2001-2002. This confirms productivity gains over the sample period depicted by evolution of HMTFP level in Table 7.6. We note that the changes in FPTFP fixed basis depicted by the green dotted line exhibit a pattern similar to the intertemporal estimation of technical efficiency done in the last chapter.

Figure 7.13 depicts the evolution of TFPE levels for HMPTFP and FPTFP for fixed

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Table 7.11: Descriptive Statistics of FPTFP Variable and Fixed Bases

Year	FPTFP variable basis							FPTFP fixed basis						
	10%	25%	median	75%	90%	geo mean	sd	10%	25%	median	75%	90%	geo mean	sd
1990	0.73	0.76	0.80	0.86	0.91	0.81	0.06	0.44	0.45	0.48	0.52	0.54	0.48	0.06
1991	0.79	0.82	0.86	0.92	0.94	0.86	0.06	0.44	0.46	0.49	0.51	0.53	0.49	0.05
1992	0.80	0.84	0.85	0.92	0.94	0.87	0.05	0.44	0.47	0.49	0.51	0.53	0.49	0.05
1993	0.77	0.82	0.87	0.89	0.92	0.85	0.05	0.45	0.48	0.51	0.53	0.60	0.52	0.06
1994	0.80	0.82	0.86	0.91	0.92	0.86	0.06	0.48	0.49	0.51	0.55	0.56	0.52	0.04
1995	0.78	0.80	0.90	0.92	0.93	0.86	0.06	0.47	0.49	0.54	0.56	0.60	0.53	0.05
1996	0.81	0.82	0.91	0.92	0.93	0.88	0.06	0.50	0.50	0.56	0.56	0.60	0.54	0.04
1997	0.83	0.84	0.89	0.94	0.94	0.88	0.05	0.51	0.51	0.55	0.57	0.58	0.54	0.04
1998	0.78	0.80	0.83	0.88	0.92	0.84	0.06	0.50	0.52	0.54	0.55	0.57	0.54	0.03
1999	0.75	0.77	0.79	0.81	0.88	0.80	0.06	0.51	0.52	0.53	0.56	0.59	0.54	0.04
2000	0.70	0.73	0.76	0.86	0.87	0.78	0.07	0.50	0.51	0.53	0.58	0.61	0.55	0.05
2001	0.66	0.71	0.74	0.79	0.84	0.73	0.10	0.46	0.48	0.51	0.54	0.59	0.51	0.05
2002	0.69	0.74	0.80	0.85	0.89	0.78	0.09	0.47	0.50	0.54	0.57	0.60	0.53	0.06
2003	0.70	0.74	0.79	0.82	0.86	0.78	0.06	0.48	0.51	0.54	0.58	0.60	0.54	0.05
2004	0.75	0.78	0.81	0.89	0.92	0.82	0.06	0.50	0.52	0.54	0.60	0.63	0.56	0.05
2005	0.50	0.60	0.67	0.72	0.83	0.65	0.11	0.50	0.52	0.56	0.60	0.62	0.56	0.05
2006	0.55	0.59	0.71	0.77	0.87	0.69	0.11	0.51	0.53	0.56	0.60	0.64	0.57	0.07
2007	0.54	0.61	0.71	0.76	0.88	0.67	0.11	0.52	0.54	0.57	0.61	0.62	0.57	0.06
2008	0.51	0.60	0.69	0.71	0.82	0.64	0.17	0.51	0.54	0.57	0.61	0.63	0.57	0.06
2009	0.69	0.76	0.80	0.84	0.87	0.78	0.09	0.49	0.54	0.58	0.61	0.62	0.56	0.06
2010	0.68	0.80	0.85	0.87	0.90	0.80	0.11	0.51	0.57	0.60	0.62	0.64	0.58	0.07
2011	0.68	0.79	0.85	0.87	0.90	0.81	0.11	0.53	0.58	0.60	0.63	0.64	0.59	0.07

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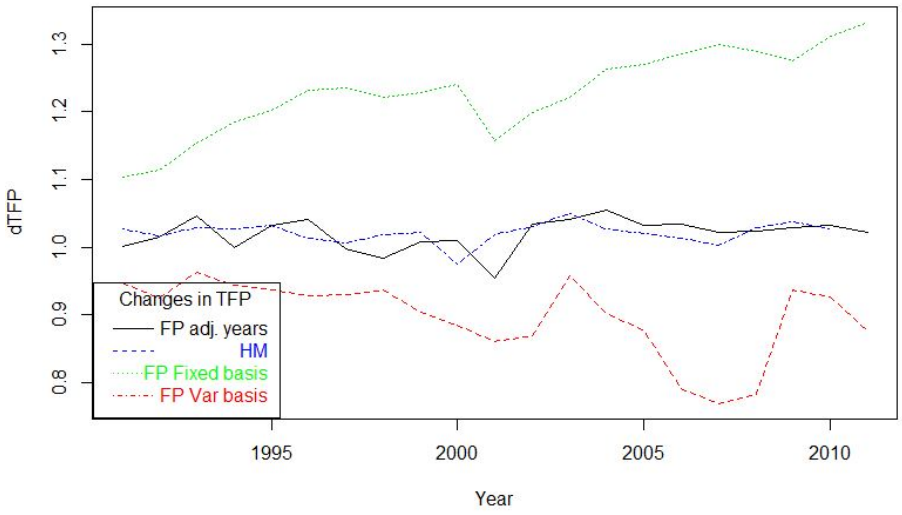

Figure 7.12: Changes in TFP - Cross Benchmarks Comparison

and variable bases. It is surprising to note that the HMTFPE depicted by the black solid line provides the lowest and most dispersed geometric average scores.

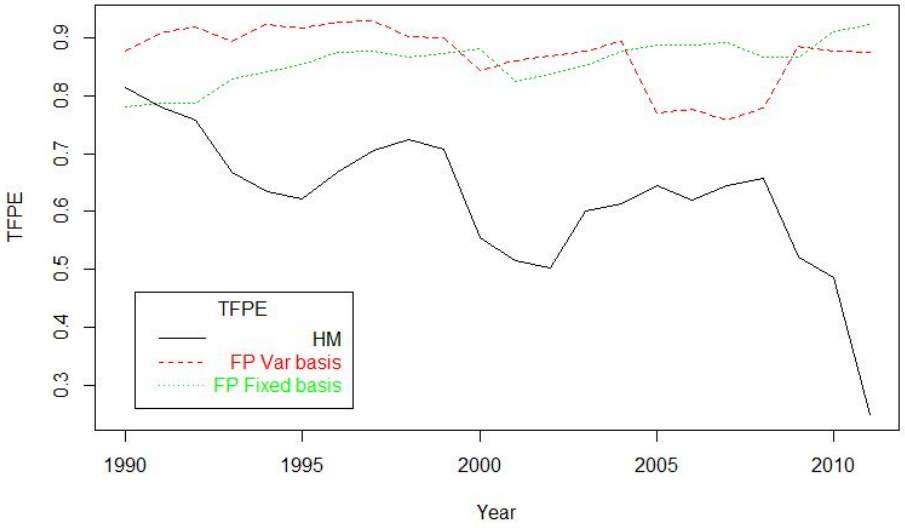

Figure 7.13: TFPE Levels for HMTFP and FPTFP Fixed and Variable Bases

FPTFP Fixed Basis Decomposition

Figure 7.14 depicts the evolution of TFP components. The green dashed line is the Färe-Primont measure of technological change, the blue dotted line depicts the changes of the FPTFPE and the red solid line the changes in FPTFP. Contrasting with HMTFP, the FPTFP is driven by the FPTFPE instead of technological change. The comparison of carriers' productivity with an old benchmark produces a virtual increase of efficiency over time.

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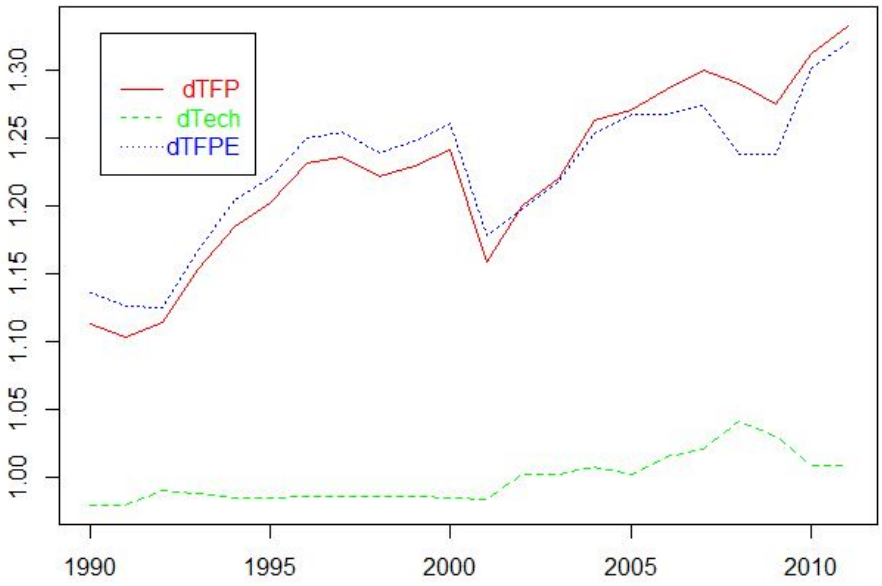

Figure 7.14: Changes in Färe-Primont TFP Fixed Basis Components

Figures 7.15 and 7.16 depict the evolution of TFPE and its output and input components respectively. Results confirm the HMTFPE decomposition. Again scale efficiency components are the main drivers of the productivity of the industry. Results differ from HMTFPE in the time needed for carriers to catch-up the shock of the terrorist attacks of 2001.

7.3.4 Relation between Stock Returns and TFP Components

Effect of Ownership on Performance

The analysis of the relation between stock performance to changes in TFP scores and components implies to remove every unlisted observation. The unlisted firms consist of 36 observations heterogeneously distributed in the sample. The sample contains unlisted firms until 2009. Figure 7.17 presents the differences in TFPE level for private and listed companies. It supports the widespread view that market discipline enhances firms' performance (Uchida and Satake (2009); Wurgler (2000)). However, the sample size does not allow for such a generalization.

Regressions Results

This section investigates the statistical relation between TFP components and stock returns. We test whether alternative TFP specifications catch a portion of the variance of returns not explained by common market factors mirrored by the Fama-French-Carhart (FFC) Model. We regress financial and TFP variables against yearly cumulated returns with a pooling OLS regression. Results consist of 48 regressions pooled in 6 regression sets given their information content. Tables 7.12, 7.13 and 7.14 report estimates for com-

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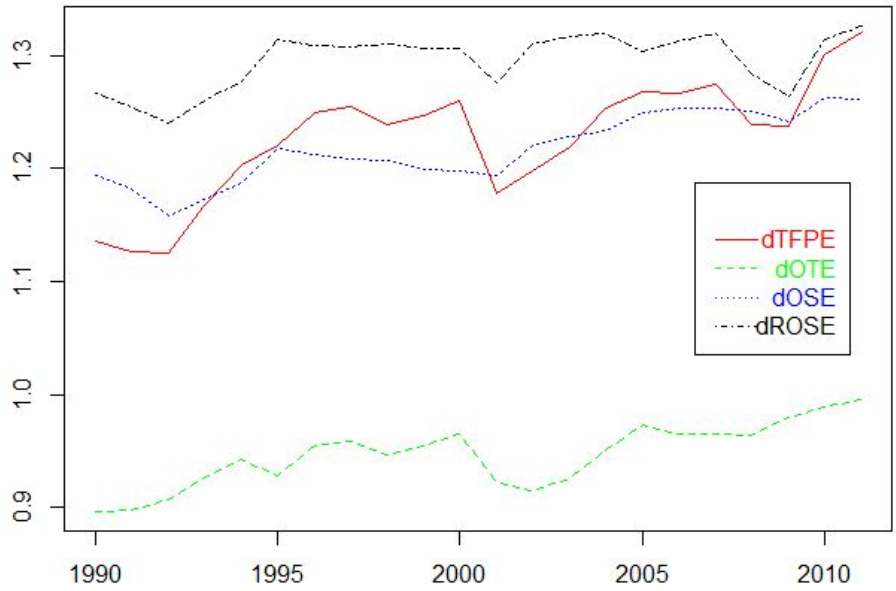

Figure 7.15: Changes in Output-Oriented Färe-Primont Fixed Basis PTFPE Components

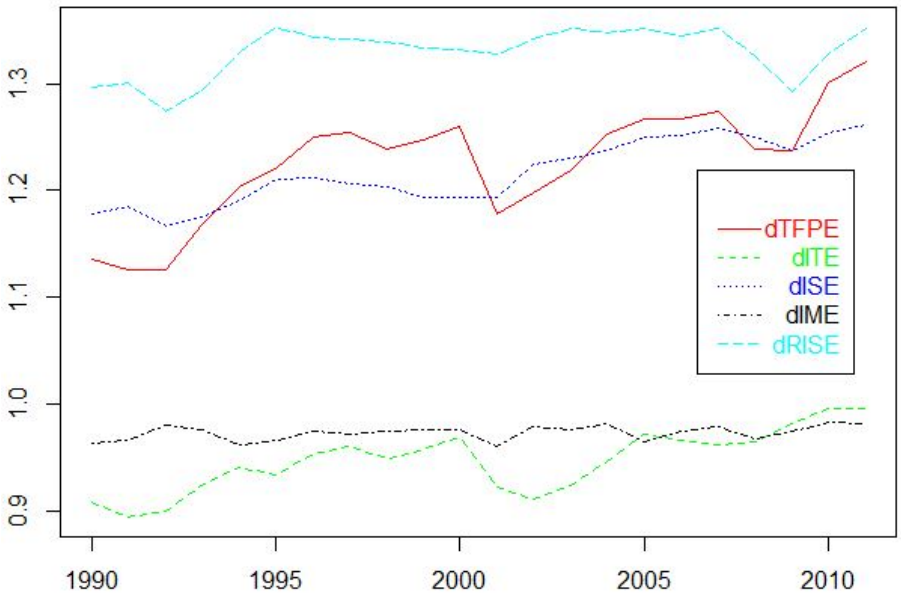

Figure 7.16: Changes in Input-Oriented Färe-Primont Fixed Basis PTFPE Components

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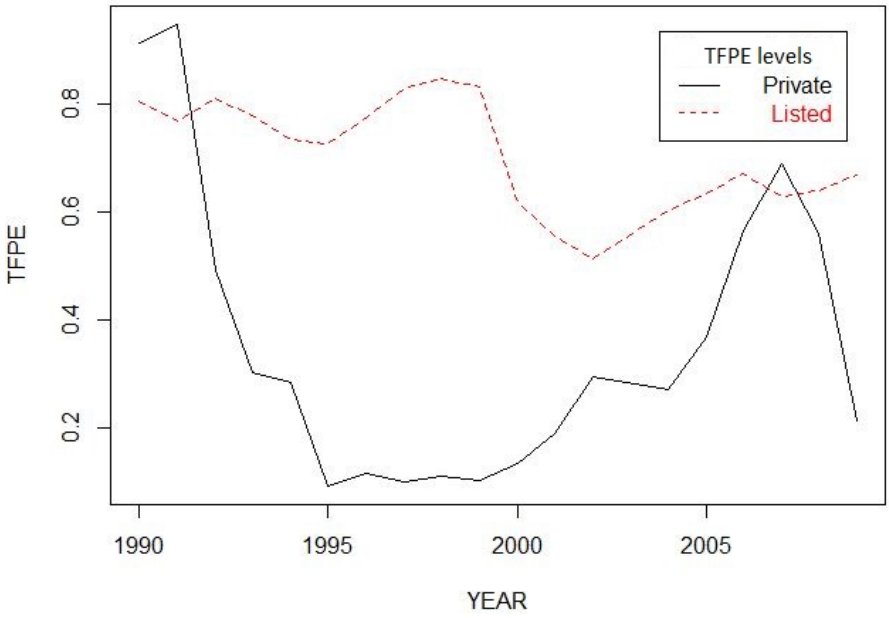

Figure 7.17: HMTFP Efficiency Levels for Listed and Unlisted Carriers

plete measures of HMTFP, FPTFP^{Fb} and FPTFP^{Vb} respectively. Tables 7.15, 7.16 and 7.17 focus on oriented measures of efficiency components. Each table reports estimates including the coefficients, the standard error, the significant levels for the variable, the *P.value* of the model and adjusted R^2. The number on the second line between brackets is the standard error. In addition, it contains a FFC Model free of TFP to assess the relative information content of TFP and TFPE components.

We note that Tables 7.15, 7.16 and 7.17 do not report estimates for changes in output mix efficiency (OME) nor changes in output scale mix efficiency (OSME). Since we have specified a single output production possibility set, OME equals one. Hence, the OSME equals the output residual scale efficiency (ROSE) as provided by the following relation:

$$OSME = OME \times ROSE \tag{7.6}$$

Consequently, 3 output-oriented and 5 input-oriented TFPE components are reported.

It is of important to note that the interpretation of HMTFP and FPTFP^{Vb} must differ from FPTFP^{Fb}. Changes in HMTFP and FPTFP^{Vb} are equivalent with the variation of the productivity of the firm relative to the variation of productivity of the benchmark of best practices. In contrast, variation of FPTFP^{Fb} is based on the productivity of Southwest Airlines in 1990. Regarding the evolution of the sector, most of the FPTFP^{Fb} computations rely on a past technology. Hence, the variation in FPTFP^{Fb} corresponds with the TFP reduction required to achieve the productivity of Southwest Airlines in 1990. The relation between FPTFP^{Fb} and stock returns provided by regressions must be then reversed.

We observe that HMTFP and FPTFP^{Fb} are significantly related to the stock return, while FPTFP^{Vb} is not. Regarding TFP components, HMTFP and FPTFP^{Vb} have sim-

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ilar pattern. In both cases TFPE and its components are negatively related to stock returns, while other components are positively related. Indeed, changes in TFP, changes in aggregated output and technological changes are positively related to stock returns. In contrast, $FPTFP^{Fb}$ is negatively related to stock returns. The negative relation between TFPE and expected stock returns holds for TFPE components too for all indices as reported in Tables 7.15, 7.16 and 7.17.

Except in the $FPTFP^{Fb}$, technological change is the most relevant component to forecast stock returns. Hicks-Moorsteen and Färe-Primont^{Vb} technological changes explain 8.3% and 2% of the total variance after taking into account market factors and the momentum effect respectively. This result is consistent with the analysis of TFP decomposition that establishes that technological changes were the main driver of TFP changes. TFPEfficiency is the second best information to forecast stock return. HMTFPE is the most relevant with an increase by +6.1% of the unexplained variance. Nevertheless, it is a bit surprising to observe that the TFP that results from the product of technological change and efficiency is less relevant than individual components. Taking into account the explanatory power of the TFP and its components, the best index for returns forecast is the Hicks-Moorsteen.

7.4 Discussion

7.4.1 Relevance of Non-Financial Information Provided by Indices

This chapter is the first contribution that tests Hicks-Moorsteen and Färe-Primont in the airline industry. In addition, this is the first contribution at investigating the explanatory power of HMTFP and FPTFP components in expected stock returns. By linking TFP components with stock returns, we provide evidence of the ability of indices at fairly reporting operating performance. Indeed, this confirms that TFP and its components are not artificial, but correspond to real operating changes integrated into investors' judgments. Likewise, consistently with the analysis of the sector and with the TFP decompositions, regressions results confirm that technological change is the most relevant factor to explain firms' performance. Strictly speaking, technological change reports the evolution of the best feasible productivity when the DMU is overall efficient that is to say optimal in techniques and scale of operations. Since this best performance is inferred from the sample, technological change reflects variations in production conditions. These changes may result from industry specific events, as well as the terrorist attack of 2001, or from the correlation of airline activity with changes in macroeconomic aggregates.

Nevertheless, it is important to note that the information conveyed by technological change differs from the relation of the specific stock returns with the industry portfolio. An industry portfolio based on SIC-membership reports a more accurate relation of market factors with market factors, but does not convey information about the industry attributes. In contrast, technological change provides information about industry attributes by individualizing the changes in production conditions at the firm level.

The second important result that confirms the ability of indices to provide relevant non-financial information centered on productivity for the analysis of stock returns is the strong significance of scale components. Again, in line with the literature about the US

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Table 7.12: OLS Regressions Results of Changes in HMTFP Components

	Dependent variable:						
	ER						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mkt.RF	-0.021^{***}	-0.024^{***}	-0.023^{***}	-0.022^{***}	-0.022^{***}	-0.024^{***}	-0.021^{***}
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB	0.047^{***}	0.046^{***}	0.047^{***}	0.047^{***}	0.048^{***}	0.050^{***}	0.046^{***}
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.013)
HML	-0.031^{***}	-0.031^{***}	-0.031^{***}	-0.031^{***}	-0.029^{***}	-0.031^{***}	-0.030^{***}
	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)
UMD	-0.049^{***}	-0.052^{***}	-0.051^{***}	-0.047^{***}	-0.044^{***}	-0.043^{***}	-0.044^{***}
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
dQ		1.917^{**}					
		(0.807)					
dX			1.167				
			(0.940)				
dTFP				5.236^{***}			
				(1.780)			
dTFPE					-2.770^{***}		
					(0.558)		
dTech						6.021^{***}	
						(1.024)	
dRME							-2.123^{***}
							(0.489)
Constant	-2.632^{***}	-4.600^{***}	-3.804^{***}	-7.997^{***}	0.001	-8.933^{***}	-0.623
	(0.145)	(0.841)	(0.955)	(1.829)	(0.544)	(1.069)	(0.484)
Observations	271	271	271	271	269	260	271
R^2	0.315	0.330	0.319	0.337	0.376	0.400	0.361
Adjusted R^2	0.305	0.317	0.306	0.324	0.364	0.388	0.349
Residual Std. Error	$1.744(df = 266)$	$1.729(df = 265)$	$1.742(df = 265)$	$1.720(df = 265)$	$1.673(df = 263)$	$1.612(df = 254)$	$1.688(df = 265)$
F statistic	$30.623^{***}(df = 4; 266)$	$26.054^{***}(df = 5; 265)$	$24.857^{***}(df = 5; 265)$	$26.935^{***}(df = 5; 265)$	$31.680^{***}(df = 5; 263)$	$33.800^{***}(df = 5; 254)$	$29.912^{***}(df = 5; 265)$

Note: *p<0.1; **p<0.05; ***p<0.01

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Table 7.13: OLS Regressions Results of Changes in FPTFP Components with Variable Basis

	Dependent variable:						
	ER						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mkt.RF	-0.022^{***}	-0.022^{***}	-0.022^{***}	-0.022^{***}	-0.027^{***}	-0.030^{***}	-0.023^{***}
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)
SMB	0.049^{***}	0.047^{***}	0.049^{***}	0.047^{***}	0.048^{***}	0.055^{***}	0.049^{***}
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
HML	-0.029^{***}	-0.025^{**}	-0.028^{***}	-0.030^{***}	-0.035^{***}	-0.037^{***}	-0.031^{***}
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
UMD	-0.048^{***}	-0.046^{***}	-0.047^{***}	-0.053^{***}	-0.057^{***}	-0.044^{***}	-0.051^{***}
	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
dQ		-1.874^{*}					
		(0.993)					
dX			-0.388				
			(0.809)				
dTFP				-1.458			
				(1.134)			
dTFPE					-3.567^{***}		
					(1.255)		
dTech						8.421^{***}	
						(2.864)	
dRME							-4.120^{**}
							(1.834)
Constant	-2.615^{***}	-0.698	-2.225^{***}	-1.100	1.098	-11.008^{***}	1.545
	(0.145)	(1.026)	(0.824)	(1.187)	(1.314)	(2.858)	(1.858)
Observations	268	268	268	268	268	268	268
R^2	0.318	0.327	0.318	0.322	0.338	0.340	0.331
Adjusted R^2	0.307	0.314	0.305	0.309	0.326	0.327	0.318
Residual Std. Error	$1.726(df = 263)$	$1.718(df = 262)$	$1.729(df = 262)$	$1.724(df = 262)$	$1.703(df = 262)$	$1.701(df = 262)$	$1.713(df = 262)$
F statistic	$30.619^{***}(df = 4; 263)$	$25.446^{***}(df = 5; 262)$	$24.470^{***}(df = 5; 262)$	$24.887^{***}(df = 5; 262)$	$26.771^{***}(df = 5; 262)$	$26.936^{***}(df = 5; 262)$	$25.881^{***}(df = 5; 262)$

Note: *p<0.1; **p<0.05; ***p<0.01

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Table 7.14: OLS Regressions Results of Changes in FPTFP Components with Fixed Basis

	Dependent variable:						
	ER						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mkt.RF	-0.021^{***}	-0.021^{***}	-0.021^{***}	-0.018^{**}	-0.021^{***}	-0.021^{***}	-0.021^{***}
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB	0.047^{***}	0.047^{***}	0.047^{***}	0.053^{***}	0.047^{***}	0.051^{***}	0.047^{***}
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
HML	-0.031^{***}	-0.031^{***}	-0.030^{***}	-0.026^{***}	-0.030^{***}	-0.029^{***}	-0.030^{***}
	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)
UMD	-0.049^{***}	-0.049^{***}	-0.048^{***}	-0.046^{***}	-0.048^{***}	-0.048^{***}	-0.048^{***}
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
dQ		0.002					
		(0.023)					
dX			-0.013				
			(0.029)				
dTFP				3.123^{***}			
				(0.765)			
dTFPE					2.414^{***}		
					(0.765)		
dTech						0.975	
						(1.243)	
dRME							-1.136
							(1.600)
Constant	-2.632^{***}	-2.645^{***}	-2.572^{***}	-6.578^{***}	-3.623^{***}	-5.644^{***}	-1.436
	(0.145)	(0.198)	(0.196)	(0.977)	(1.272)	(0.965)	(1.692)
Observations	271	271	271	271	271	271	271
R^2	0.315	0.315	0.316	0.356	0.317	0.340	0.317
Adjusted R^2	0.305	0.302	0.303	0.344	0.304	0.328	0.304
Residual Std. Error	$1.744(df = 266)$	$1.747(df = 265)$	$1.747(df = 265)$	$1.695(df = 265)$	$1.745(df = 265)$	$1.715(df = 265)$	$1.746(df = 265)$
F statistic	$30.623^{***}(df = 4; 266)$	$24.409^{***}(df = 5; 265)$	$24.468^{***}(df = 5; 265)$	$29.269^{***}(df = 5; 265)$	$24.586^{***}(df = 5; 265)$	$27.316^{***}(df = 5; 265)$	$24.554^{***}(df = 5; 265)$
Note:							*p<0.1; **p<0.05; ***p<0.01

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Table 7.15: OLS Regressions Results of Changes in HMTFPE components

	Dependent variable:								
	ER								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mkt.RF	-0.021^{***}	-0.022^{***}	-0.022^{***}	-0.022^{***}	-0.022^{***}	-0.023^{***}	-0.021^{***}	-0.022^{***}	-0.022^{***}
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB	0.047^{***}	0.046^{***}	0.048^{***}	0.047^{***}	0.046^{***}	0.048^{***}	0.047^{***}	0.047^{***}	0.047^{***}
	(0.013)	(0.013)	(0.013)	(0.012)	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)
HML	-0.031^{***}	-0.031^{***}	-0.031^{***}	-0.030^{***}	-0.031^{***}	-0.032^{***}	-0.031^{***}	-0.030^{***}	-0.030^{***}
	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)
UMD	-0.049^{***}	-0.049^{***}	-0.053^{***}	-0.045^{***}	-0.049^{***}	-0.053^{***}	-0.046^{***}	-0.046^{***}	-0.045^{***}
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
dOTE		-1.256							
		(2.780)							
dOSE			-6.067^{***}						
			(2.234)						
dROSE				-2.238^{***}					
				(0.470)					
dITE					-1.003				
					(3.109)				
dISE						-5.859^{***}			
						(2.157)			
dIME							-2.977^{*}		
							(1.688)		
dRISE								-1.876^{***}	
								(0.467)	
dISME									-2.238^{***}
									(0.469)
Constant	-2.632^{***}	-1.365	3.502	-0.493	-1.622	3.305	0.292	-0.806^{*}	-0.488
	(0.145)	(2.809)	(2.264)	(0.470)	(3.133)	(2.191)	(1.664)	(0.476)	(0.470)
Observations	271	271	271	271	271	271	271	271	271
R^2	0.315	0.316	0.334	0.369	0.316	0.334	0.323	0.355	0.369
Adjusted R^2	0.305	0.303	0.321	0.357	0.303	0.321	0.310	0.342	0.358
Residual Std. Error	$1.744(df = 266)$	$1.747(df = 265)$	$1.724(df = 265)$	$1.677(df = 265)$	$1.747(df = 265)$	$1.724(df = 265)$	$1.737(df = 265)$	$1.697(df = 265)$	$1.677(df = 265)$
F statistic	$30.623^{***}(df = 4; 266)$	$24.466^{***}(df = 5; 265)$	$26.560^{***}(df = 5; 265)$	$31.030^{***}(df = 5; 265)$	$24.437^{***}(df = 5; 265)$	$26.562^{***}(df = 5; 265)$	$25.315^{***}(df = 5; 265)$	$29.124^{***}(df = 5; 265)$	$31.060^{***}(df = 5; 265)$
Note:	*p<0.1; **p<0.05; ***p<0.01								

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Table 7.16: OLS Regressions Results of Changes in FPTFPE Components with Fixed Basis

	Dependent variable:								
	ER								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mkt.RF	−0.021***	−0.019***	−0.019**	−0.021***	−0.020***	−0.019**	−0.022***	−0.021***	−0.021***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB	0.047***	0.053***	0.049***	0.047***	0.053***	0.049***	0.046***	0.047***	0.047***
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
HML	−0.031***	−0.028***	−0.028***	−0.030***	−0.028***	−0.028***	−0.031***	−0.031***	−0.031***
	(0.010)	(0.009)	(0.010)	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)	(0.010)
UMD	−0.049***	−0.046***	−0.047***	−0.049***	−0.046***	−0.047***	−0.049***	−0.049***	−0.049***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
dOTE		7.075***							
		(1.825)							
dOSE			3.837***						
			(1.417)						
dROSE				1.143					
				(0.895)					
dITE					6.544***				
					(1.726)				
dISE						3.737**			
						(1.442)			
dIME							4.384		
							(2.893)		
dRISE								0.504	
								(0.945)	
dISME									1.033
									(0.893)
Constant	−2.632***	−9.413***	−7.374***	−4.120***	−8.909***	−7.246***	−6.902**	−3.306***	−3.976***
	(0.145)	(1.755)	(1.756)	(1.174)	(1.661)	(1.786)	(2.821)	(1.271)	(1.171)
Observations	271	271	271	271	271	271	271	271	271
R^2	0.315	0.352	0.334	0.319	0.351	0.332	0.321	0.316	0.319
Adjusted R^2	0.305	0.340	0.321	0.307	0.338	0.320	0.308	0.303	0.306
Residual Std. Error	1.744($df = 266$)	1.700($df = 265$)	1.724($df = 265$)	1.742($df = 265$)	1.702($df = 265$)	1.726($df = 265$)	1.740($df = 265$)	1.747($df = 265$)	1.743($df = 265$)
F statistic	30.623***($df = 4; 266$)	28.795***($df = 5; 265$)	26.549***($df = 5; 265$)	24.883***($df = 5; 265$)	28.605***($df = 5; 265$)	26.369***($df = 5; 265$)	25.078***($df = 5; 265$)	24.490***($df = 5; 265$)	24.797***($df = 5; 265$)
Note:	*p<0.1; **p<0.05; ***p<0.01								

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Table 7.17: OLS Regressions Results of changes in Variable Basis FPTFPE Components

	Dependent variable:								
	ER								
	(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)	(10)
Mkt.RF	-0.022^{***}	-0.024^{***}	-0.022^{***}	-0.024^{***}	-0.023^{***}	-0.023^{***}	-0.023^{***}	-0.024^{***}	-0.025^{***}
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB	0.049^{***}	0.048^{***}	0.049^{***}	0.049^{***}	0.048^{***}	0.049^{***}	0.049^{***}	0.048^{***}	0.048^{***}
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
HML	-0.029^{***}	-0.032^{***}	-0.030^{***}	-0.032^{***}	-0.032^{***}	-0.030^{***}	-0.030^{***}	-0.033^{***}	-0.032^{***}
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
UMD	-0.048^{***}	-0.051^{***}	-0.050^{***}	-0.054^{***}	-0.051^{***}	-0.050^{***}	-0.050^{***}	-0.054^{***}	-0.054^{***}
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)
dOTE		-3.850							
		(2.748)							
dOSE			-1.176						
			(2.098)						
dROSE				-3.264^{**}					
				(1.416)					
dITE					-3.966				
					(3.174)				
dISE						-1.673			
						(2.071)			
dIME							-3.192^{*}		
							(1.740)		
dRISE								-4.077^{*}	
								(2.304)	
dISME									-3.266^{**}
									(1.352)
Constant	-2.615^{***}	1.280	-1.417	0.740	1.387	-0.906	0.606	1.548	0.753
	(0.145)	(2.784)	(2.142)	(1.462)	(3.206)	(2.119)	(1.762)	(2.357)	(1.401)
Observations	268	268	268	268	268	268	268	268	268
R^2	0.318	0.323	0.319	0.331	0.322	0.319	0.326	0.326	0.333
Adjusted R^2	0.307	0.310	0.306	0.319	0.309	0.306	0.314	0.313	0.320
Residual Std. Error	$1.726(df = 263)$	$1.723(df = 262)$	$1.728(df = 262)$	$1.712(df = 262)$	$1.724(df = 262)$	$1.727(df = 262)$	$1.718(df = 262)$	$1.719(df = 262)$	$1.710(df = 262)$
F statistic	$30.619^{***}(df = 4; 263)$	$24.978^{***}(df = 5; 262)$	$24.494^{***}(df = 5; 262)$	$25.959^{***}(df = 5; 262)$	$24.860^{***}(df = 5; 262)$	$24.594^{***}(df = 5; 262)$	$25.388^{***}(df = 5; 262)$	$25.320^{***}(df = 5; 262)$	$26.113^{***}(df = 5; 262)$

Note: *p<0.1; **p<0.05; ***p<0.01

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airline industry and the TFP analysis, changes in scale components are the most relevant factors for stock returns explanation. This is consistent with the business model of carriers: hub and spoke configuration permits the expansion of inter-airports connections and the implantation of local market power. Indeed, the more the carriers obtain gates in an airport, the greater their ability at negotiating access to new routes from this airport and at preventing competitors to enter their market. In addition, the development in a hub and spoke system implies the exploitation of economies of densities related to the maximization of network utilization. Returns to density consists of minimizing the unit fixed costs by maximizing the load factor. Load factor is intrinsically related to the number of point served, that is to say the variety of trips proposed to customers. This configuration is considered by observers as a major process innovation in the airline industry that permits considerable productivity gains since deregulation.

Nevertheless, it is surprising to note that the TFP, which is a synthesis of all components are less relevant than TFPE and technological change. Since technological change and TFPE are linked with returns in opposite directions; we guess that both information neutralize one another. Finally, these results confirm the relevance of fixed basis TFP determination. The significance of the FPTFP^{Fb} components based on differentiated carriers confirms it provides a different, but relevant information.

7.4.2 Relation between TFPE and Technological Changes with Expected Stock Returns

This study is mainly concerned with the ability of indices at differentiating the sources of productive performance resulting from exogenous factors from those attributable to management skills in line with the CAPM paradigm. Regarding the TFP decomposition provided by the Hicks-Moorsteen and the Färe-Primont indices, the information provided must be sorted in two kinds of content. On the one hand, changes in aggregated output, changes in aggregated input, changes in TFP and technological changes are supposed to be affected by exogenous factors on the performance of the firm. On the other hand, TFPE and its component is likely to reflect pure managerial efficiency. Hence, it is expected these two sets of information would provide different relations. Regression results for HMTFP and FPTFP^{Vb} in Tables 7.12, 7.13, 7.15 and 7.17 confirm this hypothesis. In both indices, the statistically significant TFP variable which is positively related to stock returns belongs to the first category of information while, the variable negatively related are efficiency measures. If the expected pattern is confirmed, the results are surprising. Indeed, the fact that improvements in efficiency leads to less returns is a priori counter intuitive. In addition, this result diverges from most of the tests provided by the Malmquist decompositions. Several explanations can be provided.

The first explanation is that investors perform contrarian portfolio strategy based on efficiency information. A contrarian strategy consists of buying losers and selling winners. This explanation is at odds with the empirical literature on the relation between stock returns and efficiency. Most of the contributions refer to a relative strength portfolio strategy which consists of buying winners and short selling losers (Thore (1993); Ederisinghe and Zhang (2007, 2008, 2010); Alam and Sickles (1998)). Alam and Sickles (1998) perform such portfolio strategy in the US airline industry over the period 1970-1991. This trading strategy based on changes in technical efficiency exhibits an abnormal returns of +18%. Regarding the construction of the input/output aggregated functions, the meas-

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ure of technical efficiency provided by Alam and Sickles (1998) corresponds more with our measure of aggregated output. The latter is positively related to stock return. Unfortunately, the data required to provide a Hicks-Moorsteen decomposition for the period 1970-1991 are not available and the measure of technical efficiency provided in Alam and Sickles (1998) with DEA differs from Hicks-Moorsteen.

In contrast, our results are consistent with Nguyen and Swanson (2009). Their results indicate that a portfolio composed of highly inefficient firms significantly outperforms the portfolio composed of highly efficient peers. These results hold even after adjusting for firm characteristics and risk factors. It suggests that positive changes in firms efficiency signal persistent improvement in the organization of the production of the firm. Hence, firms becoming more efficient are becoming less risky too. Thus a lower premium is required. Figure 7.18 supports this hypothesis. Figure 7.18 depicts the evolution of the average HMTFPE level of the 30% best and 30% worst carriers during five years after the formation of the pool in t.

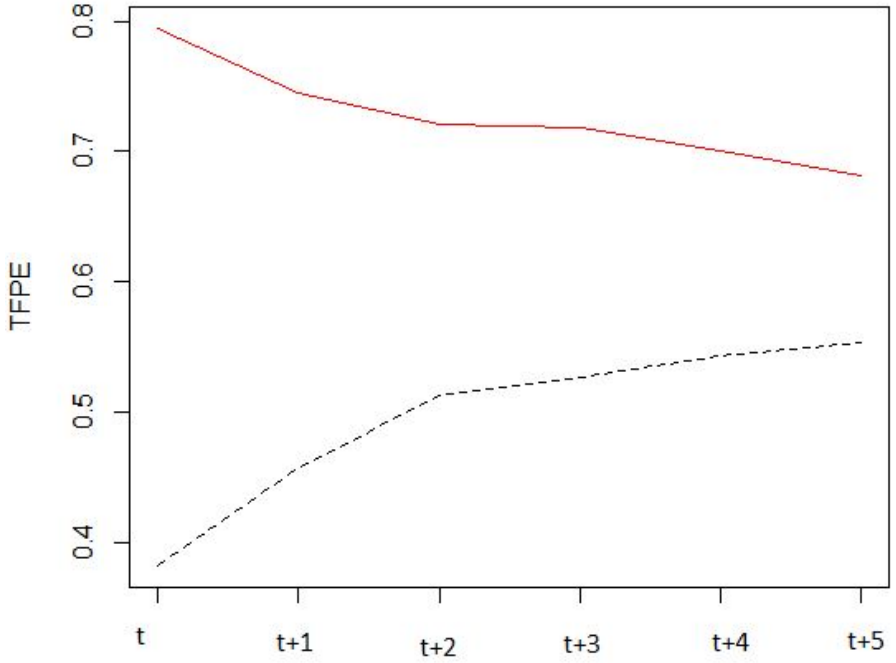

Figure 7.18: Year to Year Average TFPE Level

We observe that pools tend to converge over time. This means that improvements in TFPE are made over several years and it confirms the persistence of efficiency as shown by Kwan and Eisenbeis (1997) and Nguyen and Swanson (2009) for the capital budgeting efficiency of listed firms on NASDAQ, NYSE and AMEX. These authors provide evidence that the highly inefficient firms significantly outperform most efficient units. This pattern may reflect the regression to the mean effect taken into account by investors (Blume (1971) and Blume (1975)). Moreover, this is consistent with the nature of the production constraints in the airline industry. Switching from a production organization to another involves opportunity costs. This opportunity cost is particularly high in a sector featured by high fixed costs as the airline industry. Hence, it is no surprise if carriers do not modify their production combination to adjust for technological changes and accept to sacrifice efficiencies for the next few periods. This plausible explanation still deserves additional tests to be confirmed.

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Nevertheless, additional evidence confirms our hypothesis. Table 7.18 reports the test of the relation between the level of HMTFPE and of HM technology components with both market beta and idiosyncratic risk. Each dependent variable is constructed with CAPM based on the daily return. Results confirm a negative relation between systematic risk factors and TFPE. This means that more efficient firms are less exposed to systematic risk. Hence, their required rate of returns must decrease proportionally. In contrast, the portion of TFP explained by the frontier technology at the MPSS is a determinant of risk and increase the hurdle rate of the firm.

Table 7.18: Relation of Changes in HMTFPE and Technological Changes with Specific and Systematic Risk Computed with CAPM

	Dependent variable:			
	ALPHA	BETA	ALPHA	BETA
	(1)	(2)	(3)	(4)
Tech	-0.004^{***}	0.003^{***}		
	(0.001)	(0.001)		
TFPE			0.007^{***}	-0.013^{***}
			(0.002)	(0.003)
Constant	0.004^{***}	0.007^{***}	-0.006^{***}	0.020^{***}
	(0.001)	(0.001)	(0.002)	(0.002)
Observations	264	264	264	264
R^2	0.096	0.036	0.031	0.058
Adjusted R^2	0.093	0.032	0.027	0.055
Residual Std. Error (df = 262)	0.007	0.010	0.007	0.010
F statistic (df = 1; 262)	27.970^{***}	9.834^{***}	8.364^{***}	16.267^{***}

Note: *p<0.1; **p<0.05; ***p<0.01

However, the possibility of a data snooping effect cannot be rejected. In line with Jegadeesh and Titman (1993) and Jegadeesh and Titman (2001) the post-holding performance twelve months after the portfolio formation based on relative strength strategy reverses and exhibit negative returns. The choice of the time window for analysis may be a wrong selection. Nevertheless, contributions analyzing the time pattern of returns of relative strength and contrarian strategies focus on cross-sectors or cross-countries analysis. The extrapolation of this explanation to a single sector is not obvious. Moreover, we observe that the relation detailed for efficiency measures in Table 7.12 also holds for the one year lagged stock returns (see Appendix Table C.6).

Finally, it is important to note that the relation of TFP components has not been clearly established. Lin (2010), who provides a DEA based Malmquist decomposition in the banking sector of 9 Eastern-Asia countries, finds contradictory evidence. Indeed, the significance differs regarding the country and the time period of analysis. In most cases, she finds a negative relation between pure technical efficiency and scale efficiency with stock return. The information conveyed by TFPE differs given the underlying condition of exploitation of the firm. Then the relation may be altered. In the highly concentrated airline industry where the protection of the local market power are crucial to make the hub and spoke organization profitable, TFPE should not only reflect improvement in pro-

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ductivity. This may cover underlying realities such as the evolution of the market power of the carriers. As Durnev, Morck, and Yeung (2004) note about the relation between capital budgeting efficiency and firms-specific stock returns variation, the presence of the latent common factors related to firms-specific variation and TFPE may cause spurious relation. They write: "*Latent common factors related to both capital budgeting quality and firm-specific returns variation might cause a spurious relationship between the two. Industry concentration again illustrates. Concentrated industries, in addition to having better-quality capital budgeting decisions, might also contain homogenous firms whose fundamentals (and therefore stock returns) exhibit relatively little firm-specific variation. A negative relationship between capital budgeting quality and firm-specific returns variation might simply reflect the effects of industry concentration on both variables. Several such latent common factors could affect capital budgeting quality and fundamentals variation.* " However, even after controlling for changes in market concentration or in market shares, the negative relation between TFPE and expected stock returns still holds (see Appendix C.4.).

Conclusions

This chapter deals with the relation between the decomposition of the performance of stocks provided by the CAPM paradigm with the decomposition of total factor productivity (TFP) done by multilateral indices. The latter approach decomposes TFP changes in technological changes, related to changes in production conditions, and changes in the firms efficiency attributable to managerial practices. A productivity mainly driven by efficiency means the manager succeeds in its monitoring activity and benchmarking activity, that is to say its ability at forecasting and outperforming industry changes. The decomposition is done with three benchmarking techniques: the Hicks-Moorsteen based on a variable basis and the Färe-Primont based on variable and fixed bases. The analysis of the performance of stock is performed with the Fama-French-Carhart Model.

Based on a sample of US airline major carriers over the period 1990-2011, results reveal a positive relation of productivity and technical changes with stock returns and a negative relation with efficiency components. Further tests indicate that the negative relation of changes in efficiency with stock returns reflect the decrease in firm's hurdle rate. Indeed, efficiency change is negatively correlated with systematic risk and positively related with idiosyncratic components. The relation reverses for the technological changes. These results are consistent with Nguyen and Swanson (2009) and Lin (2010). The relation holds even after controlling for the presence of common latent factor. Nevertheless, the focus on a single industry sector whereas financial models rely on cross-sector analysis makes the checking difficult. Hence, the potential presence of a data snooping bias cannot be firmly rejected.

The chapter is also the first contribution at providing a Hicks-Moorsteen and a Färe-Primont analysis of the TFP of the US airline industry. In line with the literature, performance of carriers has been mainly impacted by exogenous events captured by the technological change. In addition, TFP analysis confirms that the efficiency of the US air carriers have been mainly driven by scale components in line with their network configuration.

It is important to note that this contribution is one of the only five studies that provide

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a TFP decomposition and the first that focuses on a complete TFP measure. Since the meaning of the TFP and its components differs according to the underlying production conditions such as the market concentration; the investigation of the relation between efficiency measures with stock returns deserves cross-checking in other sectors.

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General Conclusions

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General Conclusions

The purpose of this dissertation is to describe the interaction between technical efficiency, as measured by non-parametric frontiers, and expected stock returns. Technical efficiency and stock returns rely on two distinct types of models of the firm and its environment.

Technical efficiency approaches the firm as a collection of input and output. It measures the extent to which the firm is able to maximize its production potential with respect to the technical constraints. If the analysis of the technical constraints is the work of the engineers, then Data Envelopment Analysis (DEA) models permit their formalizations and the derivation of the production potential of the firm from the observed practices of the comparable DMUs. Regarding its construction, technical efficiency contains information about the productive performance of the firm and its competitors. In addition, the modeling of the firm implied by technical efficiency is joined with its computational method. The formalization of the technical constraints and the nature of the technical efficiency evaluated (e.g. pure technical efficiency, scale efficiency or mix efficiency) depend on the specification of the DEA model. Based on a deterministic paradigm, DEA models do not maintain any strong assumptions about the environment of the firm, or on the structure of the production technology.

By contrast, the expected stock return approaches the firm as a collection of assets producing stream of cash-flows to shareholders. It measures the ability of the firm at maximizing the value potential of assets. The hurdle potential is generally inferred from the expected relation between the returns of the firm and the changes in industry and common market factors. These common factors represent measures of risks that cannot be diversified by investors. The realized performance of the firm is assessed by the amount of cash-flows per unit of risk incurred by the activity. The greater these cash-flows per unit of risk are, the greater the ability of the firm at outperforming despite adverse market conditions. Again, the modeling of the firm and its environment implied by the measurement of the expected return is joined with the estimation method and with the Efficient Market Hypothesis. The factor analysis, investigated in this dissertation, considers that the firm evolves in an environment dominated by stochastic processes. Hence, the decision of the firm is always, to a certain extent, assumed to be contingent.

Despite differences in the level of analysis and the paradigms involved, technical efficiency and stock returns are complementary measures. While the abnormal return - that is to say, the difference between the expected and the realized return - measures the ability of the management at picking investment projects efficiency, technical efficiency focuses on the managerial ability at implementing these investment projects. In addition, both recognize that the performance of the firm ensues from the exposure to common exogenous factors and from the management strategy specific to each firm. They propose in both cases a decomposition of the performance in pure managerial effects and

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exogenous effects.

If the interaction between technical efficiency and stock returns has earlier been detailed in general equilibrium theory, the empirical evidence suggests a more complex relation than the one detailed in financial equilibrium models. The survey in Chapter 4, based on the review of 67 empirical contributions about the relation between frontiers based efficiency measures and stockholder value creation, provides the following conclusions:

- The empirical evidence confirms general equilibrium theory. Expected stock return contributes to drive the internal allocation of resources. In addition, the improvements in profitability associated with the changes in efficiency are integrated into stock prices. Moreover, the level of efficiency, which reflects the competitive advantage of the firm, is also strongly related to stock prices.
- Tests on the relation between lagged efficiency measures and stock returns reveal that the relation is persistent over time.
- Contributions provide also evidence that the sign of the relation between efficiency and stock returns may change across industries, countries and given the time window. Indeed, some studies demonstrate that the efficiency can be negatively related to stock returns.
- Value relevance analysis shows that efficiency information beats accounting ratios in the explanation of stock returns or valuation.
- There is evidence that listed firms are more efficient than private companies. This tends to confirm the role of control by the stock market.
- DEA, which is the most often employed method in the literature, seems more appropriate to predict stock returns than stochastic frontier analysis.

In the light of these results and based on the typologies of the nature of the information set provided by the Efficient Market Hypothesis, the study defends that technical efficiency contains two kinds of information. On the one hand, technical efficiency mirrors information about the exposure of the firm to the systematic risks measured by assets pricing models. On the other hand, technical efficiency conveys information about the firm-specific performance captured by the idiosyncratic risk component. Regarding the EMH of Fama (1970) and the works of Roll (1988), it implies that technical efficiency contains public and private information. In addition, the study investigates the advantages of using technical efficiency in the financial analysis when the accounting is incomplete to report the dynamic and troublesome evolution of the industry.

This investigation analyses these issues through an application on the U.S. airlines industry. The unbalanced sample constructed consists in quarterly production and financial data about 28 major air carriers over the period 1990-2012. Production data are extracted from the official reports of the U.S. Department of Transportation disclosed by the Bureau of Transportation Statistics. They provide technical information about the carriers such as the quantities employed and the characteristics of the equipments. Non-consolidated financial statements are also provided by the Bureau of Transportation Statistics. By contrast, the consolidated financial statements and the time series of stock

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prices are extracted from Bloomberg. The premia employed to perform multi-factors asset pricing models are taken from the Kenneth French website.

The results provided by the applications constitute contributions for the financial theory and the frontier framework as well. The first part of the results focuses on the value relevance of non-financial information, especially technical efficiency and related technical items, to explain stock valuation. The second part of the analysis is concerned with the relation between each TFP component and stock returns. The decomposition provided in this second part contributes to the development of the frontier framework.

The first part of the analysis concerns the relative value relevance of the level of technical efficiency with respect to accounting information. Results indicate that the level of technical efficiency and others technical information such as average stage length and engines characteristics contribute to the explanation of stock valuation. Even though the net income and the accounting stockholder value explain the most part of the stock price, technical efficiency captures information not included in accounting items. Moreover, technical efficiency is more incrementally value relevant than accounting information. This confirms Amir and Lev (1996) and Riley, Pearson, and Trompeter (2003). These results hold for true for the convex DEA model with constant returns to scale and strong disposability, and for the stochastic analysis of the Battese and Coelli (1992) time varying efficiency frontier with a log-linear functional form.

The second part of the analysis focuses on the information conveyed by TFP. The analysis consists in the decomposition of the TFP with the Hicks-Moorsteen and the Färe-Primont productivity indices. Hicks-Moorsten and Färe-Primont are multiplicatively complete productivity indices. The completeness means that the productivity scores is a ratio of output-oriented to input-oriented distance functions. It contrasts with the Malmquist index which focuses only on one of these two orientations. The second advantage to using Hicks-Moorsteen or Färe-Primont is the unambiguous decomposition they provide contrasting with Malmquist which does not convey the same information given its specification. Hicks-Moorsteen and Färe-Primont differ in the choice of the basis to solve TFP. Hicks-Moorsteen measures TFP changes of a DMU over the adjacent periods. Färe-Primont measures TFP changes of the DMU with respect to the production combination of a specified DMU at a given point in time. The purpose of the Hicks-Moorsteen and Färe-Primont decomposition is to differentiate the portion of efficiency related to changes in production conditions associated with exogenous factors from the portion related to pure managerial efficiency.

The first set of results of this second part of the analysis concerns the TFP decomposition provided. This implies multiple contributions for frontier framework and the analysis of the U.S. airline industry:

- The investigation renews the analysis of the U.S. airline industry. Previous contributions focus on samples ending at the latest in 1991.
- The analysis provides the first Hicks-Moorsteen decomposition in the U.S. airline industry. The contribution is also the first at providing a Färe-Primont decomposition in the DEA paradigm.
- The decomposition provided by both indices confirms the literature and the diagnostics of the actors of the industry. Hence, we can affirm that the Hicks-Moorsteen and Färe-Primont report a reliable description of the drivers of the performance of the firm:

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- Results confirms that the exogenous shocks such the first Gulf War, the 11^{th} September terrorist attack, the SARS epidemic and the economic recessions are captured by the measure of technological change. In addition, this measure was the main driver of the TFP over the last twenty years.
- In line with the analysts, the scale efficiency, which captures underlying effects of the returns to density, was the main driver of the technical efficiency of the industry. Other components such as the mix efficiency are relevant for periods featured by excess capacities.
- Results confirm the ability of the fixed basis Färe-Primont index at differentiating the business model of carriers. Indeed, low-costs carriers, featured by a point-to-point network organization have TFP efficiency mainly driven by technical efficiency and mix efficiency. In contrast, legacy carriers structured into hub and spoke networks are more driven by scale efficiency.
- The comparison of low-costs carriers, especially Southwest Airlines, with legacy carriers reveals that the former are less productive. This result is consistent with the advantage conferred by their network organization. Nevertheless, the point-to-point organization of the low-costs carriers provides a more flexible cost structure. This advantage is a key element in the explanation of the success of low-costs carriers.

The second set of results is at the heart of our issue, that is to say, the relation between the TFP components and the stock returns. The expected result is a different relation between each factor of performance and stock returns. The relation is tested with a Fama-French-Carhart multi-factors Model. The results reported hold for Hicks-Moorsteen and Färe-Primont indices:

- The complete TFP is positively related to expected stock returns for Hicks-Moorsteen and Färe-Primont indices alike.
- The main drivers of the TFP, that is to say the technological changes and the residual scale efficiency changes, are also the most relevant variables to explain stock returns. In addition, these variables are more relevant than TFP although it is expected to encompass the whole information content.
- As expected, technological change and efficiency change exhibit different relations with stock returns. Results reveal that technological change is positively related to the expected stock returns while efficiency changes are negatively related. These results hold even after taking into account the evolution of the market shares and the changes in market concentration as measured with the Herfindhal-Hirschman index.
- Additional tests on the relations between TFP efficiency level and technological level with the portion of the variance of the returns explained by the systematic factors and the idiosyncratic component confirm this pattern. Technology is negatively related to firms-specific returns and positively related to systematic factors of risk. In contrast, level of TFP efficiency is positively related to firms-specific component of returns and negatively with systematic factors.

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- Finally, the analysis confirms the persistence of efficiency over time. Focusing on the 30% most efficient and the 30% least efficient during five consecutive years, we observe that the losers tend to constantly increase their efficiency scores, while the winners tend to decrease theirs. This result holds for the pattern of returns too. It ensues from this observation that investors perform contrarian portfolio strategy based on efficiency information.

Two main conclusions provided by these latter results confirm the thesis: First, the measures of efficiency convey public and private information associated with common market factors and firms-specific attributes respectively. The tests of the relation between each factor of risk, provided by the asset pricing model, and the level of TFP related to both technology and efficiency reinforce this interpretation. Consequently, it is expected that, given the underlying efficiency of the firm, the relation between efficiency and stock returns may be different. In addition, results a priori confirm that Hicks-Moorsteen and Färe-Primont indices provide a distinction of the sources of the performance in line with asset pricing models.

The second conclusion concerns the counter intuitive sign of the relation between TFP efficiency and stock returns. Regarding the persistence of efficiency over time and the latter tests, we guess that the negative relation between efficiency and stock returns reflects the reduction of the required rate of return. This reduction is itself related to the reduction in risk exposure of the firms provided by efficiency improvements. This interpretation is consistent with Nguyen and Swanson (2009).

It is important to be aware of some restrictions of our contributions concerning the relation between technical efficiency and stock returns. This dissertation constitutes an exploratory analysis and deserves to be triangulated with complementary approaches:

- The analysis of the technical efficiency requires the investigation of a specific sector. It is likely that the relation established in this dissertation would differ in another sector. Such evidence has been demonstrated by Lin (2010) through a cross-countries Malmquist decomposition of the banking industry. Given the TFP change is driven by pure efficiency change or technological change and given the degree of market concentration, the time pattern and the sign of the relation can differ. Results cannot be easily generalized.

- The relation is investigated under the assumption that firms seek to maximize their shareholder value. Likewise, we assume that the surplus of value related to the productivity gains are distributed to stockholders. Nevertheless, this is not necessarily the case in practice. Indeed, if the value surplus is captured by stakeholders, it is expected that the relation would differ or will not exist. Regarding the dramatic rise in fundamental cost drivers in the U.S. airlines industry and the recurrent negative net incomes, the value created by carriers has been mostly captured by stakeholders. Consequently, it is of interest to control the relation while taking into account the repartition of the value among stakeholders. Even though, studies about the relation between changes in X-efficiency and stock returns are supposed to catch both the surplus of value associated with productivity gains and with the repartition, it is of interest to deepen the analysis. We are currently investigating this issue by implementing the surplus account method with DEA. This method consists in controlling whether changes in the items of the income statement are related

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to variations of the productivity or changes in the repartition of the value among stakeholders.

- The next step of the analysis between technical efficiency and stock returns is concerned with the portfolio theory. It is of interest to test whether the resulting premium of a portfolio strategy based on the information about efficiency components would mirror the systematic risks exposure or is only related to firms-specific attributes. This issue raised by Daniel and Titman (1998) about the meaning of the Fama-French-Carhart factors has given raise to important theoretical debates. This framework will improve our understanding of the relation between efficiency and stock returns. Nevertheless, these approaches usually focus at the market index and not at the industry level.

- There is a limitation inherent to the computation of technical efficiency. DEA provides a static description of the efficiency. Regarding the technical constraints, it is likely that the DMUs cannot be efficient in a dynamic sense. The product life cycle illustrates this issue. When a firm launches a new product, it is generally not profitable during the first periods. It requires a sufficiently long period of time for the sales of the product on the market to reach its maturity. Static technical efficiency computed at two different points in this process would provide different scores, but it does not mean that the producer has taken suboptimal production decisions. Ideally, the measure of technical efficiency should be adapted to the investment cycle and the life cycle of products/services. It is likely that investors take this issue into account. Hence, the static efficiency score can be partially disconnected from the investors judgment. Similar issue is observable in the U.S. airline industry. Sometimes, to maintain its sphere of influence or to deter the entry of competitors in a hub, a carrier may have to operate on unprofitable routes. Even though such decisions can be rational, it is measured as inefficiencies.

- The previous argument can be extended to the investors decisions. The required rate of return, supposed to contribute to investment and production decisions, ensues from the combination of the information set with the investors preferences for risk and time. Consequently, the required rate of return is supposed to reflect the weighted average of investors preferences. Nevertheless, the derivation of these preferences and their implementations in asset pricing models face issues of tractability. The mean-variance approach, the framework of reference in this study, avoids this issue by the assuming generalized risk aversion, the quadratic utility function and the homogeneity of the investors expectations and time horizon. The CAPM relies on this unrealistic set of assumptions. Consequently, the interpretation results provided may be biased by the underlying structure of investors preferences. This bias is inherent to the CAPM based on the mean-variance approach. Nevertheless, theoretical and empirical developments permit to include in the modeling the investors preferences. Hirshleifer (1965b) and Hirshleifer (1965a) and Myers (1968) developed a theoretical framework, so-called the time-state preferences approach, that permit to deal with the issues of time preferences. Empirically, recent developments in portfolio theory includes the derivation of investors preferences for returns, risk and skewness as proposed by Briec, Kerstens, and Jokung (2007) and Brandouy, Kerstens, and Van De Woestyne (2010).

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Appendices

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Appendix A

Part 1, Chapter 3: Taxonomy

The 151 tests have been ranked according to 39 criteria pooled into 8 categories:

ID of the contribution:

1. (a) ID of the contribution in the order of release (e.g. Thore (1993) is the first contribution in the topic; its ID is 1).

(b) Year of the release

(c) Name(s) of the author(s)

(d) Kind of contribution: Article, working paper or Phd dissertation

(e) Name of the journal, conference or university

(f) Number of methodological stages (e.g. stage 1: computation of efficiency; stage 2: regression analysis between efficiency and stockholder value)

When a working paper is published in a journal, it is removed from the data base.

2. Theoretical approach of the relation

(a) Efficient Market Hypothesis

(b) Capital Market Research in Accounting

(c) Merger and acquisition

(d) Factor analysis

(e) Residual framework

3. Performance evaluated

(a) The measure:

i. Technical efficiency

A. Overall technical efficiency

B. Pure technical efficiency

C. Scale efficiency

ii. X/Cost efficiency

iii. P/Profit efficiency

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iv. R/Revenue efficiency
v. Marketability efficiency
   A. Marketability efficiency based on fundamental data
   B. Marketability efficiency based on market data
   C. Shareholder value efficiency
vi. Capital budgeting efficiency
vii. Total factor productivity and components (except technical efficiency)
   A. Total factor productivity
   B. Technology
   C. Scale of technological change
viii. Allocative efficiency

(b) Inefficiency, efficiency or both

(c) Changes in efficiency, level of efficiency or both

(d) Postulated relation confirmed or not

(e) Best performance in the explanation of stock return/value (in cross-estimator evaluation only)

4. Benchmark construction for efficiency computation

(a) Stochasticity
   i. Deterministic
   ii. Stochastic
   iii. Cross-paradigms tests

(b) Technological restrictions
   i. Convex or not (DEA only)
   ii. Treatment of slacks (DEA only)
   iii. Functional form and error component decomposition (SFA only)

(c) Orientation and returns to scale
   i. Input- or output-oriented
   ii. VRS or CRS

(d) Panel data treatment
   i. Time horizon:
      A. Contemporaneous (static in DEA)
      B. Non-regressive
      C. Intertemporal
      D. Window analysis
      E. Adjacent periods indices
      F. Panel regression model (SFA only)
      G. Cross-sectional regression model (SFA only)
   ii. Number of periods

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iii. Frequency: Month, quarter, semester, year, etc.

5. Level of analysis and sample construction:

(a) Period

(b) Geographical area

(c) Sector

(d) Level of aggregation:

i. Firms' level (micro-data)

ii. Branches level (micro-data)

iii. Industry level (sector-aggregates: Price indices, aggregated quantities,...)

iv. Economy

v. Cross-systems:

A. Cross-characteristics (e.g. size, ownership structure,...)

B. Cross-branches

C. Cross-sectors

D. Cross-regions

E. Cross-countries

(e) Number of frontiers constructed (Cross-systems analyses only)

(f) Sample size (total observations)

(g) Balanced or unbalanced sample for panel data only

(h) Sample trend for panel data only (increase or decrease over time)

6. Production possibility set

(a) Input set

i. Input ID (e.g. The 1^{rst} input of the article is input 1, etc.)

ii. Input

iii. Type of data:

A. Physical

B. Accounting

C. Market

iv. Nature of data

A. Stock variable

B. Flow variable

v. Input definition/computation if needed

vi. Information about prices or not

vii. Value deflated or not

viii. Approach of the activity for banking and insurance

A. Intermediation approach

B. Production approach

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C. Value added approach
D. Other

(b) Output set
i. Output ID
ii. Output
iii. Type of data:
A. Physical
B. Accounting
C. Market
iv. Nature of data
A. Stock variable
B. Flow variable
v. Outputs definition/computation if needed
vi. Information about prices or not
vii. Value deflated or not
viii. Approach of the activity for banking and insurance
A. Intermediation approach
B. Production approach
C. Value added approach
D. Other

7. Estimation of the relation between efficiency and stock price/return

(a) Measure of stockholder value creation
(b) Frequency (Daily, Weekly, ...)
(c) Relation modeling:
i. Portfolio buy and hold strategy based on efficiency information
ii. Single factor regression
A. Dependent variable
B. Independent variable
C. Type of regression
iii. Multiple factors regression
A. Dependent variable
B. Independent variables
C. Type of regression
iv. One stage DEA
v. Robustness checks
(d) Market model type (for regression analysis)
i. CAPM
ii. Macro economic model (e.g. APT)

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iii. Industry
iv. Fundamental model
A. Fama-French-Carhart Model
B. Other model based on fundamental information (especially value relevance analyses)

(e) Measure of relevance of the efficiency for stock return/price forecast (returns, adj. R-squared,...)

(f) Incremental value relevance of efficiency (regressions only)

8. Data sources

(a) Production data

(b) Financial data

Some categories are adapted from existing taxonomies. The second taxonomy corresponds with the usual classification of efficiency by frontier framework based on the distinction between technical efficiency, allocative efficiency and economic efficiency. We are aware that pooling X efficiency with cost efficiency (and P-efficiency with profit efficiency as well) is open to criticism. X-efficiency is closer to technical efficiency regarding the construction of the measure. However, we describe the intentions of the authors as closely as possible. In most cases, authors claim they measure cost efficiency whereas their data sets do not include information about input and output prices, but focus on aggregated accounting information. Nevertheless, X-efficiency is a relative measure of profitability. It encompasses underlying productivity of the firm, but also the price mix to a certain extent. We distinguish X-efficiency from cost efficiency (and P-efficiency with profit efficiency as well) in the analysis of the results.

In addition to the usual taxonomy of performance measures, we have introduced two other distinctions: the marketability efficiency and the capital budgeting efficiency. The former covers heterogeneous approaches, but converges in the specification of the output set. They specify market value or returns as one of the output to maximize. Capital budgeting efficiency is a financial concept that measures the ability of the firm at optimizing investment decisions. This efficiency measure focuses on the deviation of the firm from the expected optimal Tobin's Q.

The taxonomy 4 and 5 is adapted from Gattoufia, Orala, and Reisman (2004). The taxonomy of Gattoufia, Orala, and Reisman (2004) ranked papers according to the Data employed, the Envelopment form, the type of Analysis and the Nature - theoretical, empirical or methodological - of the contribution (DEAN taxonomy).

The seventh category combines taxonomy corresponding to two different designs of research and theoretical backgrounds maintained in the topic. On the one hand, the classification of efficiency with regard to their ability at explaining stock returns relative to other variables is inherited from the taxonomy of Holthausen and Watts (2001) for value relevance applications. This theoretical path belongs to the field of the capital market research in accounting and is concerned with the ability of information at forecasting the riskiness, the magnitude and the time pattern of firms' future cash flows (Kothari, 2001). This classification is based on regression analysis. The adjusted R-square, the coefficients

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and the time pattern of the relation are the outcome of interest to analyze and rank the contribution. This is also concerned with the specification of the regression model and with the accounting variables implemented. The second taxonomy in category 7 (d) is concerned with the different factors models for stock returns forecasts. We refer to the classification of Connor (1995) who ranked factors model given the data employed. Given his classification, factors arise from portfolio constructed on macroeconomic information, fundamental information or from factor analysis. The Connor (1995) taxonomy is combined with King (1966) approach who ranked information given their scope.

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Thèse de Matthieu Belarouci, Lille 1, 2013

Appendix B

Part 2, Chapter 5: Sample Construction

The sample collected encompasses all carriers of the US airlines industry since 1990. Nevertheless, we perform measures only on the major air carriers, alternatively called the Group III carriers according to the US Department of Transportation (DOT) classification, over the period 1990-2012. Group III refers to the large certificated US air carriers with annual operating revenues over $1 billion. Since major carriers are the oldest and the biggest firms in the industry, they data availability and reliability is greater since they used to fill DOT reports. Moreover, Group III carriers are entitled to release more specific information about the characteristics of assets. On average, majors accounted for 88% of the total market share between 1990-2012. Consequently, conclusions about the relation of efficiency to stock returns in the US airline can be made without loss of generality.

This chapter aims at describing the sample and the collection process. The sample relies on secondary data only. It has been constructed with multiple sources. Production and non-consolidated financial data have been downloaded from the DOT Bureau of Transportation Statistics (RITA). The consolidated data and the time series of stock prices have been extracted from Bloomberg.

B.1 Sample Description

Our study is focusing on the Major carriers of the US airlines industry. Major carriers also called Group III carriers exhibit annual revenue that exceeds $1 billion. Even though the US Department of Transportation releases information on other carrier groups, we are focusing on Major certificated carriers for the sake of consistency with Alam and Sickles (1998) who provide a similar study over the period 1970 to 1990. Moreover, the reporting requirements for major carriers ensure better data availability and accuracy. Air carriers provide cargo and passenger services all over the world. Except DHL Airways, Fed Ex and United Parcel Service specialized in cargo services, all of them are providing both. Their activities differ regarding the proportion of cargo and passenger services and their region of operation.

Our unbalanced panel data set contains 28 US Major air carriers over 19 years from 1991 to 2009 on quarterly basis. Only 10 carriers span the entire period. The number

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of observations remains constant over the first decade 1991 to 2000. It passes from 13 decision making units (DMU) in 1990-2000 towards 22 in 2009. Except Pan American World Airways, DHL Airways and Hawaiian Airlines Inc., every DMU is quoted or belongs to a quoted holding on the US stock exchange. We note that carriers or holdings are not listed during the entire period, most of them passed under the Chapter 11 procedures. Continental Airlines delisted in 1991 and 1993. Delta Air Group delisted during the first two quarters of 2008 and changed ticker code the first quarter of 2007. It acquired Comair in November 2000 and merged with Northwest Airlines in November 2008. Northwest Airlines is listed from 1994 to 2007 under NWACQ ticker and from 2007 to its acquisition if Delta Air Group under NWA. US Airways Group was not delisted, but changed three times ticker codes due to Chapter 11. It merged with America West Holding in July 2005 and since 100% owns America West Airlines. America West Holding changed in ticker too the third quarter 1994. United Airlines changed ticker three times. The stock prices of United Parcel Service are available over the period 1999-2010. ATA Holding whose American Trans Air is the main subsidiary is listed from 2000-2006. Trans World Airways went to banckrupt at the end of 2001 and is consequently listed only over 1995-2001. Express Jet listed from 2004 to the begining of 2009. At the end of the first quarter 2009, Express Jet delisted for Chapter 11 purpose until its merger with Skywest Holding in November 2010. This latter holding encompasses two 100% owned majors: Skywest Airlines and Atlantic Southeast Airlines. Frontier Airlines is acquired at the end of the second quarter 2009 by Republic Airways, but continue its operations under Frontier Airlines name. In every case each time a holding changes ticker code, it is delisted during weeks and the market valuations prior and post changes are extremely low. In addition, the changes in capital structures do not affect carriers' reporting in a sense it does not lead to the creation of a new operating entity. Yet, it affects the cooperations, alliances and local market power strategies. Finally, we describe here only the subsidiaries listed as major by the US DOT, but every holding also owns medium or large carriers and firms providing services related to their activities such as insurances, booking systems, commuters (...).

B.2 Production Data

The input and output sets have been recomposed with multiple sources. Three kinds of information has been constructed:

- Capacities, stages characteristics and equipments
- The number of employee
- Fuel gallon consumed

All of this information are provided by the US DOT. Nevertheless, their different format and level of analysis require treatment to provide a consistent production possibility set.

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B.2.1 Revenue Ton Miles, Load Factors and Engines' Characteristics

Four sources are employed. Three are disclosed by the US DOT and one by the SEC. The alternative sources and their details are provided in Table B.1.

Table B.1: Revenue Ton Miles, Load Factors and Engines' Characteristics: Sources

Source	T1	T100	On Time Perf	Edgar SEC
Period	1974-2012	1990-2012	1987-2012	
Frequency	Monthly	Monthly	Monthly	Quarterly
Units	Quantity	Quantity	Daily	Quantity
Filters	Carrier name Region of operation Carrier group Service class	Carrier name Region of operation Carrier group Service class Airport ID departure Airport ID arrival Aircraft type Aircraft config Aircraft Group	Carrier name Airport ID departure Airport ID arrival Carrier group Flight number Tail number	Carrier name
Information	RTM ATM Load factors	Payloads Stage length Stage distance Engines characteristics	Operating fleet Stage characteristics Engines characteristics	Operating fleet Engines characteristics
Number of files	468	276	312	NA

Form T-1 US Air Carrier Traffic And Capacity Summary by Service Class

This table summarizes the T-100 traffic data reported by the US air carriers. The monthly summary is compiled by carrier entities (geographical regions in which a carrier operates) and service classes, and includes available seat miles (ASMs), available ton miles (ATMs), revenue passengers enplaned (PAX), revenue passenger miles (RPMs), revenue ton miles (RTMs), revenue air hours (RAHs), revenue miles flown (MILES), and revenue departures performed (FLIGHTS). T1 summary includes reported international flights

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and military service which may not be available in the T100 segment and T100 market data tables released in TranStats.

This files contains the following information:

- The output: revenue ton miles for various class of services
- the input: Available ton miles for various class of services
- The load factors

```
rm(list=ls())
setwd("C:/Users/Matthieu/Documents/T1/")

T1<-read.csv("1060250193_T_SCHEDULE_T1_All_All.csv", sep=";", dec=".", header=TRUE)
dim(T1)

#NOMS DES MAJORS EXTRAITS GROUP NEW 3 1990-2012
noms<-c("CO" ,"DL" ,"FX" ,"WN" ,"5X" ,"AA" ,"NW" ,"PAPA","PA" ,"UA" ,"US" ,"AS"
,"HP"
,"TW" ,"EA" ,"ER" ,"TZ" ,"MQ" ,"XE" ,"OH" ,"B6" ,"ABX" ,"FL" ,"OO" ,"EV" ,
"F9" ,"YV" ,"5Y" ,"HA" ,"KAQ" )

#SUBSET REGION
REGION<-function(X)
{Z<-X[c(which(X$REGION=="A"),which(X$REGION=="D"),
which(X$REGION=="L"),which(X$REGION=="P")),]}

T1<-REGION(T1)

#EXTRACTION DES MAJORS ET RECOMPOSITION DU FICHIER
TRIER<-function(X,i){Z<-X[which(X$UNIQUE_CARRIER==noms[i]),]}

for (i in 1:length(noms))
assign(noquote(paste("T1",noms[i],sep="")),TRIER(T1,i))

X<-NULL
for (i in 1:length(noms))
X<-rbind(X,get(noquote(paste("T1",noms[i],sep=""))))

#AGGREGATE AVEC SERVICE CLASS COMME CLE
a<-data.frame(X[,14:37])
c<-aggregate(a,list(X$YEAR, X$QUARTER, X$UNIQUE_CARRIER,
X$CARRIER_GROUP_NEW), sum)

write.table(c,"AGGT1HClass.csv", sep=";", dec=".")

names(X)
#AGGREGATE AVEC SERVICE CLASS COMME CLE
```


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```
Y<-data.frame(X[,14:37])
Z<-aggregate(Y,list(X$YEAR, X$QUARTER, X$UNIQUE_CARRIER, X$REGION ,
X$CARRIER_GROUP_NEW, X$SERVICE_CLASS), sum)
$
```

Form T-100 Segment

The files combines domestic and international T-100 segment data reported by the US air carriers, and contains non-stop segment data by aircraft type and service class for transported passengers, freight and mail, available capacity, scheduled departures, departures performed, aircraft hours, and load factor. For a uniform end date for the combined databases, the last 3 months US carrier domestic data released in T-100 Domestic Segment (US Carriers Only) are not included. Flights with both origin and destination in a foreign country are not included. It has been employed to compute:

- The load factors.
- The number of nodes as proxy for returns to density measures.
- The number of departures performed.
- The characteristics of engines.
- The average stage length.

The treatment of T-100 has been performed on R:

```
rm(list=ls())

setwd("C:/Users/Matthieu/Documents/T100/")

#Chargement du fichier de donnes
lecture<-function(X){
read.csv(X, sep=",", dec=".", header=TRUE)
}

for(i in 1990:2012)
assign(noquote(paste("T100y",i,sep="")),
lecture(paste("695985586_T_T100_SEGMENT_ALL_CARRIER_",i,".csv",sep="")))




#EXTRACTION DES MAJORS ET RECOMPOSITION DU FICHIER POUR MAJORS
TRIER<-function(X,j){Z<-X[which(X$UNIQUE_CARRIER==noms[j]),]}


noms<-c("CO" ,"DL" ,"FX" ,"WN" ,"5X"
```


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```
,"AA" ,"NW" ,"PAPA","PA" ,"UA" ,"US" ,"AS" ,"HP"
,"TW" ,"EA" ,"ER" ,"TZ" ,"MQ" ,"XE" ,"OH" ,
"B6" ,"ABX" ,"FL" ,"OO" ,"EV" ,
"F9" ,"YV" ,"5Y" ,"HA" ,"KAQ" )


for (i in 1990:2012) for (j in 1:length(noms))
assign(noquote(paste("T100y",i,noms[j],sep="")),TRIER(
get(noquote(paste("T100y",i,sep=""))),j))


#REFORMATION DU FICHIER ID DEBUT
REFORMATION<-function(X){Z<-
cbind(X[,11:19],X[,42:49],X[,1:2],X[,2]-X[,1],X[,3:10],X[,20:41],X[,50])}


for (i in 1990:2012) for (j in 1:length(noms))
assign(noquote(paste("T100y",i,noms[j],sep="")),REFORMATION(
get(noquote(paste("T100y",i,noms[j],sep="")))))

#####################################################


#BIEN REFLECHIR A LA RECOMPOSITION DU FICHIER
#COMPTER LE NOMBRE DE NODE 1) AIRPORT ID ET 2) CITY PAIR MARKET
#SUM DES DEPARTS SUR LE TRIMESTRE PAR REGION
#TENIR COMPTE DES AVIONS


############################
#AGGREG NODE A POUR OBJECTIF DE MESURER LE NB OF ROUTE:
#1.PAR AIRPORT
AGGREGnodeAirp<-function(X){
W<-dim(X)
if (W[1]!=0){
Y<-data.frame(X[,18:28])
Z<-aggregate(Y, list(X$UNIQUE_CARRIER, X$REGION ,
X$CARRIER_GROUP_NEW, X$ORIGIN_AIRPORT_ID,
 X$DEST_AIRPORT_ID,
 X$YEAR, X$QUARTER), sum)
}
}


for (i in 1990:2012) for (j in 1:length(noms)){{
assign(noquote(paste("T100y",i,noms[j],"AGGAirp",sep="")),
AGGREGnodeAirp(get(noquote(paste("T100y",i,noms[j],sep=""))))
)
```


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```
}}
############################
#2. PAR CITY PAIR MARKET
AGGREGnodeCity<-function(X){
W<-dim(X)
if (W[1]!=0){
Y<-data.frame(X[,18:28])
Z<-aggregate(Y, list(X$UNIQUE_CARRIER, X$REGION ,
X$CARRIER_GROUP_NEW,
X$ORIGIN_CITY_MARKET_ID,
 X$DEST_CITY_MARKET_ID, X$YEAR, X$QUARTER), sum)
}
}


for (i in 1990:2012) for (j in 1:length(noms)){{
assign(noquote(paste("T100y",i,noms[j],"AGGCity",sep="")),
AGGREGnodeCity(get(noquote(paste("T100y",i,noms[j],sep=""))))
)
}}
############################
#AGGREG IS A POUR OBJECTIF DE PREPARER UN FICHIER QUI SERA
#INTERCALER DANS L'IS
AGGREGIS<-function(X){
W<-dim(X)
if (W[1]!=0){
Y<-data.frame(X[,18:28])
Z<-aggregate(Y, list(X$UNIQUE_CARRIER, X$REGION ,
X$CARRIER_GROUP_NEW
,X$CLASS, X$YEAR, X$QUARTER), sum)
}
}


for (i in 1990:2012) for (j in 1:length(noms)){{
assign(noquote(paste("T100y",i,noms[j],"AGGIS",sep="")),
AGGREGIS(get(noquote(paste("T100y",i,noms[j],sep=""))))
)
}}

#RECOMPO
X<-NULL
for (i in 1990:2012) for (j in 1:length(noms))
X<-rbind(X,get(noquote(paste("T100y",i,noms[j],"AGGIS",sep=""))))

CL<-unique(X[,4])

write.table(X,"T100class.csv",sep=",",dec=".")
```


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```
#AGGREG IS A POUR OBJECTIF DE PREPARER UN FICHIER QUI SERA
#INTERCALER DANS L'IS hors class
AGGREGISHC<-function(X){
W<-dim(X)
if (W[1]!=0){
Y<-data.frame(X[,18:28])
Z<-aggregate(Y, list(X$UNIQUE_CARRIER, X$REGION ,
X$CARRIER_GROUP_NEW, X$YEAR, X$QUARTER), sum)
}
}


for (i in 1990:2012) for (j in 1:length(noms)){{
assign(noquote(paste("T100y",i,noms[j],"AGGISHC",sep="")),
AGGREGISHC(get(noquote(paste("T100y",i,noms[j],sep=""))))
)
}}

#RECOMPO
X<-NULL
for (i in 1990:2012) for (j in 1:length(noms))
X<-rbind(X,get(noquote(paste("T100y",i,noms[j],"AGGISHC",sep=""))))

write.table(X,"T100aggISHC.csv",sep=",",dec=".")


#TRIE PAR TRANSPORTEUR
X<-NULL
for (j in 1:length(noms)) for (i in 1990:2012)
assign(noms[j],
rbind(X,get(noquote(paste("T100y",i,noms[j],sep=""))))
)

X<-NULL
for (i in 1990:1991) for (j in 1:length(noms))
X<-rbind(X,get(noquote(paste("T100y",i,noms[j],sep=""))))
```

On Time Performance

Airline on time performance monthly data reported by the US certified air carriers that account for at least one percent of domestic scheduled passenger revenues–includes scheduled and actual arrival and departure times for flights.

The collection has been automatized by the following Javascript code:

```
<input value="BOUTON DL AIR PERF" type="button" onClick="downloadAll()" />
```


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```
<script>

var i = 1990;
var j = 1;

function downloadAll() {

var zip_filename = "On_Time_On_Time_Performance_"  + i + "_" + j + ".zip";

location.replace("http://www.transtats.bts.gov/Download/"+zip_filename);

j = j+1;
if (j == 13) {
j = 1;
i = i+1;
}
if (i == 2014) window.location.reload();

setTimeout("downloadAll()",1500);
}

</script>
```

The treatment of this data set has been particularly difficult since its size is 61Go. We had to perform an

```
rm(list=ls())

setwd("C:/Users/Matthieu/Documents/On time perf/")


lecture<-function(X){
  Z<-read.csv(X, sep=",", dec=".", header=TRUE)

Y<-data.frame(Z[,12])
Z<-aggregate(Y, list(Z$Year, Z$TailNum, Z$UniqueCarrier), sum)
}


AGGR<-function(x){
ZOB<-data.frame(x[,4])
Z<-aggregate(ZOB, list(x[,1], x[,2], x[,3]), sum)

ZOB<-data.frame(Z[,4])
Y<-aggregate(ZOB, list(Z[,1], Z[,3]), length)
}
###################################
```


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```
for (i in 1995:2006){
for (j in 1:12)
assign(noquote(paste("P",i,"m",j,sep="")),
lecture(noquote(paste("On_Time_On_Time_Performance_",i,"_",j,".csv",sep=""))))

X<-NULL
for (j in 1:12)
X<-rbind(X,(get(noquote(paste("P",i,"m",j,sep="")))
)

A<-AGGR(X)

write.table(A,paste(i,"_aircraft.csv",sep=""), dec=".", sep=",")


}


x<-NULL
for (j in 1:12)
x<-rbind(x,get(noquote(paste("P",2009,"m",j,sep=""))))

ZOB<-data.frame(x[,4])
Z<-aggregate(ZOB, list(x[,1], x[,2], x[,3]), sum)

ZOB<-data.frame(Z[,4])
Y<-aggregate(ZOB, list(Z[,1], Z[,3]), length)


is.numeric(x[,4])


TRIER<-function(X){Z<-X[which(X[,3]=="AS"),]}
for (j in 1:12)
assign(noquote(paste("AS",j,sep="")),TRIER(
get(noquote(paste("P",2009,"m",j,sep="")))))

x<-NULL
for (j in 1:12)
x<-rbind(x,get(noquote(paste("AS",j,sep=""))))

ZOB<-data.frame(x[,4])
Z<-aggregate(ZOB, list(x[,1], x[,2], x[,3]), sum)
dim(Z)$
```


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SEC-Official Reports

To complete the file "On time performance", we have collected manually information about the size of the operating fleet in the official reports disclosed by the SEC.

B.2.2 Number of Employees

The standard definition of labor input is an aggregate of pilots, flight attendants, mechanics, passenger and aircraft handlers and others. It is expressed in number of employees. The DOT provides information on the number of employee from the following listed sources in Table D.2.

Table B.2: Format of Sheets per Source about Employee

Source	Form 41 Schedule P-10	Monthly Airline Employment Data	Yearly Airline Employment Data
Period	1990 to 2009	1990 to 2010	1970 to 1989
Frequency	Yearly	Monthly	yearly
Unit	Quantity	Quantity	Quantity
Filters	• Carrier name • Region of operation • Labor per category	• Carrier name • Carrier group • Full time, part time and equivalents	• Carrier name • Carrier group
Nber of files	21	252	21
Format	xls	csv	csv

The Monthly Airline Employment Data is the selected source. Regarding the number of files to download, we employ a the following Javascript code to automatize the request:

```
<form action="http://www.bts.gov/airline_employment/src/datadisp_csv.xml?o=NAME+ASC"
 method="post" name="formulaire"><input type="hidden" name="month" id="month" />
<input type="hidden" name="year" id="year" />
</form>

<input value="BOUTON GO" type="button" onClick="downloadAll()" />

<script>
```


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```
var i = 1990;
var j = 1;

function downloadAll() {
document.getElementById('year').value = i;
document.getElementById('month').value = j;
document.formulaire.submit();
j = j+1;
if (j == 13) {
j = 1;
i = i+1;
}
if (i == 2011) window.location.reload();
setTimeout("downloadAll()",1500);
}

</script>
```

The merger of files into a unique file has been done with the following VBA code:

```
Sub Labor2()
Dim Source As String
Dim month, x, y, z As Integer
Dim appExcel As Excel.Application 'Application Excel

    z = Worksheets(1).Range("A65536").End(xlUp).Row

    For month = 1 To z
    Source = Worksheets(1).Cells(month, 1)

    Set appExcel = CreateObject("Excel.Application")
    appExcel.Workbooks.Open (Source)
    appExcel.Visible = True

    'Mise en forme du fichier
        Set GRP = appExcel.Cells.Find(what:="Group", lookAt:=xlWhole).Offset(1, 0)
        Set YR = appExcel.Cells.Find(what:="Year", lookAt:=xlWhole).Offset(1, 0)
        f = appExcel.Range("A9").Value

        appExcel.Range(GRP, YR).Copy
    For i = 7 To 200
        If appExcel.Cells(i, 1).Value = f Then
appExcel.Cells(i, 1).PasteSpecial xlPasteAll
Else: appExcel.Range(appExcel.Cells(i, 1), appExcel.Cells(i, 3)).Copy
    Next i

        appExcel.Range("A1", GRP.Offset(-2, 0)).Select
```


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```
        appExcel.Selection.EntireRow.Delete

        appExcel.Range("A1:G1").Select
        appExcel.Selection.AutoFilter
        appExcel.ActiveSheet.Range("$A$1:$G$76").AutoFilter field:=4,
Criteria1:="="
        x = appExcel.Range("A65536").End(xlUp).Row
        y = appExcel.Range("XFD1").End(xlToLeft).Column

        appExcel.Range(appExcel.Cells(1, 1).Offset(1, 0),
appExcel.Cells(x, y)).Select
        appExcel.DisplayAlerts = False
        appExcel.Selection.Delete
        appExcel.Selection.AutoFilter

    'Concatenation du fichier
        appExcel.Range("A1").CurrentRegion.Copy
        If Worksheets(2).Range("A1").Value = "" Then GoTo jan90 Else GoTo postjan90
jan90:
        Worksheets(2).Range("A1").Select
        ActiveSheet.Paste

        'Fermeture fichier
        appExcel.DisplayAlerts = False
        appExcel.ActiveWorkbook.Close
        GoTo suivant

postjan90:

        V = Worksheets(2).Range("A65536").End(xlUp).Row
        w = Worksheets(2).Range("XFD1").End(xlToLeft).Column
        Worksheets(2).Cells(V, 1).Offset(1, 0).Select
        ActiveSheet.Paste

        'Fermeture fichier
        appExcel.DisplayAlerts = False
        appExcel.ActiveWorkbook.Close

suivant:
    Next month

        'Suppression des lignes de titres doublons
        V = Worksheets(2).Range("A65536").End(xlUp).Row
        'g = Worksheets(2).Range("A65")
        For j = 2 To V
        If Worksheets(2).Cells(j, 7).Value = "Total" Then GoTo suppr Else GoTo cool
suppr:
        Worksheets(2).Cells(j, 7).Select
```


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```
        Selection.EntireRow.Delete
cool:
        Next j

        'Ajout variable QUARTER
        Worksheets(2).Range("C1").Select
        Selection.EntireColumn.Insert
        Worksheets(2).Range("C1").Value = "QUARTER"

    V = Worksheets(2).Range("A65536").End(xlUp).Row 'a supprimer aprs

    For k = 2 To V
        If Worksheets(2).Cells(k, 2) = "Jan" Or Worksheets(2).Cells(k, 2) = "Feb"
Or Worksheets(2).Cells(k, 2) = "Mar" Then Worksheets(2).Cells(k, 3).Value = 1
        If Worksheets(2).Cells(k, 2) = "Apr" Or Worksheets(2).Cells(k, 2) = "May"
Or Worksheets(2).Cells(k, 2) = "Jun" Then Worksheets(2).Cells(k, 3).Value = 2
        If Worksheets(2).Cells(k, 2) = "Jul" Or Worksheets(2).Cells(k, 2) = "Aug"
Or Worksheets(2).Cells(k, 2) = "Sep" Then Worksheets(2).Cells(k, 3).Value = 3
        If Worksheets(2).Cells(k, 2) = "Oct" Or Worksheets(2).Cells(k, 2) = "Nov"
Or Worksheets(2).Cells(k, 2) = "Dec" Then Worksheets(2).Cells(k, 3).Value = 4
    Next k


Worksheets(2).Range("A1").CurrentRegion.Copy
Worksheets(3).Range("A1").PasteSpecial xlPasteAll

w = Worksheets(3).Range("A65536").End(xlUp).Row

    For l = 2 To w
        If Worksheets(3).Cells(l, 5).Value = "TOTAL"
Or Worksheets(3).Cells(l, 5).Value = "GRAND TOTAL" Then GoTo finish Else GoTo encore
finish:
        Worksheets(3).Cells(l, 5).Select
        Selection.EntireRow.Delete
encore:
    Next l

        'Sauvegarde
        ActiveWorbooks.Save

End Sub

Sub pb()
  'Filtre majors quarter end
        Worksheets(2).Range("A1").CurrentRegion.Select
        Selection.AutoFilter field:=1, Criteria1:="Major", field:=2,
Criteria2:=Array("Mar", "Jun", "Sep", "Dec"), Operator:=xlFilterValues
        Worksheets(2).Range("A1").CurrentRegion.Copy
```


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```
        Worksheets(3).Range("A1").PasteSpecial xlPasteAll

        Worksheets(3).Range("A1").CurrentRegion.Select
        Selection.Sort Key1:=Cells(1, 4), Order1:=xlAscending, Key2:=Cells(1, 3),
Order2:=xlAscending, Key3:=Cells(1, 5), Order3:=xlAscending, Header:=xlGuess

End Sub
```

Fuel Gallon

The total gallons of fuel consumed is disclosed in the Form 41-P12(a). This table contains monthly reported fuel costs, and gallons of fuel consumed, by air carrier and category of fuel use, including scheduled and non-scheduled service for domestic and international traffic regions. It is important to note that the disclosure systems frequently changes. Initially, the fuel gallons employed by carriers were disclosed only for the period 2000-2009. The first sample measured fuel gallons with the a weighted cost index for the period 1990-1999. Now the precise quantities are disclosed for the period 1990-2012.

B.3 Non-Consolidated Financial Data

The sample involves financial data downloaded from the US DOT at carriers' level. Data provided by DOT are fined grained, but are frequently incomplete. The reconstruction of missing data have been an important part of the work. All items are in the US GAAP and follow SEC requirements. It is important to note that the reporting process did not always follow the SEC requirements. Hence, particular checking have been done for accounts disclosed before 2006.

B.3.1 Income Statement

DOT provides different pro format income statements. I'm focusing only on the income statement Form-41 P12 and the operating expenses Form-41 P6. Form-41 P12 provides quarterly profit and loss statements for carriers with annual operating revenues of $20 million or more. The data include operating revenues, operating expenses, depreciation and amortization, operating profit, income tax, and net income. Form 41 - P6 focuses only on operating expenses. It contains quarterly operating expenses, by objective grouping, for carriers with annual operating revenues of $20 million or more. It includes items such as salaries, benefits, materials purchased, services purchased, depreciation, amortization, food, and other operating expenses. Both are obtained on: $http://www.transtats.bts.gov$. Table B.3 reports information about Form-41 P6 and P12.

Since, P6 is more precise regarding the reporting of operating expenses, a merger of both files is required. The recomposition of the income statement implied sveral steps.

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Table B.3: Income Statement Forms

Form	Data	Frequency	Availability	Filters	OBS	Gp III OBS
P6	Operating expenses	Quarterly	1990-2013	Carrier region Carrier group	9936	4584
P12	Income Statement	Quarterly	1990-2013	Carrier region Carrier group	9927	4582

Preliminary preparation:

- Files is restructured to make the treatment easier.
- Missing values are replaced by "NA".
- Panam Airlines unique carrier's code "PA_(1)" is replaced by PAPA.
- Each carrier may have several ID's. UNIQUE CARRIER is kept as reference ID since this is stable and the most complete over the data base. When it is missing, AIRLINE ID is chosen to recompose missing information.
- Then Group III carriers are extracted with the following R-script:

```
P12<-read.csv("rcup major P12.csv", sep=";", dec=".", header=TRUE)

#NOMS DES MAJORS EXTRAITS GROUP NEW 3 1990-2012
noms<-c("CO" ,"DL" ,"FX" ,"WN" ,"5X" ,"AA" ,"NW" ,
"PAPA","UA" ,"US" ,"AS" ,"HP" ,"TW" ,"EA" ,"ER"
,"TZ" ,"MQ" ,"XE" ,"OH" ,"B6" ,"ABX" ,"FL" ,"OO"
 ,"EV" ,"F9" ,"YV" ,"5Y" ,"HA" ,"KAQ" )

#EXTRACTION DES MAJORS ET RECOMPOSITION DU FICHIER
TRIER<-function(X,i){Z<-X[which(X$UNIQUE_CARRIER==noms[i]),]}
for (i in 1:length(noms))
assign(noquote(paste("P12_",noms[i],sep="")),TRIER(P12,i))

P12GP3<-NULL
for (i in 1:length(noms))
P12GP3<-rbind(P12GP3,get(noquote(paste("P12_",noms[i],sep=""))))
$
```

The effect of this operation on the sample size is detailed in Table B.4.

Table B.4: Output of First Step of Data Reconstitution Process

	P12	P6
Raw file	9936	9927
Filtered file	4584	4582

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Even though the resulting files seem to coincide regarding the number of observation in Table B.4, P12 suffered important lacks in ID that prevented merger. These lacks are depicted in Table B.5.

Table B.5: P12 - Missing ID's

AIRLINE_ID	*UNIQUE CARRIER*	*UNIQUE CARRIER NAME*	*UNIQUE CARRIER ENTITY*	*REGION*	*CARRIER GROUP NEW*	*CARRIER GROUP*	*YEAR*	*QUARTER*
0	0	39	1109	1236	1294	1321	1348	1422

We note that AIRLINE_ID has no missing value, but is frequently incomplete. The ID's of interest, that is to say the ID's that corresponds with an information that cannot be triangulated, are for each cross-section: UNIQUE_CARRIER, YEAR, QUARTER and REGION. Regarding these ID's, the number of missing data are reported in Table B.6.

Table B.6: P12 - Most Important Missing ID's

Region only	*Region and quarter only*	*Region, Year and Quarter*
1236	1348	1236

Form 41-P12 Missing ID's Recovering:

The issue with P12 is that there is at least 1422 missing values. In contrast, P6 has no missing ID for majors. The triangulation of P-12 with P-6 is performed with the total operating expenses and the presence of other ID. 2 kinds of criteria are employed:

The permanent criteria are used in every iterative comparison between P6 and P12. In addition to the permanent criteria, at least one transitory criteria is introduced. All missing observations in P6 missing in P12 are compared with the incomplete ID's of P12. If the three criteria match for each statement; the ID's of P12 are recomposed with the ID's of P6 if and only if there is no double entry possible. When an ID of P6 is employed to recompose P12, we exclude it for the further comparison. The comparison is an iterative process with multiple steps.

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Table B.7: Criteria Employed for P-12 ID's Recovering

Permanent criteria	Transitory criteria
UNIQUE CARRIER	YEAR
OPERATING EXPENSES +/- 3\$ of differences	QUARTER
	REGION OF OPERATION

- First step: All criteria are tested
- Second step: Alternatively 2 transitory criteria are tested in addition to permanent criteria.
- Third step: Alternatively 1 transitory criteria is tested in addition to permanent criteria.
- Last step: Permanent criteria are tested only.

At the end of this process, the number of missing ID's is given by Table B.8.

Table B.8: Number of Missing ID's of Form-41 P12 After Recomposition Process

AIRLINE_ID	*UNIQUE CARRIER*	*UNIQUE CARRIERNAME*	*UNIQUE CARRIER ENTITY*	*REGION*	*CARRIER GROUP NEW*	*CARRIER GROUP*	*YEAR*	*QUARTER*
0	0	7	26	26	26	26	26	26

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The gain of information for most important ID's is reported in Table B.9.

Table B.9: Information Gain After Recomposition of P12

	REGION	CARRIER GROUP NEW	CARRIER GROUP	YEAR	QUARTER
Number of OBS	1211	1269	1296	1323	1397

It has been performed by the following VBA code:

```
Sub recomp6()
Dim i As Integer, j As Integer, X As Integer, Y As Integer

    X = Worksheets(3).Range("A200000").End(xlUp).Row
    Y = Worksheets(1).Range("A200000").End(xlUp).Row

    For i = 2 To Y
        For j = 2 To X
           If Application.WorksheetFunction.Or(IsEmpty(Worksheets(1).Cells(i, 1)),
IsEmpty(Worksheets(1).Cells(i, 2)), IsEmpty(Worksheets(1).Cells(i, 3)),
IsEmpty(Worksheets(1).Cells(i, 4)), IsEmpty(Worksheets(1).Cells(i, 5)),
IsEmpty(Worksheets(1).Cells(i, 6)), IsEmpty(Worksheets(1).Cells(i, 7)),
IsEmpty(Worksheets(1).Cells(i, 8)), IsEmpty(Worksheets(1).Cells(i, 9)),
IsEmpty(Worksheets(1).Cells(i, 10)), IsEmpty(Worksheets(1).Cells(i, 11)))
Then GoTo testA Else GoTo suite1
testA:
    If (Worksheets(3).Cells(j, 37).Value - Worksheets(1).Cells(i, 42).Value)
> -6 And (Worksheets(3).Cells(j, 37).Value - Worksheets(1).Cells(i, 42).Value)
< 6 Then GoTo testB Else GoTo suite2

testB:
   If Application.WorksheetFunction.Or(IsEmpty(Worksheets(3).Cells(j, 1)),
IsEmpty(Worksheets(3).Cells(j, 2)), IsEmpty(Worksheets(3).Cells(j, 3)),
IsEmpty(Worksheets(3).Cells(j, 4)), IsEmpty(Worksheets(3).Cells(j, 5)),
IsEmpty(Worksheets(3).Cells(j, 6)), IsEmpty(Worksheets(3).Cells(j, 7)),
IsEmpty(Worksheets(3).Cells(j, 8)), IsEmpty(Worksheets(3).Cells(j, 9)),
IsEmpty(Worksheets(3).Cells(j, 10)), IsEmpty(Worksheets(3).Cells(j, 11)))
Then GoTo suite3 Else GoTo fill
fill:
 Worksheets(3).Range(Worksheets(3).Cells(j, 1), Worksheets(3).Cells(j, 11)).Copy
 Worksheets(1).Cells(i, 1).PasteSpecial xlAll
 Worksheets(1).Cells(i, 43).Value = "ID_filled_from_p12"

suite2:
        Next j
suite1:
```


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```
suite3:
    Next i

End Sub


Sub recomposep12avecp6()

Dim i As Integer, j As Integer, X As Integer, Y As Integer

    X = Worksheets(3).Range("A200000").End(xlUp).Row
    Y = Worksheets(1).Range("A200000").End(xlUp).Row

    For i = 2 To X
        For j = 2 To Y
        'UNIQUE CARRIER puis AIRLINE ID
           If Worksheets(3).Cells(i, 1).Value = Worksheets(1).Cells(j, 1).Value
Then GoTo test2 Else GoTo suite
test2:
           'If IsEmpty(Worksheets(3).Cells(i, 2)) penser  le virer au premier tour
           If IsEmpty(Worksheets(3).Cells(i, 2))
Or IsEmpty(Worksheets(3).Cells(i, 10))
Or IsEmpty(Worksheets(3).Cells(i, 11))
Or IsEmpty(Worksheets(3).Cells(i, 7))
Then GoTo test3 Else GoTo suite

test3:
If (Worksheets(3).Cells(i, 37).Value - Worksheets(1).Cells(j, 42).Value) > -6
And (Worksheets(3).Cells(i, 37).Value - Worksheets(1).Cells(j, 42).Value) < 6
Then GoTo fillit Else GoTo suite

fillit:
Worksheets(1).Range(Worksheets(1).Cells(j, 1), Worksheets(1).Cells(j, 11)).Copy
Worksheets(3).Cells(i, 1).PasteSpecial xlAll
'Worksheets(3).Selection.PasteSpecial xlAll

Worksheets(3).Cells(i, 53).Value = "OK2"
Exit For
suite:

        Next j
    Next i
End Sub



Sub finalfantasyvrai()
'a n'est pas assez prcis, le test sur les ope exp n'est pas
```


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```
suffisant donc ajouter au moins qlq critres
Dim i As Integer, j As Integer, X As Integer, Y As Integer

    X = Worksheets(3).Range("A200000").End(xlUp).Row
    Y = Worksheets(1).Range("A200000").End(xlUp).Row

    For i = 2 To X
        For j = 2 To Y
  'si ope i = ope j et q des id manquent
            If IsEmpty(Worksheets(3).Range(Worksheets(3).Cells(i, 1),
Worksheets(3).Cells(i, 1))) Then GoTo testA Else GoTo suite


testA:
'Pays Region Origin Unique Time
           If Application.WorksheetFunction.And((Worksheets(3).Cells(i, 37).Value -
Worksheets(1).Cells(j, 42).Value)
> -6, (Worksheets(3).Cells(i, 37).Value -
Worksheets(1).Cells(j, 42).Value) < 6) Then GoTo prout Else GoTo garbage

prout:

'alors on test doublon
                For k = 2 To X
      If Application.WorksheetFunction.And(Worksheets(3).Cells(k, 37).Value
= Worksheets(3).Cells(i, 37).Value, k <> i) Then GoTo degage Else GoTo encore

encore:
               Next k
'si y a pas doublon; k s'puise et remplit le champs puis c exit for
   Worksheets(1).Range(Worksheets(1).Cells(j, 1), Worksheets(1).Cells(j, 11)).Copy
   Worksheets(3).Cells(i, 1).PasteSpecial xlAll
   Worksheets(3).Cells(i, 54).Value = "OK_test_de_la_mort"
degage:
Exit For
'si y a doublon tu dgages


garbage:
Next j

suite:
Next i



End Sub
```


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At this stage of the process,

Recomposition of the Income Statement

```
rm(list=ls())

setwd("C:/Users/Matthieu/Documents/")

P12ET2<-read.csv("P12ETAPE2.csv", sep=";", dec=".", header=TRUE)
P6ET2<-read.csv("P6ETAPE2.csv", sep=";", dec=".", header=TRUE)


#########################################################
X<-NULL
Y<-NULL
for (i in 1:length(P12ET2[,1])) {
for (j in 1:length(P6ET2[,1])){
if (isTRUE(P12ET2[i,2]==P6ET2[j,2])&
isTRUE(P12ET2[i,7]==P6ET2[j,7])&
isTRUE(P12ET2[i,10]==P6ET2[j,10])&
isTRUE(P12ET2[i,11]==P6ET2[j,11]))
{X<-cbind(P12ET2[i,1:27],P6ET2[j,12:42],P12ET2[i,28:43])
Y<-rbind(Y,X)}
}
}

#write.table(Y,"P12opeP6.csv",sep=",",dec=".")

#########################################################
rm(list=ls())
#Recoder le fichier avant de lancer la procdure
setwd("C:/Users/Matthieu/Documents/")
P10ET1<-read.csv("P10ETAPE2.csv", sep=";", dec=".", header=TRUE)
P12opeP6<-read.csv("P12opeP6.csv", sep=";", dec=".", header=TRUE)

X<-NULL
Y<-NULL
for (i in 1:length(P12opeP6[,1])) {
for (j in 1:length(P10ET1[,1])){
if (isTRUE(P12opeP6[i,2]==P10ET1[j,3])&
isTRUE(P12opeP6[i,7]==P10ET1[j,7])&
isTRUE(P12opeP6[i,10]==P10ET1[j,1])
)
{X<-cbind(P12opeP6[i,1:38],P10ET1[j,23],P12opeP6[i,39:74])
Y<-rbind(Y,X)}
```


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```
}
}

#write.table(Y,"P10P12.csv",sep=",",dec=".")
```

Non-Consolidated Statement of Financial Position

The non-consolidated statement of financial position - so-called balance sheet - is obtained from the Form 41-B1. We did not perform recomposition for this file since it is only employed for the production of descriptive statistics in the previous chapter.

B.4 Consolidated Financial Statements and Stock Prices Time-Series

All consolidated financial statements, industry index and stock prices time-series have been downloaded on Bloomberg. Since, most of the carriers have been delisted during the sample periods, the ticker codes have been obtained manually.

B.5 Premia for the Fama-French-Carhart Model

The Premia for the Fama-French-Carhart model and the value weighted industry returns are disclosed on the Kenneth French website:
$http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html$

B.6 Harmonization of the ID's

In order to provide a unified data base, we standardized ID. The following VBA code have been imposed on the input set, the output set and the non-consolidated financial data.

```
Sub Idnumeric()
Dim i, j, k As Integer
Dim ID_carrier(1 To 29), ID_region(1 To 5) As String

ID_carrier(1) = "5X"
ID_carrier(2) = "5Y"
ID_carrier(3) = "AA"
ID_carrier(4) = "ABX"
ID_carrier(5) = "AS"
ID_carrier(6) = "B6"
ID_carrier(7) = "CO"
```


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```
ID_carrier(8) = "DL"
ID_carrier(9) = "EA"
ID_carrier(10) = "ER"
ID_carrier(11) = "EV"
ID_carrier(12) = "F9"
ID_carrier(13) = "FL"
ID_carrier(14) = "FX"
ID_carrier(15) = "HA"
ID_carrier(16) = "HP"
ID_carrier(17) = "KAQ"
ID_carrier(18) = "MQ"
ID_carrier(19) = "NW"
ID_carrier(20) = "OH"
ID_carrier(21) = "OO"
ID_carrier(22) = "PA"
ID_carrier(23) = "TW"
ID_carrier(24) = "TZ"
ID_carrier(25) = "UA"
ID_carrier(26) = "US"
ID_carrier(27) = "WN"
ID_carrier(28) = "XE"
ID_carrier(29) = "YV"

ID_region(1) = "D"
ID_region(2) = "I"
ID_region(3) = "A"
ID_region(4) = "L"
ID_region(5) = "P"

X = Range("A65000").End(xlUp).Row

For i = 2 To X
    For j = 1 To 29
            If Cells(i, 3).Value = ID_carrier(j) Then Cells(i, 3).Value = j
    Next j
Next i


For i = 2 To X
    For k = 1 To 5
            If Cells(i, 4).Value = ID_region(k) Then Cells(i, 4).Value = k
    Next k
Next i
End Sub
```


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Appendix C

Part 2, Chapter 7: Relation between Changes in Hicks-Moorsteen TFP Components and Stock Returns

C.1 TFP Computation

C.2 Outliers

Analysis of TFP is done after removing extreme observations. They are listed below:

Table C.1: Outliers Removed for Regression

Year	Obs	Firm	HOLDING TICKER	dQ	dX	dTFP	dTech
2011	26	DL	DAL US EQUITY	1,0071	1,0285	0,9792	230,7221
2011	29	FX	FDX US EQUITY	1,0134	1,0372	0,977	230,7221
2010	20	5X	UPS US EQUITY	1,1162	1,0188	1,0955	27,7942
2010	35	OO	SKYW US EQUITY	1,1315	0,9947	1,1375	29,657
2011	36	WN	LUV US EQUITY	1,0733	1,0534	1,0188	29
2009	30	EV	XJT US EQUITY	0,9667	0,7269	1,3299	14,011
2009	33	FX	FDX US EQUITY	0,9145	0,9155	0,9989	12,7919
2010	31	FX	FDX US EQUITY	1,1275	1,0777	1,0462	11,6088
2009	37	OO	SKYW US EQUITY	1,0505	0,8691	1,2087	14,011
2009	36	OH	DAL US EQUITY	0,7732	0,8053	0,9602	5,0454

C.3 Descriptive Statistics of Changes in TFP Components Used in Regression Analysis

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Table C.2: Changes in HMTFP Adjacent Years: Descriptive Statistics

	dQ	dX	dTFP	dTech	dTFPE	dOTE	dOSE	dOME	dROSE	dOSME	dITE	dISE	dIME	dRISE	dISME	dRME
1990-1991	1.07	1.05	1.01	0.97	1.05	1.01	1.04	1.00	1.04	1.04	1.01	1.03	1.00	1.04	1.04	1.00
1991-1992	1.09	1.07	1.01	1.02	0.99	1.00	1.01	1.00	0.99	0.99	1.01	1.00	1.00	0.98	0.98	0.98
1992-1993	1.02	0.98	1.04	1.05	0.99	1.00	1.01	1.00	0.98	0.98	1.00	1.02	0.99	0.99	0.99	0.97
1993-1994	1.09	1.03	1.06	0.97	1.09	1.04	1.01	1.00	1.05	1.05	1.02	1.03	1.00	1.06	1.06	1.03
1994-1995	1.04	1.03	1.01	1.02	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.99	1.00	0.99	0.99	1.00
1995-1996	1.08	1.05	1.03	1.02	1.01	1.00	1.02	1.00	1.01	1.01	1.00	1.01	1.01	1.01	1.01	1.00
1996-1997	1.05	1.04	1.02	1.00	1.01	1.00	0.99	1.00	1.01	1.01	1.00	0.99	1.00	1.00	1.01	1.02
1997-1998	1.03	1.05	0.99	0.99	1.00	1.01	0.99	1.00	0.99	0.99	1.01	0.99	1.00	0.99	0.99	1.00
1998-1999	1.06	1.06	1.01	1.03	0.98	0.99	0.99	1.00	0.99	0.99	0.99	0.99	1.00	0.98	0.99	1.00
1999-2000	1.07	1.05	1.01	1.06	0.96	0.99	0.99	1.00	0.97	0.97	0.99	0.99	1.00	0.97	0.97	0.98
2000-2001	0.96	1.01	0.95	0.89	1.07	1.00	1.02	1.00	1.06	1.06	1.00	1.02	1.00	1.06	1.06	1.04
2001-2002	1.01	0.98	1.03	1.08	0.96	1.00	0.99	1.00	0.96	0.96	1.00	0.99	0.90	1.06	0.96	0.97
2002-2003	1.03	0.99	1.04	1.01	1.03	1.01	1.00	1.00	1.02	1.02	1.01	1.00	0.99	1.02	1.02	1.02
2003-2004	1.11	1.05	1.06	1.08	0.97	1.00	1.01	1.00	0.97	0.97	1.00	1.01	0.99	0.99	0.98	0.97
2004-2005	1.01	0.99	1.03	1.02	1.01	1.01	1.01	1.00	1.00	1.00	1.01	1.01	0.98	1.02	1.00	0.99
2005-2006	0.99	0.96	1.03	1.06	0.97	0.97	1.02	1.00	1.00	1.00	0.98	1.02	1.00	0.99	0.99	0.97
2006-2007	1.06	1.04	1.02	1.01	1.01	0.99	1.02	1.00	1.01	1.01	0.99	1.02	1.00	1.02	1.02	1.00
2007-2008	0.99	0.97	1.02	0.99	1.03	1.03	1.01	1.00	1.00	1.00	1.02	1.02	1.01	1.00	1.01	0.99
2008-2009	0.90	0.87	1.03	1.15	0.90	1.03	1.05	1.00	0.87	0.87	1.03	1.05	0.95	0.92	0.87	0.83
2009-2010	1.08	1.05	1.03	1.10	0.94	0.98	1.01	1.00	0.96	0.96	0.98	1.02	0.98	0.98	0.96	0.94
2010-2011	1.15	1.13	1.01	1.10	0.92	0.99	0.95	1.00	0.93	0.93	0.99	0.96	0.98	0.95	0.93	0.97
10%	0.93	0.92	0.97	0.97	0.91	0.97	0.97	1.00	0.93	0.93	0.97	0.97	0.98	0.93	0.92	0.92
25%	0.99	0.98	0.99	0.99	0.96	1.00	0.99	1.00	0.96	0.96	1.00	0.99	0.99	0.97	0.96	0.96
Median	1.04	1.02	1.02	1.02	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.99
75%	1.09	1.07	1.04	1.07	1.03	1.01	1.02	1.00	1.02	1.02	1.01	1.02	1.00	1.02	1.02	1.01
90%	1.15	1.13	1.07	1.11	1.07	1.04	1.05	1.00	1.07	1.07	1.03	1.05	1.01	1.08	1.07	1.04
Geo mean	1.04	1.02	1.02	1.03	0.99	1.00	1.01	1.00	0.99	0.99	1.00	1.01	0.99	1.00	0.99	0.98
sd	0.14	0.12	0.06	0.09	0.07	0.04	0.05	0.00	0.07	0.07	0.03	0.05	0.05	0.09	0.07	0.07

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Table C.3: Changes in FPTFP Variable Basis: Descriptive Statistics

	dQ	dX	dTFP	dTFP.	dTFPE	dOTE	dOSE	dOME	dROSE	dOSME	dITE	dISE	dIME	dRISE	dISME	dRME
1990-1991	1.02	0.94	1.08	1.03	1.05	1.01	1.03	1.00	1.04	1.04	1.02	1.03	1.00	1.03	1.03	1.00
1991-1992	1.07	1.06	1.01	0.99	1.02	1.00	1.01	1.00	1.01	1.01	1.01	1.01	0.98	1.03	1.01	1.01
1992-1993	1.02	1.04	0.97	1.01	0.96	0.97	1.00	1.00	1.00	1.00	0.98	0.99	1.02	0.97	0.99	1.00
1993-1994	1.05	1.04	1.01	0.98	1.03	1.02	1.01	1.00	1.01	1.01	1.01	1.02	0.99	1.03	1.02	1.00
1994-1995	1.03	1.03	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
1995-1996	1.03	1.01	1.02	1.01	1.01	1.00	1.01	1.00	1.02	1.02	1.00	1.01	1.01	1.00	1.02	1.00
1996-1997	1.01	1.01	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.01
1997-1998	0.98	1.03	0.96	0.98	0.97	1.01	0.98	1.00	0.97	0.97	1.01	0.98	0.99	0.98	0.97	0.98
1998-1999	0.98	1.03	0.95	0.96	1.00	0.99	0.99	1.00	1.00	1.00	0.99	0.99	1.01	1.00	1.00	1.01
1999-2000	1.18	1.22	0.97	1.03	0.94	0.97	0.98	1.00	0.97	0.97	0.97	0.98	1.01	0.96	0.97	0.99
2000-2001	0.96	1.02	0.94	0.93	1.02	1.01	1.02	1.00	1.01	1.01	1.01	1.02	1.00	1.01	1.01	0.99
2001-2002	0.98	0.94	1.05	1.05	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.01	0.99	1.00	1.01
2002-2003	0.99	0.98	1.01	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	1.00	0.99	1.01	1.00	1.00
2003-2004	1.14	1.08	1.06	1.03	1.02	1.00	1.01	1.00	1.02	1.02	1.00	1.01	1.01	1.01	1.02	1.02
2004-2005	1.07	1.33	0.81	0.91	0.88	0.99	0.95	1.00	0.89	0.89	0.99	0.95	0.94	0.95	0.90	0.94
2005-2006	1.13	1.04	1.08	1.05	1.03	0.98	1.01	1.00	1.05	1.05	0.99	1.01	1.04	1.00	1.04	1.03
2006-2007	1.10	1.08	1.02	1.00	1.02	0.98	1.03	1.00	1.03	1.03	0.98	1.04	1.00	1.03	1.04	1.00
2007-2008	1.05	1.07	0.98	0.93	1.06	1.03	1.01	1.00	1.03	1.03	1.03	1.01	1.03	1.01	1.04	1.02
2008-2009	0.92	0.75	1.22	1.07	1.14	1.03	1.07	1.00	1.11	1.11	1.03	1.07	1.01	1.09	1.11	1.04
2009-2010	0.98	0.95	1.03	1.04	0.99	0.99	1.01	1.00	1.01	1.01	0.99	1.01	1.01	1.00	1.01	0.99
2010-2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10%	0.92	0.89	0.92	0.93	0.94	0.97	0.96	1.00	0.95	0.95	0.97	0.96	0.97	0.95	0.95	0.97
25%	0.97	0.95	0.97	0.98	0.98	1.00	0.99	1.00	0.98	0.98	1.00	0.99	0.99	0.99	0.98	0.99
Median	1.02	1.02	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
75%	1.10	1.10	1.05	1.03	1.04	1.00	1.02	1.00	1.04	1.04	1.00	1.02	1.01	1.02	1.03	1.01
90%	1.18	1.21	1.10	1.05	1.07	1.03	1.05	1.00	1.08	1.08	1.03	1.05	1.03	1.06	1.07	1.04
Geo mean	1.03	1.02	1.01	1.00	1.01	1.00	1.01	1.00	1.01	1.01	1.00	1.01	1.00	1.01	1.01	1.00
sd	0.12	0.16	0.11	0.04	0.10	0.04	0.05	0.00	0.08	0.08	0.04	0.06	0.06	0.06	0.09	0.06

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Table C.4: Changes in FPTFP Fixed Basis: Descriptive Statistics

	dQ	dX	dTFP	dTech	dTFPE	dOTE	dOSE	dOME	dROSE	dOSME	dITE	dISE	dIME	dRISE	dISME	dRME
1990-1990	3.18	2.86	1.11	0.98	1.14	0.90	1.19	1.00	1.27	1.27	0.91	1.18	0.96	1.30	1.25	1.06
1990-1991	3.40	3.08	1.10	0.98	1.13	0.90	1.18	1.00	1.25	1.25	0.90	1.19	0.97	1.30	1.26	1.06
1990-1992	3.80	3.41	1.11	0.99	1.13	0.91	1.16	1.00	1.24	1.24	0.90	1.17	0.98	1.27	1.25	1.07
1990-1993	2.97	2.58	1.15	0.99	1.17	0.93	1.17	1.00	1.26	1.26	0.92	1.18	0.98	1.29	1.26	1.07
1990-1994	3.18	2.69	1.18	0.98	1.20	0.94	1.19	1.00	1.28	1.28	0.94	1.19	0.96	1.33	1.28	1.08
1990-1995	3.44	2.86	1.20	0.98	1.22	0.93	1.22	1.00	1.31	1.31	0.93	1.21	0.97	1.35	1.31	1.08
1990-1996	3.72	3.02	1.23	0.99	1.25	0.95	1.21	1.00	1.31	1.31	0.95	1.21	0.98	1.34	1.31	1.08
1990-1997	3.90	3.15	1.24	0.99	1.25	0.96	1.21	1.00	1.31	1.31	0.96	1.21	0.97	1.34	1.30	1.08
1990-1998	4.05	3.31	1.22	0.99	1.24	0.95	1.21	1.00	1.31	1.31	0.95	1.20	0.98	1.34	1.31	1.09
1990-1999	4.31	3.51	1.23	0.99	1.25	0.95	1.20	1.00	1.31	1.31	0.96	1.19	0.98	1.33	1.30	1.09
1990-2000	4.60	3.71	1.24	0.98	1.26	0.97	1.20	1.00	1.31	1.31	0.97	1.19	0.98	1.33	1.30	1.09
1990-2001	3.32	2.87	1.16	0.98	1.18	0.92	1.19	1.00	1.28	1.28	0.92	1.19	0.96	1.33	1.28	1.07
1990-2002	4.15	3.46	1.20	1.00	1.20	0.91	1.22	1.00	1.31	1.31	0.91	1.22	0.98	1.34	1.31	1.07
1990-2003	4.26	3.49	1.22	1.00	1.22	0.93	1.23	1.00	1.32	1.32	0.92	1.23	0.98	1.35	1.32	1.07
1990-2004	4.71	3.73	1.26	1.01	1.25	0.95	1.23	1.00	1.32	1.32	0.95	1.24	0.98	1.35	1.32	1.07
1990-2005	4.23	3.33	1.27	1.00	1.27	0.97	1.25	1.00	1.30	1.30	0.97	1.25	0.97	1.35	1.30	1.04
1990-2006	3.21	2.50	1.29	1.01	1.27	0.97	1.25	1.00	1.31	1.31	0.97	1.25	0.98	1.35	1.31	1.05
1990-2007	2.98	2.29	1.30	1.02	1.27	0.97	1.25	1.00	1.32	1.32	0.96	1.26	0.98	1.35	1.32	1.05
1990-2008	2.62	2.03	1.29	1.04	1.24	0.96	1.25	1.00	1.28	1.28	0.97	1.25	0.97	1.33	1.28	1.03
1990-2009	2.28	1.79	1.27	1.03	1.24	0.98	1.24	1.00	1.26	1.26	0.98	1.24	0.97	1.29	1.26	1.02
1990-2010	2.91	2.22	1.31	1.01	1.30	0.99	1.26	1.00	1.31	1.31	1.00	1.25	0.98	1.33	1.31	1.04
1990-2011	3.27	2.45	1.33	1.01	1.32	1.00	1.26	1.00	1.33	1.33	1.00	1.26	0.98	1.35	1.33	1.05
10%	0.61	0.60	1.07	0.91	1.04	0.86	1.13	1.00	1.10	1.10	0.86	1.13	0.92	1.16	1.12	0.98
25%	1.42	1.22	1.15	0.94	1.14	0.91	1.21	1.00	1.24	1.24	0.92	1.20	0.97	1.29	1.23	1.03
Median	4.28	3.61	1.24	0.99	1.26	0.98	1.26	1.00	1.34	1.34	0.98	1.26	0.99	1.39	1.33	1.09
75%	9.03	6.77	1.34	1.08	1.35	1.00	1.27	1.00	1.40	1.40	1.00	1.27	1.00	1.42	1.40	1.11
90%	12.27	10.17	1.41	1.15	1.41	1.00	1.27	1.00	1.42	1.42	1.00	1.27	1.00	1.43	1.42	1.12
Geo mean	3.43	2.79	1.23	1.00	1.23	0.95	1.22	1.00	1.30	1.30	0.95	1.22	0.97	1.33	1.29	1.06
sd	4.50	3.59	0.14	0.09	0.14	0.06	0.07	0.00	0.12	0.12	0.06	0.08	0.04	0.11	0.12	0.07

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C.4 Relation between HMTFPE with Cumulated Excess Returns Including Herfindhal Index

Since the measure can be altered by the degree of concentration of the sector, I've tested the relation when taking into account the effect of level and changes in Herfindhal index as well as the changes in market shares. In every case, variables are not significantly related except if we test for the cross effect. Nevertheless, these additional variables do not change the sign of the relation.

Table C.5: Relation between Changes in HMTFP Components and stock returns Including Changes in Market Concentration

	Dependent variable:
	ER
Mkt.RF	-0.022^{***}
	(0.007)
SMB	0.056^{***}
	(0.013)
HML	-0.028^{***}
	(0.009)
UMD	-0.044^{***}
	(0.006)
dTFPE	-6.715^{***}
	(1.440)
dHHI	-1.890
	(1.305)
Constant	4.395^{***}
	(1.446)
Observations	256
R^2	0.388
Adjusted R^2	0.374
Residual Std. Error	$1.630 (df = 249)$
F statistic	$26.340^{***} (df = 6; 249)$
Note:	*p<0.1; **p<0.05; ***p<0.01

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Table C.6: Relation Between Changes in HMTFPE and One Year Lagged Cumulated Excess Returns

	Dependent variable:
	ER_{t-1}
dTFPE	-6.600^{***}
	(1.741)
Constant	3.252^{*}
	(1.726)
Observations	238
R^2	0.057
Adjusted R^2	0.053
Residual Std. Error	$1.936(df = 236)$
F statistic	$14.375^{***}(df = 1; 236)$
Note:	*p<0.1; **p<0.05; ***p<0.01

C.5 Relation between HMTFPE with One Year Lagged Cumulated Excess Returns

C.6 Relation between HMTFP with Lee and Hooy (2012) Specification of the Fama French Carhart (FFC)

Lee and Hooy (2012) suggest to refer to the international CAPM to estimate the expected cost of equity of US carriers since their activities are globally diversified. The model is provided by the following Equation:

$$\text{Cumulated Excess Return} = Rf + R_{Mworld} + R_{Industry} + HML + SMB + MOM + \epsilon \quad \text{(C.1)}$$

We did not follow their methodology since it requires to construct an industry portfolio for each firm. In addition, taking into account the dependency of the US carriers with the domestic market, we think that the standard FFC provides sufficient information. Besides, results of the Lee and Hooy regression applied to TFP decomposition confirm the relations provided.

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Table C.7: Relation between HMTFP Components and Excess Returns Following Lee and Hooy (2004) Specification

	Dependent variable:						
	ER						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mkt.RF Inter.	0.031***	0.031***	0.032***	0.027***	0.026***	0.020**	0.029***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)
Aero US	−0.036***	−0.037***	−0.038***	−0.034***	−0.033***	−0.029***	−0.033***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
SMB US	0.044***	0.045***	0.045***	0.045***	0.050***	0.054***	0.049***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
HML US	−0.002	−0.001	−0.0003	−0.004	−0.004	−0.007	−0.002
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)
UMD US	−0.041***	−0.043***	−0.043***	−0.040***	−0.037***	−0.033***	−0.034***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
dQ		1.876**					
		(0.771)					
dX			1.490*				
			(0.898)				
dTFP				4.112**			
				(1.783)			
dTFPE					−5.479***		
					(1.409)		
dTech						6.537***	
						(1.201)	
dRME							−4.595***
							(1.682)
Constant	−2.114***	−4.025***	−3.590***	−6.360***	3.245**	−9.066***	2.293
	(0.194)	(0.810)	(0.910)	(1.851)	(1.391)	(1.290)	(1.624)
Observations	258	258	258	258	258	258	258
R^2	0.370	0.384	0.377	0.383	0.406	0.436	0.388
Adjusted R^2	0.357	0.370	0.362	0.368	0.392	0.423	0.374
Residual Std. Error	1.657($df = 252$)	1.641($df = 251$)	1.651($df = 251$)	1.643($df = 251$)	1.612($df = 251$)	1.570($df = 251$)	1.636($df = 251$)
F statistic	29.594***($df = 5; 252$)	26.127***($df = 6; 251$)	25.292***($df = 6; 251$)	25.971***($df = 6; 251$)	28.564***($df = 6; 251$)	32.400***($df = 6; 251$)	26.539***($df = 6; 251$)

Note: *p<0.1; **p<0.05; ***p<0.01

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Appendix D

Marginal Value Relevance of CCR, BCC and FDH modeling

D.1 Efficiency Computations

Test of the relation between technical efficiency and stock prices have been oriented towards the Free Disposal Hull to account for sticky costs of the US airlines industry. Tests have performed for strongly disposable technologies under:

- convex and constant returns to scale modeling (CCR)
- convex and variable returns to scale modeling (BCC)
- non-convex and variable returns to scale modeling (FDH)

In every cases, computations are made with window analysis and non-regressive panel data treatments.

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D.2 Efficiency Scores

Table D.1: Descriptive Statistics of Technical Efficiency Scores (N=1286)

Model	Mean	Standard deviation	First quartile	Median	Third quartile
Sequential					
CCR	0.8277	0.10749338	0.7569	0.8249	0.9116
BCC	0.8713	0.10588642	0.7995	0.8845	0.9643
FDH	0.9582	0.08734918	0.94772	1	1
Window analysis					
CCR	0.8361	0.1056968	0.7661	0.8347	0.921
BCC	0.886	0.09580749	0.8185	0.8983	0.9734
FDH	0.96906	0.07366701	0.97333	1	1

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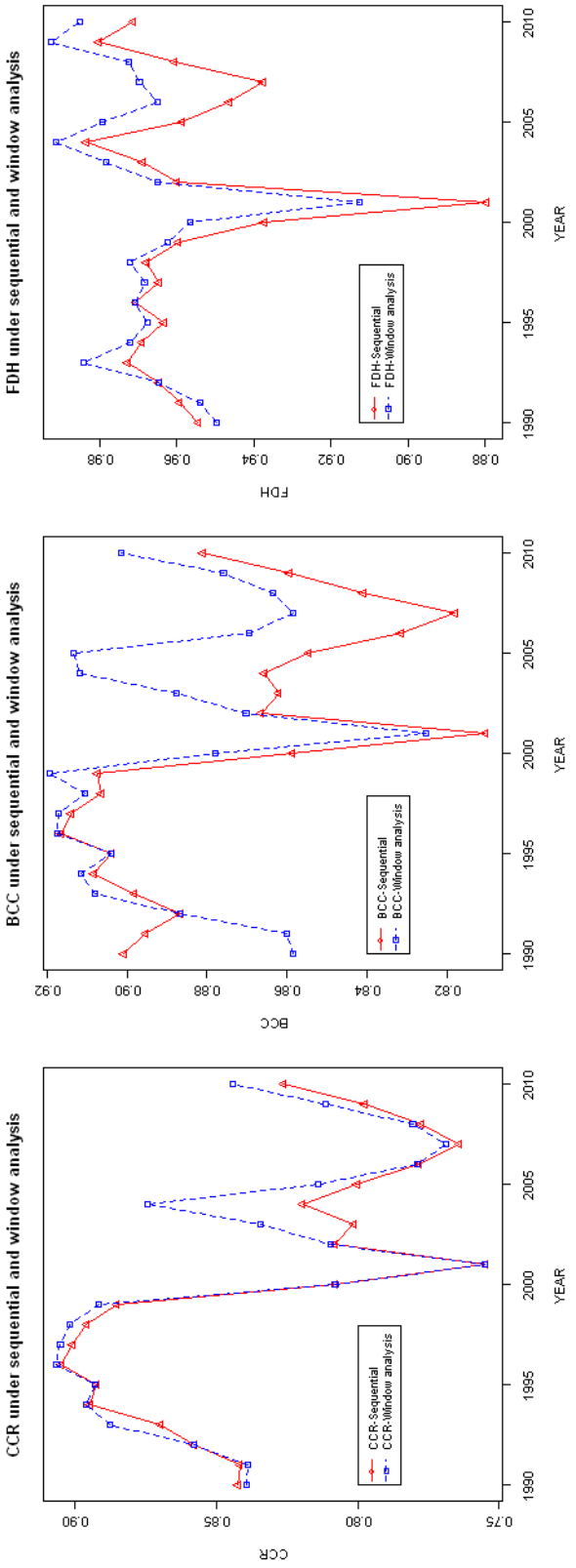

Figure D.1: Yearly Mean Technical Efficiency

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D.3 Relating Technical Efficiency to Monthly Stock Prices: Marginal Value Relavance Analysis

Table D.2: Regression Models at Month of Technical Efficiency Release m=0

Model (for m=0)	Description
Non-regressive computation of technical efficiency	
1) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{CCR-Seq,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal CCR model under constant returns to scale and convexity assumptions. The computation of technical efficiency relative to non-regressive panel data treatment.
2) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{BCC-Seq,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal BCC model under variable returns to scale and convexity assumptions. The computation of technical efficiency relative to non-regressive panel data treatment.
3) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{FDH-Seq,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal FDH model under variable returns to scale and non-convexity assumptions. The computation of technical efficiency relative to non-regressive panel data treatment.
Window analysis computation of technical efficiency (Three years based period)	
4) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{CCR-WA,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal CCR model under constant returns to scale and convexity assumptions. The computation of technical efficiency relative to window analysis.
5) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{BCC-WA,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal BCC model under variable returns to scale and convexity assumptions. The computation of technical efficiency relative to window analysis
6) $\mathrm{SP}_{i,q,0} = \alpha_0 + \beta TE_{FDH-WA,i,q} + \epsilon_{i,q,0}$	Estimation of the relation based on technical efficiency modeled with free disposal FDH model under variable returns to scale and non-convexity assumptions. The computation of technical efficiency relative to window analysis.

D.4 Regressions Results

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Table D.3: Relative Information Content of Technical Efficiency Scores Analysing US Publicly Listed Airlines

PANEL A : 25% of best and poorest performers (N=618)

Non-regressive

	CCR			BCC			FDH		
Monthly end stock prices	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value
m-2	71.932***	0.18011966	4.55E-26	64.466***	0.1223048	9.58E-18	23.010***	0.02015084	0.00044653
m-1	73.348***	0.1897939	1.63E-27	66.015***	0.13040577	7.02E-19	25.296***	0.0263365	0.0000685
m	78.228***	0.21083499	8E-31	71.551***	0.14992328	1E-21	32.767***	0.04221106	5.49E-07
m+1	77.802***	0.20810275	2.68E-30	71.657***	0.15173561	6.47E-22	32.151***	0.04096631	8.35E-07

Window analysis

	CCR			BCC			FDH		
Monthly end stock prices	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value
m-2	72.71***	0.19310404	5.16E-28	68.077***	0.1360495	1.12E-19	23.493*	0.01399019	0.00294903
m-1	74.053***	0.20359872	1.31E-29	70.57***	0.1479016	2.3E-21	26.052**	0.01871803	0.00069091
m	79.191***	0.22476798	5.34E-33	77.603***	0.1722787	5.45E-25	35.488***	0.03451033	0.00000562
m+1	78.499***	0.22102049	2.66E-32	77.467***	0.17074147	1.11E-24	37.617***	0.03935864	0.00000135

PANEL B: 10% of best and poorest performers (N=248)

Non-regressive

	CCR			BCC			FDH		
Monthly end stock prices	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value
m-2	63.651***	0.2488981	8.8E-16	68.967***	0.19644285	1.83E-12	4.11621134	-0.00200473	0.45834926
m-1	66.199***	0.26712107	5.5E-17	71.74***	0.21030494	2.54E-13	1.80999298	-0.00397012	0.73571847
m	71.280***	0.29785736	4.4E-19	78.373***	0.24502199	1.57E-15	-3.76709151	-0.00197635	0.45578505
m+1	71.017***	0.29104618	1.31E-18	78.037***	0.24037582	3.15E-15	-4.79330294	-0.00065903	0.35685104

Window analysis

	CCR			BCC			FDH		
Monthly end stock prices	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value	Coefficients	adj.R^2	P.value
m-2	60.966***	0.24577943	1.41E-15	56.718***	0.12041241	5.47E-08	9.94363821	0.00775913	0.09856078
m-1	63.444***	0.26241873	1.13E-16	62.002***	0.14030055	3.98E-09	7.01407087	0.00208876	0.22680789
m	67.981***	0.29605425	5.87E-19	70.83***	0.17934904	1.99E-11	-0.85828815	-0.00438152	0.88005814
m+1	67.321***	0.28541719	3.18E-18	69.211**	0.17032663	6.91E-11	-2.36414525	-0.00371638	0.67996429

*p<0.1; **p<0.05; ***p<0.01

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Thèse de Matthieu Belarouci, Lille 1, 2013