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Business Models and Stock Exchange Performance - Empirical Evidence

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Abstract

In recent years stock exchanges have been increasingly diversifying their operations into related business areas such as derivatives trading, post-trading services and software sales. This trend can be observed most notably among profit-oriented trading venues. While the pursuit for diversification is likely to be driven by the attractiveness of these investment opportunities, it is yet an open question whether certain integration activities are also efficient, both from a social welfare and from the exchanges' perspective. Academic contributions so far analyzed different business models primarily from the social welfare perspective, whereas there is only little literature considering their impact on the exchange itself. By employing a panel data set of 28 stock exchanges for the years 1999-2003 we seek to shed light on this topic by comparing the factor productivity of exchanges with different business models. Our findings suggest three conclusions: (1) Integration activity comes at the cost of increased operational complexity which in some cases outweigh the potential synergies between related activities and therefore leads to technical inefficiencies and lower productivity growth. (2) We find no evidence that vertical integration is more efficient and productive than other business models. This finding could contribute to the ongoing discussion about the merits of vertical integration from a social welfare perspective. (3) The existence of a strong in-house IT-competence seems to be beneficial to overcome lower productivity growth associated with complex business models.

Keywords: exchanges, demutualization, post-trading, derivatives, software, DEA, Malmquist-Productivity, bootstrapping

JEL Classification: F39, G32, C23, C24, C61

1 Introduction

In recent years stock exchanges have increasingly diversified their operations into related business areas such as derivatives trading, post-trading services and software sales. Considering the world's 50 largest stock exchanges according to the World Federation of Stock Exchanges (FIBV), figure 1 displays the number of those exchanges that have provided related activities besides their traditional cash market operations for the years 1999 to 2003.[1] The number of exchanges that added post-trading services to their business portfolio rose from 22 to 30, while the number of venues that operate a derivatives trading platform marked up from 25 to 31. Despite the strongest relative increase, providers of software solutions remained rather scarce, with three exchanges offering this service in 1999 and seven in 2003.

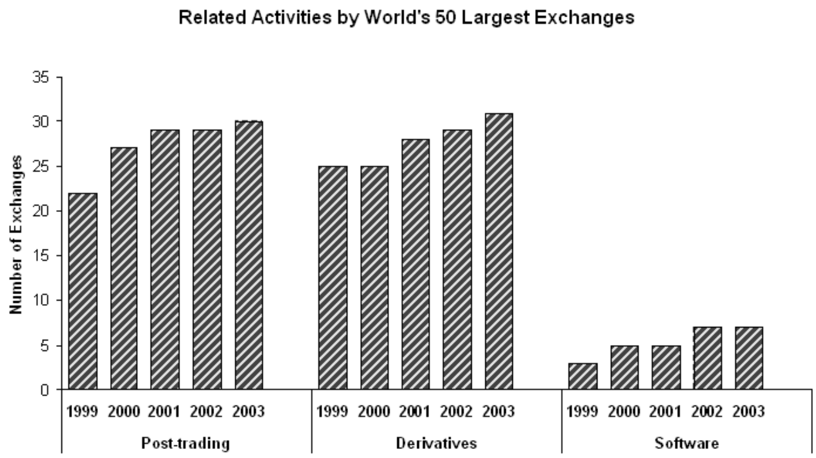

Figure 1: Related Activities by Exchanges 1999-2003

Integration activity and governance Interestingly, the great majority of exchanges that contributed to this rise were organized as profit-oriented trading venues. To be specific, stock exchanges that diversified into post-trading or software sales activities were exclusively profit-oriented, while the same group accounted for half of the increase in derivatives trading during the considered time span.[2] There are at least two reasons why predominantly profit-oriented exchanges are pursuing the integration of related activities: First, these areas possessed a stronger growth potential than the traditional cash market, an aspect which is particularly relevant

[1] We considered an exchange to be engaged in derivatives trading, post-trading or software sales if it indicated the derived segment revenues in its financial statements.

[2] In particular, the exchanges that added post-trading to their business during 1999 and 2003 were Hellenic Exchange, Copenhagen, Deutsche Börse, Italian Exchange, OMHEX, Vienna, National Stock Exchange India, and Philippine. Derivatives trading was introduced by Bermuda, Amex, Lima, Hellenic Exchanges, Istanbul, Johannesburg, and London Stock Exchange. One exchange, namely the Toronto Stock Exchange, ceased to operate a derivatives platform. Therefore, the net increase in integrated derivatives platforms is six. A software sales division was established by Singapore, Toronto and Tokyo.

for exchanges that strive for profit-maximization and hence is relatively unimportant for non-profit entities such as mutual exchanges. Second, demutualized exchanges also have presumably more leeway to pursue attractive business opportunities due to their differing control structure: Traditional mutual exchanges are usually owned and dominated by their customers[3] which not only seek to maximize the value of their share in the venue, but also take into account their own business interest as customers of the exchange. Therefore, as they ultimately control the activities of the exchange they can e.g. prevent investment decisions that would increase the value of the trading franchise but at the same time threaten their own business interests.[4] In contrast, profit-oriented exchanges are mostly demutualized and some of them are even publicly listed. In these firms the influence of their customers on investment decisions is usually not as strong. This is particularly the case for publicly listed exchanges, which are mostly dominated by outside owners that merely have a financial interest in the entity.[5] Therefore, as the vested interests of customer-owners are replaced by the outside-owners' common goal of maximizing the value of their company, an exchange's management can more freely pursue value-enhancing projects such as diversifying into related business fields.

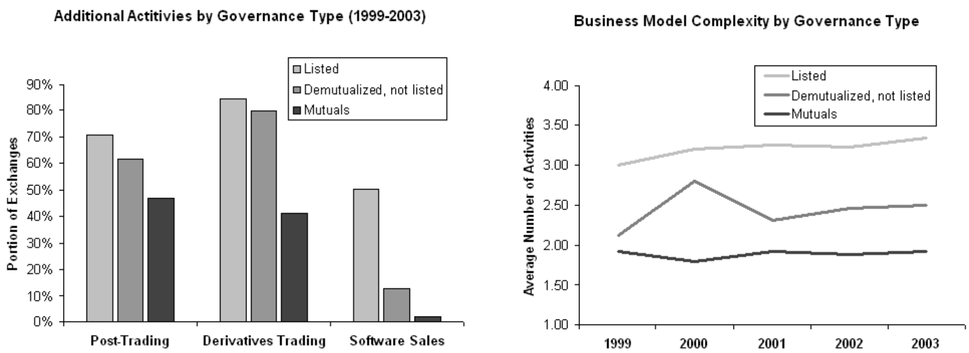

Figure 2: Related Activities by Governance Type 1999-2003

To demonstrate how integration activity varies among different governance structures, we present the two graphs in figure 2. The graph on the left side groups the exchanges according to their governance type (mutual, demutualized, publicly listed) and displays the five-year average portion that is diversified into the considered activities for each group. It can be seen that diversification into related activities is most pronounced for the group of publicly listed exchanges (light grey bars) as

[3] These are mainly banks and brokers that conduct their businesses on the exchange.

[4] A prominent example in this respect is the reluctance of some customer-owners to introduce an electronic trading platform due to fears that this could adversely affect their brokerage business. In analogous manner, this could be observable for investments in related business activities. Confer Steil (2002) for an elaborate discussion on this matter.

[5] Nevertheless outsider ownership can also have the opposite effect on integration activity as a recent case at the Deutsche Börse demonstrates. Here, a public dispute between the management of the Deutsche Börse and one of its owners, a hedge fund called TCI, emerged over the economic merits of a merger with the London Stock Exchange and culminated in the withdrawal of the takeover offer. TCI named the overly expensive bid price as the main reason for their strict opposition against a merger.

71% of them provide post-trading services, 84% offer a derivatives trading platform and 50% are active in the software sales field compared to only 47%, 41% and 2%, respectively, for the group of mutual exchanges (dark grey bars). The graph on the right side provides a slightly different perspective on the same issue. Here, the average number of activities provided by mutuals, demutualized and publicly listed exchanges are shown for the considered time period. Mutual exchanges have on average two business activities, i.e. one additional besides the traditional cash market operation, whereas listed exchanges are engaged on average in approximately three activities. Demutualized exchanges lie in between these extremes. This further strengthens the notion that profit-oriented and outsider dominated exchanges are more actively integrating related businesses into their core operations.

In order to assess the different degrees of importance of related activities for profit-oriented as opposed to non-profit stock exchanges, figure 3 displays the average revenue breakdowns of publicly listed and mutual firms for a sample of 28 exchanges during the years 1999 and 2003.[6] The revenues from derivatives trading, post-trading services and software sales were substantial for the listed exchanges, since they represented roughly half of their total operating revenues (left graph). For mutual exchanges, related activities played a subordinate role and the lion share of their revenues was generated on the traditional cash market (right graph).

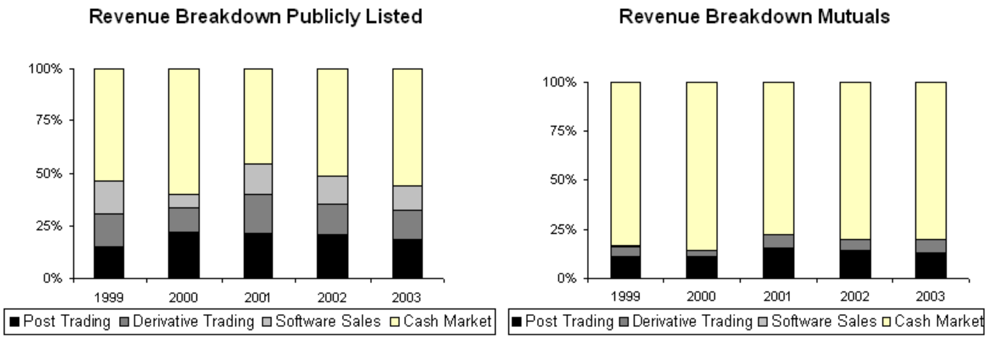

Figure 3: Average Revenue Breakdown of Mutual and Listed Exchanges in Sample

Integration activity and efficiency While diversification seems to be an attractive way to boost revenue and profit of an exchange, industry participants, politicians and academics point to the possibility that some business combinations could have detrimental effects on social welfare. They claim that particularly vertical integration, i.e. the combination of cash trading and post-trading activities, could lead to anti-competitive foreclosure strategies by (profit-oriented) exchanges

[6] These exchanges are also used in the subsequent efficiency and factor productivity analysis and represent approximately 85% of the world's equity trading volume executed on exchanges. The sample will be presented in more detail in section 3.1. Note that the yearly average revenue breakdown does not comprise the same exchanges for the respective years since several exchanges changed their governance. Hence, the average revenue breakdown of listed exchanges consists of two exchanges in 1999, whereas the 2003-figure includes the average of ten stock exchanges.

resulting in higher entry barriers for potential competitors and therefore higher prices.[7] However, there are also proponents of vertical integration claiming that the combination of trading and post-trading activities enables the exchanges to handle transactions faster, more safely and less costly by using straight-through-processing applications, which would ultimately result in lower prices for customers.[8] We believe that this discussion touches multiple - potentially intertwined - dimensions that need separate analysis beforehand in order to be able to assess the overall effects on welfare in a second step. In particular, we want to disentangle aspects of (1) *proper corporate governance regimes* from those that are related to (2) *efficient business models* in this industry.

(1) The governance regime of the entities is certainly a highly relevant aspect that needs to be analyzed from a social welfare perspective. Special attention should be devoted to the impact of ownership structure and objective function of an exchange on the price and quality of its services. While profit-oriented entities will seek to earn rents and therefore may charge prices that are above marginal costs, these rents may also induce the necessary incentives to invest in quality-enhancing technologies and which may not exist if non-profit firms provide these services.[9]

(2) Irrespective of the governance regime, it needs to be clarified whether the combination of certain business activities makes sense from an operational efficiency perspective. Generally, integration of related business fields ceteris paribus raises difficulties in managing the firm efficiently, since it adds to the complexity of existing business processes. However, certain business combinations may enable the exchange's management to utilize inherent economies of scope between activities. An efficiency analysis that seeks to answer this question can be conducted in two different ways. The first approach, depicted on the left hand side of figure 4, would be to compare the relative efficiency of exchanges that may or may not possess related activities on top of their traditional cash market operations. If the results indicate that diversified exchanges (e.g. firms A, C or D) are more efficient and productive than cash market-only exchanges (e.g. firm B), then this would be a clear case to support the former business models from a social welfare perspective, provided that an optimal governance regime can be implemented. However, if diversified firms do not exhibit a higher operative efficiency then a clear-cut conclusion cannot be drawn from this method. Instead, a second approach, as shown on the right hand side of figure 4, would be necessary that compares the efficiency of an entity that combines certain activities under one roof with the efficiency of multiple firms providing these activities separately. Hence, the efficiency of e.g. vertical integration would necessitate the comparison of an exchange that combines trading and post-trading activities (e.g. firm A) with a setting where these services are provided by three independent entities, namely an exchange, a clearing house and

[7]For academic contributions discussing the merits of horizontal and vertical integration in the (European) securities transaction industry, see for example Milne (2002), Köppl and Monnet (2003), Tapking and Yang (2004), van Cayseele (2004), and Serifsoy and Weiss (2005).

[8]A strong advocate of vertical integration is the management of Deutsche Börse. In their view, competition among European post-trading institutions is foremost negatively affected by different regulatory regimes in Europe. See for example Seifert (2003) and Deutsche Börse Group (2005).

[9]A more elaborate discussion on this issue can be found in Serifsoy and Weiss (2005).

a settlement institution (e.g. firms B, C, and D). Evidence of the superiority of combined entities over separate entities would then lead to the conclusion that such an integration of activities is preferable, and vice versa. As will be outlined shortly,

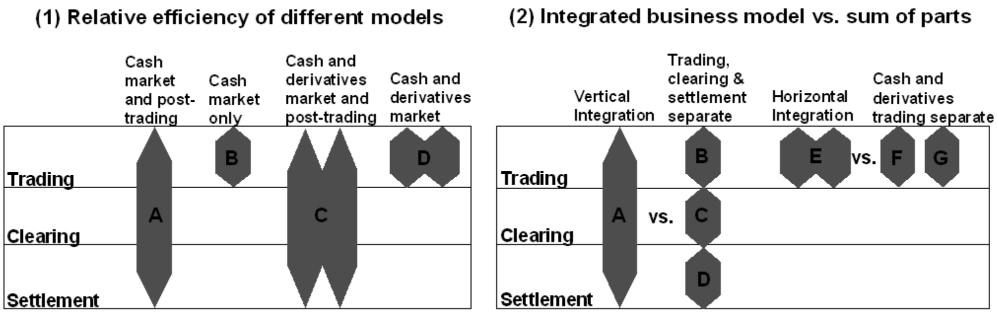

Figure 4: Two Efficiency Measurement Methods

we will limit our analysis to the first approach, measuring the relative efficiency and productivity of stock exchanges with different business models. Due to missing data on other entities providing the related activities, i.e. independent derivatives exchanges, clearing houses or settlement providers, we are not in the position of conducting an efficiency analysis outlined as the second approach.

Related literature To date, there exists only a small number of studies on how integration strategies may affect the operative performance of exchanges. We are aware of two contributions which analyze the performance of exchanges and take different business models into account. The author of both papers is Schmiedel. He analyzes stock exchange performance by employing frontier efficiency methods in order to derive relative efficiency and productivity values. He uses two different methods. While Schmiedel (2001) employs a parametric stochastic frontier model to evaluate the cost efficiency of European stock exchanges, he applies a non-parametric method in his second paper (Schmiedel (2002)).[10] Schmiedel's findings on business models are ambiguous, however. His first paper, which controls within the regression for exchanges that possess both derivatives trading and post-trading services, shows a positive impact of integration on cost efficiency[11], whereas his second paper indicates that the mean of productivity gains is lower for diversified operators[12]. In both papers the main aim is to apply the methodology on the stock exchange industry in general rather than analyzing certain aspects of the industry such as different business models.

The motivation of our paper is to fill this void by conducting a productivity analysis that devotes particular attention to business models and which uses more recent data. As in Schmiedel (2002), we will employ a non-parametric method to

[10]Both methodologies are widely accepted and were already used for efficiency measurement of financial institutions by a myriad of other papers. Berger and Humphrey (1997) provide an comprehensive survey on this topic.

[11]Confer Schmiedel (2001, p.22)

[12]Confer table 7, the 'Malmquist index'-column for "Equity only" and "Exchanges with derivatives" on page 26 of Schmiedel (2002).

calculate productivity scores, albeit using a broader set of output variables. Furthermore, we go one step further than Schmiedel by regressing the derived estimations for productivity against a set of factors mapping the frameworks in which the respective exchanges are embedded. This procedure serves to highlight whether there is a significant impact of different business models on the performance of stock exchanges.

The papers is organized as follows. Section 2 describes the methodology used in our paper. Section 3 presents the employed data and our results. An interpretation as well as the robustness of our findings are also discussed here. Section 4 concludes by summing up our findings and drawing some policy implications.

2 Methodology

This section discusses the methodology used in the paper. As outlined in section 1 the main objective of this paper is to isolate the effects of different business models on the factor productivity of stock exchanges. For that matter we first provide a brief overview of how to measure total factor productivity via a non-parametric frontier approach in section 2.1. Section 2.2 describes how the specific effects of further factors such as different business setups can be disentangled via regression analysis.

2.1 Data Envelopment Analysis and Malmquist-Productivity

In order to measure total factor productivity of stock exchanges we will first calculate relative efficiency scores via Data Envelopment Analysis (DEA) and apply these values to determine the Malmquist-productivity index, a method that captures changes in efficiency of firms over time and which bases on similar DEA-like linear programming techniques.

Data Envelopment Analysis DEA was introduced by Charnes, Cooper, and Rhodes (1978). Using their linear programming algorithm enables the calculation of relative technical efficiency[13] values for similar entities which process multiple inputs of resources into multiple outputs of products or services. Our analysis will focus on technical instead of economic efficiency as it liberates the analysis from assuming a potentially ill-defined economic objective function such as profit motivation. This is a more appropriate means to assess the relative performance between for-profit and not-for-profit entities from the same industry.[14] The efficiency of each entity under evaluation is determined by calculating the deviation

[13]The terms technical and economic efficiency were coined by Farrell (1957). In his definition, *technical efficiency* is achieved when an increase in any output requires a reduction in at least one other output or an increase in at least one other input and if a reduction in at least one input requires an increase in at least one other input or a reduction in at least one output. *Economic efficiency*, on the other hand, incorporates information on prices for the respective inputs and outputs and an economic objective to be pursued such as cost minimization or revenue maximization. It is achieved by implementing the cost minimizing or revenue maximizing production plan. Confer Fried, Lovell, and Schmidt (1993, p. 9-18)

[14]Confer for example Pestieau and Tulkens (1993, p.300-301).

each organization has from an efficient frontier. The frontier itself is set up as a piece-wise linear combination of best-practice observations spanning a convex production possibilities set. The computed efficiency value is thus a *relative* measure as it quantifies the performance of each entity in comparison to a set of "best"-performing peers. DEA is a non-parametric approach that has no predetermined functional relation between inputs and outputs, i.e. there are no a priori weights attached to these factors. Instead, the weighting of the factors that are involved in the production process is endogenously optimized for each decision making unit (DMU)[15] individually. By doing so, the weighting factors of the inputs and outputs, i.e. the underlying production technology, can vary substantially among the DMUs. This allows each DMU to attain the highest possible efficiency value subject to the constraint that the efficiency values of all remaining DMUs stay within the defined boundaries of the efficiency measure when using the same weighting scheme.[16] The resulting flexibility in the production function is an advantage whenever the true functional relationship between inputs and outputs is unknown. This is clearly the case in the stock exchange industry so that it seems sensible to allow for different types of production functions during the analysis. Considerable uncertainty also remains on the technological setting that is appropriate for this industry. As a consequence, we will calculate efficiency and productivity scores for both a constant returns-to-scale (CRS) as well a variable returns-to-scale (VRS) environment.[17]

The Malmquist-productivity index The Malmquist productivity was introduced by Caves, Christensen, and Diewert (1982). While DEA measures the relative efficiency of a DMU for a certain year, the Malmquist-productivity index compares year-on-year *changes* in technical efficiency. The method gained additional appeal when Färe et al. refined it by decomposing the productivity change into two separate effects, namely the *change in efficiency* and *technological progress*. In the following, we sketch the fundamental issues of this method.[18]

Consider the left panel of figure 5 (CRS) where a DMU's one-input (x), one-output (y) constant returns-to-scale production process is depicted for two subsequent periods t and $t+1$ with respective efficient production frontiers T^t and T^{t+1}. Irrespective of the observed input-output-combinations (x^t, y^t) and (x^{t+1}, y^{t+1}) the slopes of the two best practice frontiers indicate whether *technological progress* has occurred from period t to $t+1$. As the slope of T^{t+1} is steeper than that of T^t, technology must have progressed, for it is possible in $t+1$ to produce the same amount of output with fewer inputs. This can readily be seen when focusing on

[15]The term "DMU" was introduced by Charnes, Cooper, and Rhodes (1981) and has been widely adopted by other authors.

[16]This procedure ensures that a DMU's activity can be justified from an economic point of view as it assumes that the respective decision makers act according to certain factor prices and thus give appropriate weights to the employed inputs and produced outputs in line with the notion of striving for maximum efficiency.

[17]VRS allows for differing returns-to-scale characteristics for different levels of input-output combinations whereas CRS holds these combinations constant. Confer Banker, Charnes, and Cooper (1984) for the VRS-refinement of the linear programm.

[18]Confer Färe, Grosskopf, Norris, and Zhang (1994, p.68-75) and Fried, Lovell, and Schmidt (1993, p.50-53) for a more detailed discussion.

points b and c in the figure which determine the inputs that are required to produce the same output level y^t in the respective periods. Thus, using technology T^{t+1} enables the same output to be converted by $(0b - 0c)$ fewer inputs. To see the *change in efficiency*, one needs to take a closer look at the actual input-output combinations, i.e. (x^t, y^t) and (x^{t+1}, y^{t+1}) of the decision making unit (DMU). Apparently, neither of the two is produced in an efficient manner. Note, that the points b and f represent the minimum input levels for the given output levels y^t and y^{t+1}. As the deviation from the frontier has increased in period $t+1$ compared to period t, there was a decline in efficiency for this DMU. In total, the two factors that comprise the productivity change of the DMU are running in opposite directions in our illustration. The right panel (VRS) depicts the case for variable returns-to-scale and can be analyzed analogously. Here, $T^t \subset T^{t+1}$ which again implies that technological progress must have occurred.

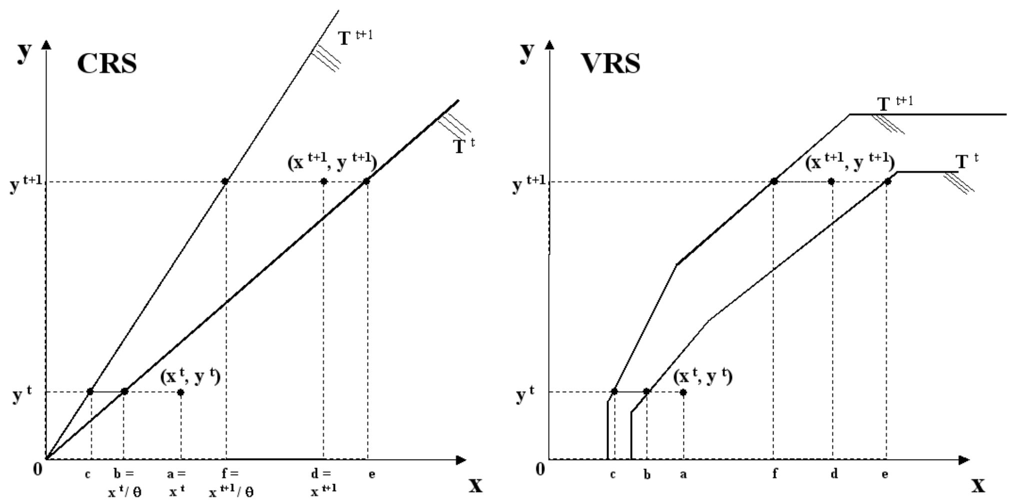

Figure 5: Input-oriented Malmquist approach for CRS and VRS

In order to determine the aggregate change in productivity, Färe et al. define input distance functions - that are the reciprocals of Farrell's technical efficiency measure - with respect to the two adjacent time periods in such a way that they measure the maximum proportional change in inputs required to make (x^{t+1}, y^{t+1}) feasible in relation to technology T^t and make (x^t, y^t) feasible in relation to T^{t+1}.[19] They define the productivity index as the geometric mean of two mixed period distance functions[20]:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}} \qquad (1)$$

[19]The methodology of Färe et al. for the output-oriented index is adapted here for the input-oriented approach. Confer Färe, Grosskopf, Norris, and Zhang (1994, p.69-70)

[20]The measurement of productivity in the VRS-case has to be treated with caution since the results could be flawed as was noted by Grifell-Tatjé and Lovell (1995). Additionally, Färe, Grosskopf, Norris, and Zhang (1994, p.73 FN 15) note that solutions from the mixed-period distance functions might not be feasible.

where the first factor uses time period t and the second factor time period $t+1$ as the respective reference technology. Equation (1) can be transformed into equation (2) which uncovers the two decomposed effects stated earlier.

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}} \quad (2)$$

The factor outside the square root indicates the change in efficiency as it is equivalent to the ratio of Farrell's technical efficiency for periods t and $t+1$. The factor under the square root displays the geometric mean of shifts in technology at output levels y^t and y^{t+1}, respectively. The calculation of the distance functions can again be illustrated by figure 5:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{0d/0f}{0a/0b} \sqrt{\frac{0d/0e}{0d/0f} \cdot \frac{0a/0b}{0a/0c}} \quad (3)$$

Note that for both factors, a value of unity indicates no change whereas a value above (below) unity signifies a positive (negative) change in technology and efficiency. Note further that exchanges that possess a low DEA-efficiency value will possess a larger potential to improve their productivity than exchanges that are already highly efficient. In the extreme, an exchange that is fully efficient in two adjacent periods cannot improve its technical efficiency at all. Therefore, we need to treat comparisons between productivity gains of highly efficient and less efficient exchanges with caution.[21]

For the m-input/s-output case, the following four DEA-like linear programs need to be solved for all $i = 1, ..., n$ DMUs in order to calculate the respective changes in productivity[22], keeping in mind that the required input distance functions are the reciprocal of Farrell's input-oriented technical efficiency measure. Thus,

$$\begin{aligned} [D^t(x_1^t, y_1^t)]^{-1} &= \min_{\theta,\lambda} \quad \theta & (4) \\ s.t. \qquad \theta X_1^t &\geq \mathbf{X}^t \lambda \\ Y_1^t &\leq \mathbf{Y}^t \lambda \\ \mathbf{1}\lambda &= 1 \quad (only\ for\ VRS) \\ \lambda &\geq 0 \end{aligned}$$

gives the distance function $D_1^t(x_1^t, y_1^t)$ of DMU 1. Similarly, $D_1^{t+1}(x_1^{t+1}, y_1^{t+1})$ is calculated by substituting the indices t by $t+1$ in equation (4). The remaining two linear problems are mixed period calculations meaning that the reference technology is constructed from data of period t (and $t+1$, respectively), whereas the input-output-combinations to be evaluated are from period $t+1$ (and t, respectively). Hence, they provide solutions for $D_1^t(x_1^{t+1}, y_1^{t+1})$ and $D_1^{t+1}(x_1^t, y_1^t)$:

[21] In our second stage regressions we will control for this effect by employing the exchanges' efficiency values as additional independent control variable.

[22] Confer Fried, Lovell, and Schmidt (1993, p. 180-186).

$$
\begin{aligned}
[D^t(x_1^{t+1}, y_1^{t+1})]^{-1} &= \min_{\theta,\lambda} \quad \theta && (5)\\
s.t. \qquad \theta X_1^{t+1} &\geq \mathbf{X}^t\lambda\\
Y_1^{t+1} &\leq \mathbf{Y}^t\lambda\\
\mathbf{1}\lambda &= 1 \quad (only\ for\ VRS)\\
\lambda &\geq 0
\end{aligned}
$$

and

$$
\begin{aligned}
[D^{t+1}(x_1^{t}, y_1^{t})]^{-1} &= \min_{\theta,\lambda} \quad \theta && (6)\\
s.t. \qquad \theta X_1^{t} &\geq \mathbf{X}^{t+1}\lambda\\
Y_1^{t} &\leq \mathbf{Y}^{t+1}\lambda\\
\mathbf{1}\lambda &= 1 \quad (only\ for\ VRS)\\
\lambda &\geq 0
\end{aligned}
$$

2.2 Regression analysis

Section 2.1 presented our approach to calculate DEA-efficiency and Malmquist-productivity values. We so far assumed to employ input and output variables into the calculation that are directly related to the operations of an exchange. Additional factors representing the framework in which the exchanges operate, such as differing business models, have so far been not included in our analysis. We will use a two-stage process that provides a linkage between these *operational* and *framework* factors. Stage one encompasses the aforementioned calculation of efficiency and productivity values and is based solely on operational inputs and outputs. In the second stage, the resulting productivity values are used as statistical estimators for productivity in the regression analysis[23] and are regressed against the framework variables. The variables employed will then explain the impact on overall Malmquist productivity (MQ) as well as on the two decomposed effects, namely on the change in technical efficiency (ΔEFF) and on technological progress ($\Delta TECH$). This procedure enables us to disentangle the individual effects of framework variables and provides a solid basis to judge whether there are significant differences along the varying business models. Hence, we obtain three regression models:

$$
\begin{aligned}
MQ_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} && (7)\\
\Delta EFF_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} && (8)\\
\Delta TECH_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} && (9)\\
where \qquad \epsilon_{i,t} &= \alpha_i + \eta_{i,t} \qquad respectively
\end{aligned}
$$

[23] We also regressed against the efficiency values employing a Tobit random effects regression model. This procedure is necessary as the efficiency values are truncated from above at a value of one. Confer Dusansky and Wilson (1994) and McCarty and Yaisawarng (1993) for a similar approach. We present our results in table 7 of appendix D.

Here, $MQ_{i,t}$, $\Delta EFF_{i,t}$ and $\Delta TECH_{i,t}$ represent the values of Malmquist productivity, change in technical efficiency and technological progress of exchange i from period $t-1$ to period t, respectively. Hereby, $X_{i,t} = [1 \quad x']$ is a $((1 \times (K+1))$ vector of K framework variables plus one and β is an $((L+1) \times 1)$ vector of parameters. In these regressions we will use a fixed effects model, since the Hausman tests mostly reject the hypothesis that there is no systematic difference between the fixed and the random effects estimation - as we will see in section 3.3.2.[24] We will make use of $K = 11$ framework variables due to be presented in section 3.2. Additionally, we will employ the calculated DEA-efficiency value of period $t-1$ (EFF_{t-1}) of each exchange as a further independent variable in order to control for the fact that less efficient exchanges can potentially improve their productivity by a larger extent than highly efficient exchanges.[25] Since the dependent variables are calculated by comparing two adjacent periods, i.e. MQ_t consumes data from periods t and t-1, we have four observations per DMU. Thus, we regress for $i = \{1, ..., n = 28\} \times t = \{1...(T-1) = 4\} = 112$ observations.[26]

3 Data and empirical results

3.1 The sample

The study employs a balanced panel data set that includes 28 stock exchanges for a five year time period (1999-2003) as can be seen in table 1.

The sample encompasses five exchanges from the Americas, fourteen from Europe/Africa and nine from the Asia/Pacific region. All relevant accounting and transaction data have been converted into US-dollars and adjusted for inflation.[27] Although the sample lacks completeness of the whole exchange population, it does comprise on average 85% of the total equity trading volume on stock exchanges reported to the World Federation of Stock Exchanges (FIBV) by roughly 75 exchanges.

In order to see how representative our sample is concerning the discussed business models, we re-present a modified version of figure 1, which shows the exchanges' related activities in our sample as a portion of the 50 largest trading venues worldwide. The filled areas of the bars represent the number of exchanges that are part of our sample. As can be seen, we included all exchanges that provide software services, whereas we incorporated more than half of the exchanges with derivatives

[24] The Hausman specification test verifies whether the coefficients of a regression model with random effects are unbiased compared to the coefficients of a fixed effects model. The underlying assumption is that fixed effects models always produce consistent but potentially inefficient estimators whereas a random effects model is always efficient but can be inconsistent. Confer for example Johnston and DiNardo (1997, p.403-404) or Greene (1993, p.479-480) for further details.

[25] Confer our explanation in section 2.1, formula (2) and footnote 21.

[26] In order to employ White-corrected estimators to control for cross-sectional heteroscedasticity we use EViews 5 as statistical package.

[27] The accounting data was acquired from the annual reports of the exchanges, whereas transaction and other descriptive data was obtained from the databases of the FIBV, the Federation of European Stock Exchanges (FESE), the HP Handbook of World Stock, Derivatives & Commodity Exchanges 2001, 2002 and 2003, direct correspondence with the exchanges, company web sites and general internet research.

No.	Exchange	Region	Related Activities			Avg. World
			Post-Trading	Derivatives	Software	Market Share
1	BOVESPA	Americas	-	√	-	0.2%
2	Lima	Americas	-	2003-	-	0.0%
3	NASDAQ	Americas	-	-	-	25.7%
4	NYSE	Americas	-	-	-	25.1%
5	Toronto TSX	Americas	-	-1999	2002-	1.1%
6	Budapest	Europe/Africa	-	√	-	0.0%
7	Copenhagen	Europe/Africa	2000-	√	-	0.2%
8	Deutsche Börse	Europe/Africa	2000-	√	√	3.7%
9	Euronext†	Europe/Africa	√	√	√	7.7%
10	Hellenic*	Europe/Africa	2000-	2002-	2000-	0.2%
11	Istanbul	Europe/Africa	-	2001-	-	0.1%
12	Johannesburg JSE	Europe/Africa	√	2001-	-	0.2%
13	London	Europe/Africa	-	2003-	-	10.0%
14	Malta	Europe/Africa	√	-	-	0.0%
15	Oslo	Europe/Africa	-	√	-	0.2%
16	OM Gruppen	Europe/Africa	2001-	√	√	1.0%
17	SWX Zurih	Europe/Africa	-	√	-	1.5%
18	Vienna	Europe/Africa	2000-	√	-	0.0%
19	Warsaw	Europe/Africa	-	√	-	0.0%
20	Australian	Asia/Pacific	√	√	-	0.7%
21	Hongkong	Asia/Pacific	√	√	-	0.7%
22	Jakarta	Asia/Pacific	√	-	-	0.0%
23	Kuala Lumpur	Asia/Pacific	√	√	-	0.1%
24	Phillippine	Asia/Pacific	2003-	-	-	0.0%
25	Singapore SGX†	Asia/Pacific	√	√	2000-	0.2%
26	Taiwan	Asia/Pacific	√	-	-	1.8%
27	Thailand	Asia/Pacific	√	-	-	0.1%
28	Tokyo	Asia/Pacific	√	√	2002-	4.8%
	Total		17	20	7	**85.2%**

*: Athens Stock Exchange in 1999
†: Pro forma figures for 1999
√: Exchange possessed this activity since 1999 or earlier

Table 1: Sample of exchanges used in the analysis, 1999-2003

trading and about a third of the exchanges with post-trading services. Hence, particularly exchanges with post-trading facilities are underrepresented in our sample. This is due to this group's relatively large portion of mutual exchanges - as was observable in figure 2. These exchanges are usually not obliged to comprehensively disclose their activities to the public. Hence, we were not able to include these exchanges in our sample due to a lack of available comprehensive information.

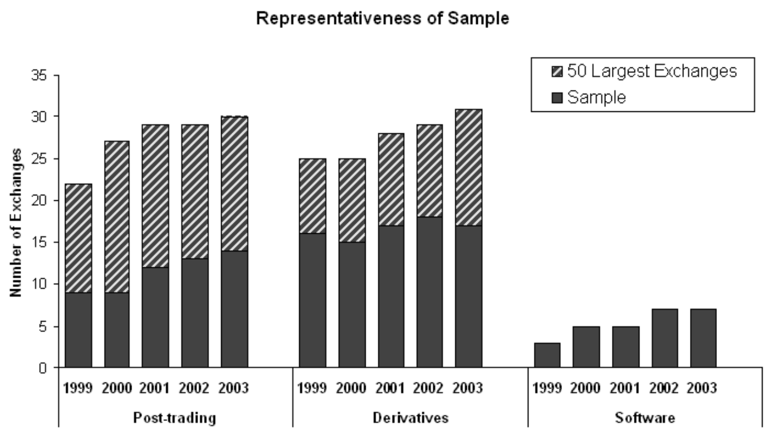

Figure 6: Representativeness of Sample

3.2 Variables

Table 2 provides an overview of the two different sets of variables employed in the analysis. They will be discussed in sections 3.2.1 and 3.2.2. Accompanying descriptive statistics on the variables are given in Appendix A.

	FIRST STAGE: Operational Variables
	Inputs
$\mathbf{x^1_{i,t}}$	Number of staff employed at exchange i in period t (year-end figures)
$\mathbf{x^2_{i,t}}$	Tangible assets at exchange i in period t (in thousand dollars)
	Outputs
$\mathbf{y^1_{i,t}}$	Number of listed companies at exchange i in period t
$\mathbf{y^2_{i,t}}$	Total trading volume in bonds and shares at exchange i in period t (in million dollars)
$\mathbf{y^3_{i,t}}$	Total number of derivatives contracts traded at exchange i in period t
$\mathbf{y^4_{i,t}}$	Post-trading services and software sales at exchange i in period t (in thousand dollars)
	SECOND STAGE: Framework Variables
	Business Model
$\mathbf{HORIZONTAL_{i,t}}$	Dummy variable indicating whether exchange i operates a derivatives platform in period t.
$\mathbf{VERTICAL_{i,t}}$	Dummy variable indicating whether exchange i provides post-trading services in period t.
$\mathbf{HORI-VERTICAL_{i,t}}$	Dummy variable indicating whether exchange i is both vertically and horizontally integrated in period t.
$\mathbf{FULL\ INTEGRATION_{i,t}}$	Dummy variable indicating whether exchange i is both vertically and horizontally integrated and also provides software services in period t.
$\mathbf{OUTSOURCING_{i,t}}$	Dummy variable indicating whether exchange i has outsourced its IT-system in period t.
	Governance
$\mathbf{DEMUT_{i,t}}$	Dummy variable for demutualized exchange i in period t
$\mathbf{LISTED_{i,t}}$	Dummy variable for publicly listed exchange i in period t
	Competitive Position and Attractiveness of the Capital Market
$\mathbf{LIQUIDITY_{i,t}}$	Level of liquidity at exchange i in period t. Liquidity is defined as the ratio of annual trading volume in domestic equity and market capitalization of domestic firms. (year-end figures, in %)
$\mathbf{\Delta TRADING_{i,t}}$	Relative y-o-y change in equity trading at exchange i from period t-1 to period t. The exchange's percentage change in trading volume is deducted by the sample median change of trading volume (year-end figures, in %)
$\mathbf{FOREIGN\ LISTING_{i,t}}$	World market share in new listings of foreign companies at exchange i in period t measured as the portion of new foreign listings at exchange i compared to the total number of new foreign listings worldwide (year-end figures, in %).
	Financial Flexibility
$\mathbf{\Delta LTFINANCE_{i,t}}$	Growth of equity and long term debt on exchange i's balance sheet from period t-1 to period t. (book values, year-end figures, in %)
	Control Variable
$\mathbf{\Delta EFF_{i,t-1}}$	Corresponding efficiency values (CRS or VRS) of exchange i in period t-1.

Table 2: Variables used in the two-stage process

3.2.1 Operational variables

In the first stage, the Malmquist-index calculations will be based on variables that are directly related to the operations of an exchange and can be influenced by the management. An appropriate choice of variables that represent the "production process" of an exchange is not a clear-cut task.[28] When considering plausible input variables, it seems sensible to cover both capital and labor aspects of the production process. Thus, labor will be approximated by the *number of staff* working for an exchange i in period t ($x^1_{i,t}$) whereas the utilization of capital for investments such as the setup of an IT-infrastructure, a trading space and the necessary buildings are subsumed by the value of *tangible assets* employed at exchange i in period t ($x^2_{i,t}$).

On the output side, four different services are considered that are 'produced' by an exchange. The variable $y^1_{i,t}$ stands for the *number of listed companies* at exchange i in period t. It will be used as a proxy for the exchange's effort to monitor the listed firms on the exchange in order to ensure fair trading and equal disclosure practices of company-specific information. Thus, the supervision of listed firms can be regarded as a service for trading participants to achieve market transparency. Secondly, the total *trading volume* in equities as well as in bonds will approximate the activities of exchange i on the cash market in period t ($y^2_{i,t}$).[29] As several exchanges have diversified their businesses into related activities such as derivatives trading and post-trading services as well as into the development and maintenance of exchange-related software systems, it is necessary to include them in the output set. Therefore, variable $y^3_{i,t}$ captures the total *number of derivative contracts* traded on the forward markets. Variable $y^4_{i,t}$ represents the *revenues from post-trading activities and software sales* at exchange i in period t. The use of revenue numbers for the latter variable is not the most appropriate figure to be included in the output set. The number of clearing and settlement transactions serviced and the number of software systems sold would have been better proxies. However, due to the lack of this type of data for all exchanges in our sample, we opted for this proceeding.

Before proceeding to the next paragraph a few words should be devoted to the choice of the proper DEA-model. Considering the applied inputs and outputs in this paper it makes sense to use an input-oriented DEA-model since the number of staff and the tangible assets of an exchange can be more directly altered by the management than the level of demand for their products and services. Thus, the management's effort to reduce the exchange's inputs seems to be a fairer yardstick than its exertion to augment the venue's output levels.

[28] Depending on the input and output variables incorporated in the calculation, the efficiency scores might have a bias towards certain DMUs. As an example, consider omitted output variables that only some DMUs in the sample produce. If we cannot adjust the input variables of these DMUs accordingly in such a manner that we merely include the amount of inputs devoted to the outputs considered in the calculation the unadjusted input value will be too high. We mitigate this problem by calculating productivity scores for the broadest possible output-set, for it is easier to obtain information on additional outputs than to acquire a detailed breakdown of the used inputs in order to adjust them for the omitted outputs.

[29] The employment of the number of transactions performed on an exchange would have been a more precise measure of the activity. Unfortunately, this sort of data was not available for all 28 exchanges.

3.2.2 Framework variables

The second stage now considers additional determinants arising from the framework in which an exchange is embedded and that may also have an influence on its performance. As noted by Fried, Lovell, and Schmidt (1993, p.53-54), the variables of the second stage may have an impact on the efficiency with which inputs are transformed to outputs, but they should not affect the production process itself. Thus, the authors maintain the requirement that the variables of the first and second stage are uncorrelated.[30] We will consider four types of factors that deserve particular attention and present corresponding variables that will function as proxies in our regressions. These are (1) the exchange's business model (2) exchange's corporate governance regime (3) the competitive environment and the attractiveness of the exchange's home capital market and (4) the exchange's financial flexibility.

Business model As outlined in section 1, several exchanges extended their activities to other areas besides the operation of a cash market. Some exchanges integrated horizontally by providing an institutionalized derivatives trading venue, others followed a vertical silo model by integrating post-trading services into the existing operations. Yet others are engaged as software-systems providers, most notably for other stock exchanges. As a consequence, there are several distinct business models present in this industry which could have different effects on the exchanges' productivity: On the one hand, the integration of certain activities could be beneficial due to potential synergies. Consider for example the combination of a cash and a forward market, which could be operated by a single trading system, and would therefore save (input) resources. In a similar fashion one could expect economies of scope when combining trading and post-trading services by utilizing a common transaction platform.[31] Furthermore, it could be argued that exchanges with a pronounced software development competence are more apt in technologically integrating different activities and thus avoiding (technical) inefficiencies when operating them. However, there are also potential drawbacks attached to integration activity. A combination of several business lines may lead to diseconomies due to the difficulty to efficiently manage an increased level of complexity of business processes. Therefore, it is difficult to provide ex ante expectations of the productivity characteristics of certain business models. To test for any differences in productivity among these business setups we will employ four dummy variables covering five distinct business models. By doing so, we explicitly distinguish between cash markets-only operators and exchanges that operate (1) both a cash and a forward market using a dummy variable denoted as $HORIZONTAL$ (2) a cash market and post-trading facilities employing a variable denoted as $VERTICAL$ (3) a cash and

[30] However, for some of our variables we cannot maintain this point as can be seen in appendix C, where table 6 displays the correlation among the employed variables. In particular the correlation between the first stage variables x^1, x^2, y^1, and y^2 with the second stage variables $FOREIGN$ $LISTING$ and $LIQUIDITY$ is highly positive. Therefore our coefficient estimates may possess some bias. Nevertheless, our findings remain robust when we drop the latter variables from our regressions as displayed in table 8.2.

[31] Confer Serifsoy and Weiss (2005) for a discussion on the European securities transaction industry from an industrial organization perspective.

a forward market as well as post-trading facilities by introducing a dummy denoted as $HORI - VERTICAL$ and (4) all of these activities as well as a software sales division. Exchanges that fall under this category will receive a value of one at a dummy variable denoted as $FULL\ INTEGRATION$.[32]

Some exchanges do not develop and operate their trading systems themselves but buy this service from an external provider. Thus, such an exchange rather incurs additional operating costs, which primarily materialize in the profit-loss statement and to a much lesser extent in its staff size and its tangible assets, which are the considered input factors in our analysis. Therefore, ignoring the outsourcing of IT-services would ceteris paribus result in a disadvantage for exchanges that develop their own trading system by employing staff and assets for that matter. Consequently, we need to control for this aspect. We do so by employing a dummy variable, denoted as $OUTSOURCING$, which equals one when the exchange under consideration outsources its trading system. Since outsourcing ceteris paribus reduces the required input factors and hence increases the calculated efficiency values, we would expect a positive coefficient sign at this variable.

Governance We consider three different governance regimes, namely a (1) mutual structure (2) a demutualized, customer-dominated structure and (3) a demutualized, outsider-dominated structure. The distinction between the latter two forms is whether the stock exchange is publicly listed. To operationalize the distinctions, we define two dummy variables as shown in table 2. The variables can take the following configurations: (1) A mutual exchange, denoted as $DEMUT = 0 \wedge LISTED = 0$, i.e. neither demutualized nor listed. (2) A demutualized exchange, denoted as $DEMUT = 1 \wedge LISTED = 0$, i.e. demutualized but not listed. (3) A publicly listed exchange, denoted as $DEMUT = 1 \wedge LISTED = 1$, i.e. both demutualized and listed.[33] Note that the $LISTED$-variable will only display the additional influence, i.e. on top of being demutualized, on stock exchange efficiency and productivity. Ex ante, we would expect that both demutualized and listed exchanges will outperform mutuals in both efficiency and productivity scores. Furthermore, since some authors emphasize the importance of being publicly listed in order to operate efficiently[34], we expect a stronger performance by outsider-dominated exchanges.

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[32] Other combinations of business models such as "cash market and software" or "cash and derivatives market and software" were omitted since the subsample size was too small to draw inferences. As a consequence, we subsumed the Toronto Stock Exchange under "cash only"-operator in 2002 despite their operations in software sales. In an analogous manner we assigned the OM-Gruppen (in 1999-2000) and the Deutsche Börse (in 1999) to the $HORIZONTAL$-variable although both firms possessed a software division in the indicated periods. Finally, we assigned the Hellenic Exchange to the $VERTICAL$-variable in 2000 and 2001 with the same reasoning. An additional problem occurred here as we were not able to get transaction data of Hellenic's derivative trading activity. Therefore, since their derivatives activity was not taken into account during the first stage productivity calculation, we decided to treat them in a similar way in the second stage. Otherwise we could have assigned the exchange to the $FULL\ INTEGRATION$-variable in 2000 and 2001 as they both possessed derivatives trading and software sales activities.

[33] Note that the configuration $DEMUT = 0 \wedge LISTED = 1$ does not exist, since all listed exchanges underwent a demutualization process before.

[34] Confer for example OECD (2003).

Competition and attractiveness of capital market A meaningful variable that captures the exchange's competitive environment and the general attractiveness of its home capital market, is difficult to find. Nevertheless, since the omittance of competitive pressure and capital market attractiveness as an influencing variable would not be satisfactory, a crude measurement is attempted. In the following we present three variables that accentuate distinct aspects.

Our first variable, denoted as $LIQUIDITY$, measures the *depth* of the market operated by an exchange and thereby provides a proxy for an exchange's importance and market power vis-à-vis other exchanges. A common way to calculate the existing level of liquidity on an exchange's trading platform is simply to divide the annual (equity) trading volume by the market capitalization of the firms listed on the exchange.

The second variable, denoted as $\Delta TRADING$, proxies an exchange's *performance* capturing year-on-year changes in the competitive position. To operationalize, we employ year-on-year (y-o-y) changes in equity trading volume at an exchange. In order to control for broader market movements we deduct the median y-o-y change of the whole sample from each exchange's performance in the respective period. The rationale behind this procedure is the following: A relative gain in trading volume, i.e. the exchange was able to capture more trading volume than the median exchange of the sample, signals a relatively strong competitive position as opposed to other exchanges. By contrast, a relative loss in trading volume would suggest a deterioration in the competitive position.

Our third variable, denoted as $FOREIGN\ LISTING$ captures the general *attractiveness* of the exchange's home capital market by calculating an exchange's market share in new foreign firms listings as a percentage of the total new foreign listings worldwide. We believe that this describes the general attractiveness of a capital market quite well since there are mainly two reason for such a behavior by a foreign firm: Either the firm is forced to list abroad for its home capital market is not attractive or it lists itself additionally on foreign exchanges in order to seek capital from these markets that presumably possess a large and thus attractive pool of potential investors.[35]

When we regress these variables against the technical efficiency and productivity of an exchange, it is difficult to establish an ex ante expectation concerning the theoretically correct sign of the regression coefficients. Both directions seem plausible. Consider for example the $LIQUIDITY$-variable: An exchange with a relatively deep market can be considered to be in a strong competitive position which may result in a better exploitation of its resources and thus in higher efficiency. The contrary may also hold as monopolistic inertia symptoms could cause excessive (input) spending and contribute to lower efficiency values. We would argue that both directions of the coefficient's sign of the $FOREIGN\ LISTING$-variable can be explained in a similar fashion. The $\Delta TRADING$-variable may also display differing

[35] Support for this notion can be found in an empirical paper on cross-listings by Pagano, Randl, Röell, and Zechner (2001) who find that firms seeking cross-listing tend to choose foreign capital markets with large and liquid markets as well as where investor protection and efficiency of courts are high.

signs: It could have a positive sign when the relative loss in trading volume causes a decrease in efficiency. This will be the case when unfavorable market conditions coincide with lower absolute equity trading volumes, since this will negatively affect the level of the DEA-output variable $y_{i,t}^2$ and thus ceteris paribus a decrease of the efficiency value. Yet, the sign could also be negative when a relative loss in trading volume means that the exchange overcompensates this by a disproportionate reduction in the input variables and thereby achieves higher efficiency values. By the same token a DMU could spend overly much in its inputs than the increase in trading volume would allow to do so.

Financial flexibility In reality we observe that several exchanges raised external funds in order to finance the modernization of their trading venues or to pursue other projects that were aimed to boost their competitiveness.[36] Thus, the financial flexibility of an exchange, i.e. its ability to raise new funds to finance future investments may also have an effect on an exchange's efficiency and productivity, albeit it remains ex ante unclear whether it will be a positive or an adverse one. On the one hand, it could lead to inefficiencies due to overinvestments resulting from (too) abundant funds. On the other, the capability of acquiring new proceeds could be a necessary prerequisite to induce efficiency-enhancing investments. We employ a variable which seeks to capture the exchange's inflow of new proceeds in long term capital in a certain period. Ideally, we would measure this by looking at the respective cash flow statements of each exchange in order to capture the actual capital inflow. However, these figures are not available for all exchanges. Hence, we are forced to use a less accurate means and employ a variable denoted as $\Delta LTFINANCE$, which denotes the year-on-year change in equity and long-term debt as is stated in the exchanges' balance sheets.[37]

3.3 Results

3.3.1 Results from the first stage

In Appendix B, table 5 presents the first-stage results of the DEA-efficiency and Malmquist-productivity analysis for both constant and variable returns-to-scale.[38] The results of the efficiency scores indicate that four exchanges, namely Copenhagen, Deutsche Börse, Euronext and Malta, are fully efficient in all five considered periods in the VRS-case, whereas there are only two such cases in the CRS-environment (Copenhagen and Euronext). Both underlying technologies display an overall increase in mean productivity except for the 2001/2002-period where we calculated an overall stagnation in productivity. The most remarkable increase is

[36]Most explicitly this has occurred at exchanges that went public but one can imagine that - irrespective of the governance - fresh capital was provided for the exchanges to better cope with increased competitive pressure.

[37]In order to prevent distortions from currency fluctuations we use inflation-adjusted book values of the exchanges' home currencies.

[38]We are grateful to Holger Scheel whose program 'EMS' we utilized for the calculation of the efficiency and productivity scores.

accomplished by the Brazilian exchange BOVESPA, which improved its productivity by an annual arithmetic average of 29% to 34% for the respective settings.

3.3.2 Results from the second stage

Table 3 displays the results from the regression analysis using the first stage results as dependent variables as was outlined in section 2.2.

	Constant Returns-To-Scale			Variable Returns-To-Scale		
	(2) MQ	(3) ΔEFF	(4) ΔTECH	(5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	-0.199	-0.321***	0.132**	-0.098	-0.206***	0.098
Std. Err.	*0.143*	*0.127*	*0.061*	*0.129*	*0.040*	*0.103*
VERTICAL	-0.447***	-0.507***	0.072	-0.457***	-0.348***	-0.101
Std. Err.	0.096	0.112	0.076	0.114	0.125	0.083
HORI-VERTICAL	-0.331***	-0.381***	0.065	-0.243***	-0.222***	-0.043
Std. Err.	*0.097*	*0.071*	*0.109*	*0.064*	*0.021*	*0.085*
FULL INTEGRATION	-0.164*	-0.300***	0.115*	-0.058	-0.194	0.092
Std. Err.	*0.092*	*0.056*	*0.065*	*0.090*	*0.153*	*0.186*
OUTSOURCING	-0.239***	-0.427***	0.213***	-0.290**	-0.399***	0.155**
Std. Err.	*0.075*	*0.065*	*0.055*	*0.145*	*0.099*	*0.072*
DEMUT	-0.007	-0.190***	0.210**	-0.093**	-0.124**	0.035***
Std. Err.	*0.042*	*0.053*	*0.094*	*0.046*	*0.054*	*0.006*
LISTED	0.011	-0.055	0.051†	0.064	-0.041	0.115†
Std. Err.	*0.133*	*0.106*	*0.032*	*0.137*	*0.122*	*0.075*
LIQUIDITY	-0.017	0.011	-0.041	-0.012	0.065	-0.057
Std. Err.	*0.020*	*0.028*	*0.034*	*0.039*	*0.061*	*0.094*
ΔTRADING	0.019	-0.036	0.067	0.046†	0.003	0.066
Std. Err.	*0.032*	*0.026*	*0.054*	*0.028*	*0.071*	*0.079*
FOREIGN LISTING	0.649	-0.810	1.641*	-0.468	-0.247	-0.285
Std. Err.	*0.678*	*0.990*	*0.960*	*0.786*	*0.504*	*1.073*
ΔLT FINANCE	-0.060	0.015	-0.084***	-0.047	0.060	−0.117†
Std. Err.	*0.072*	*0.080*	*0.033*	*0.081*	*0.068*	*0.080*
EFF	-0.993***	-0.917***	-0.085	-0.531**	-0.984***	0.379**
Std. Err.	*0.307*	*0.349*	*0.137*	*0.224*	*0.325*	*0.166*
CONST	1.958***	2.079***	0.894***	1.721***	2.030***	0.757***
Std. Err.	*0.174*	*0.149*	*0.031*	*0.128*	*0.220*	*0.136*
Observations	112	112	112	112	112	112
R^2(adj.)	0.329	0.413	0.064	0.304	0.375	-0.070
Hausman Test (p)	0.0004	0.0001	0.0778	0.0024	0.0000	0.4287

Table 3: Results from the second-stage regression analysis

The table presents the results of White-corrected regressions against Malmquist-productivity (MQ), change in technical efficiency (ΔEFF) and progress in technology ($\Delta TECH$). The table is divided into two panels. The left panel displays the results for constant returns-to-scale. The right panel provides our estimations when assuming variable returns-to-scale. We indicated the coefficients' levels of significance by the symbols †, $*$, $**$, $***$, representing 15%, 10%, 5% and 1% significance levels, respectively. Additionally, we numerated the columns (2-7) for convenience. Overall, the adjusted R^2-values of the productivity regressions are reasonable, save for the less appealing values in columns four and seven. When comparing the individual coefficients between the two panels we find that their signs, if they are significant, do not change. The results of the Hausman test demonstrate that a random effects model is likely to produce inconsistent estimates for our regressions in all but one case (column seven), since the p-values display a significant rejection of the null-hypothesis. Thus, the use of a fixed effects model is more appropriate.

Influence of governance We find no significant evidence that demutualized exchanges have a higher productivity than mutual exchanges in the CRS-case whereas in the VRS-case they perform even significantly worse compared to mutuals. The source of the underperformance is explained in both technology settings by a significantly negative value in changes of technical efficiency (ΔEFF) as can be seen in columns three and six indicating that mutual exchanges were more able to improve their technical efficiency. However, the demutualized exchanges' progress in technology ($\Delta TECH$), the second component of productivity, is significantly higher than at mutual exchanges (columns four and seven). As a result, demutualized exchanges are able to compensate their underperformance in ΔEFF in the CRS-case and reach an overall productivity that converges with that of the mutuals' average performance. In the VRS-case however, the higher technological progress is not sufficient to recoup the underperformance in ΔEFF. As a consequence, the resulting aggregate effect for productivity growth is here on average lower vis-à-vis the mutuals' performance (column five).

The $LISTED$-variable, which indicates the additional effects of an outsider-owned governance structure on productivity remains largely negligible. The only noticeable significance can be observed in columns four and seven. Here, due to a significantly positive sign, we find evidence that the observed pattern of demutualized exchanges, i.e. a higher technological progress, is more pronounced for publicly listed exchanges.

Influence of competition, financial flexibility, efficiency The impact of variables representing the competitive environment on exchange productivity is mostly insignificant. Our variable representing the financial flexibility of an exchange, i.e. $\Delta LT\ FINANCE$, displays no significant result except for a negative relation with technological progress (column four and seven). The control variable EFF shows that productivity indeed is lower for exchanges that possess higher efficiency values (columns two and five). Thus, productivity gains are easier to accomplish for exchanges with lower efficiency values.

Although some interesting points could be derived from our results so far, we want to emphasize that the discussed variables were primarily introduced as control variables. Our main focus aims on the influence of our business model variables, which will be discussed in the following.

Influence of business models From our $OUTSOURCING$ variable we infer that outsourcing significantly reduces overall productivity (columns two and five). Focusing on the sources of this underperformance we observe that the reduction stems primarily from the negative effect on improvements in technical efficiency (columns three and six), which cannot be recouped by the significantly positive effect of outsourcing on the technological progress (columns four and seven). However, our Tobit regressions in appendix D indicate that outsourcing has a positive effect on the *efficiency* of exchanges. Depending on the assumed technology, the effect lies between 7.4 and 13.4 percentage points. Thus, as productivity growth of these exchanges is lower we conclude that it is more difficult for these exchanges to improve efficiency by the same amount as less efficient exchanges.

Our business model variables indicate that the integration of related activities does not enhance productivity. In the contrary, our variables $VERTICAL$ and $HORI - VERTICAL$ indicate that these forms of integration lead to significantly lower overall productivity compared to cash market-only operators. While vertically integrated exchanges - depending on the considered technological setting - are on average 44.7 to 45.7 percentage points less productive than cash market-only operators (columns two and five), the underperformance is less pronounced for exchanges that are both horizontally and vertically integrated. Here, we calculate a lower productivity of 24.3 and 33.1 percentage points as opposed to cash market operators (columns two and five). In both cases, lower improvements in technical efficiency (ΔEFF) are responsible for the overall lower productivity growth (columns three and six). At first glance, horizontally integrated exchanges at least do not seem to be less productive than cash market exchanges as their overall productivity is not significantly different from zero (columns two and five for the $HORIZONTAL$-variable). However, the negative signs of the overall productivity in columns two and five suggest that this business model could be inferior in overall productivity growth. This is confirmed by our robustness checks which show that the coefficients turn significantly negative.[39] As before, the main reason lies in the lower ΔEFF-values, which remains on average between 20.6 and 32.1 percentage points below the values of cash market operators (columns three and six). Exchanges that provide all of the considered additional activities under one roof and which are subsumed by the $FULL\ INTEGRATION$-variable also display a weakly significant underperformance by 16.4 percentage points in the CRS-case (column two) and no significantly different performance in the VRS-setting (column five). In contrast to our $HORIZONTAL$-variable, however, our robustness checks indicate here that the finding of a significantly negative performance in the CRS-case cannot be supported in alternative regressions and in our bootstrap estimation. This leads us to the conclusion that fully integrated exchanges do not seem to be significantly less productive than cash market-only venues.

Our Tobit-regressions on the *efficiency* of these business models mostly confirm our findings on productivity growth. As indicated in appendix D, none of these setups is significantly more efficient than cash market-only operators while there is some evidence that exchanges with both derivatives and post-trading (i.e. the $HORI - VERTICAL$-case) are even less efficient in the VRS-case.

Interpreting the results of the business model variables The results from the business model variables indicate that a combination of activities is not necessarily productivity-enhancing. In the contrary, exchanges that merely focus on cash-markets seem to perform superior in productivity growth vis-à-vis some other setups. A possible reason why for example the additional provision of derivatives trading creates technical inefficiencies could be related to the inability of the exchanges to combine this activity with their existing cash market operations in a

[39] Refer to our discussion on robustness checks in the next but one paragraph.

resource saving manner. As the Economist noted in a recent issue, most exchanges offering cash and derivatives trading have not yet consolidated these services onto a single platform.[40] Instead, the exchanges usually provide cash and derivatives trading on two separate platforms, which adds to the complexity of the business process on the one hand, and which on the other hand does not take advantage of potential scope economies. An analogous reasoning can be established for vertically integrated exchanges. Since institutions that combine cash trading and post-trading activities also perform poorly in their ability to improve technical efficiency we conclude that potential benefits from combining these activities on productivity are outweighed by the increased complexity resulting thereof to manage the operations efficiently. Our findings, however, do not give conclusive evidence whether these forms of integration are indeed inefficient. For that purpose, we would need to measure efficiency according to the second methodological approach, as was indicated in figure 4. Furthermore, we do not imply that (profit-oriented) exchanges should not diversify into related businesses as the integration may still be a profitable investment for them. Finally, it may also be possible that diversification strategies are more driven by risk reduction motives than by the exploitation of potential scope economies.[41]

It comes a little surprising that the most complex business model does not seem to suffer too much from its complexity as it displays a productivity growth that is comparable to that of cash market-only operators. Since the distinction between this business model and the others lies in the exchanges' provision of software services, we suggest that this activity could be a critical driver for efficient integration strategies. It seems that strong IT-competence in the form of an in-house software development and sales division plays a pivotal role for exchanges with multiple business lines as most transaction activities are nowadays IT-based. It facilitates an efficient interconnection and organization of the different transaction platforms within the institution. Furthermore, economies of scale might be realizable when the (fixed) development costs of transaction software are spread over more than one platform.[42]

Robustness of findings To check the robustness of our results, in particular of our findings on the business model variables, we conducted several robustness checks. On the one hand, we changed the composition of our regression model in several ways to verify if this has any significant impact on our business model variables. On the other hand, we verified the validity of our inference by using bootstrapped standard errors for our regressions.[43] In appendix E we present tables

[40] Confer Economist (2005).

[41] In the extreme, this policy may not even be in the interest of the exchange but rather of risk-averse managers as described by Amihud and Lev (1981) for conglomerates in general.

[42] A software programmer, who works with the Deutsche Börse, indicated that the company's transaction software for cash trading (XETRA) and derivatives trading (EUREX) base on comparable programming algorithms which would confirm the notion of potential economies of scale in software development.

[43] In particular, we replicated a random drawing with replacement from our sample 2000 times in order to derive a frequency distribution of coefficient estimates that allows us to estimate a sample-specific standard error. Furthermore, we constructed 85%, 90% and 95%-confidence intervals by using the 2.5%, 5%, 7.5% and the 92.5%, 95%, 97.5% percentiles of the distribution, respectively. We also controlled for our panel data structure by using clusters. Confer Bradley and Tibshirani

8 and 9 that indicate the results of alternations to our model. Tables 8.1 and 8.2 display the impact on the business model variables when the variables describing the financial background and governance as well as the competitive situation of an exchange are omitted, respectively. Tables 9.1 and 9.2 show regressions where competition-variables are substituted by other variables from the same field. Our alternations focus primarily on competition variables since here we have the least certainty about the appropriateness of the employed variables. To be more precise, in table 9.1 we replace the $\Delta TRADING$-variable by the same variable with a one-year lag in order to provide more reaction time for the management to act on changing market circumstances. Table 9.2 displays the results when substituting the $\Delta TRADING$-variable by a $\Delta LIQUIDITY$-variable, which provides information on the y-o-y change in liquidity subtracted by the median liquidity change of the whole sample. Finally, table 10 shows our regression results when utilizing the bootstrap method.

Overall, we find that the variables' coefficients from our original regression model are quite robust. There are very few changes in the coefficients' signs and all of those occur for coefficients that have been insignificant in the original regression or turn insignificant during the robustness check. Two points are worth mentioning as they influenced our perception of their overall productivity performance. First, the $HORIZONTAL$-variable turned significantly negative in tables 8.2, 9.1, and in our bootstrapped regressions (table 10). Second, the $FULL\ INTEGRATION$-variable turns insignificant in tables 8.1, 9.2 and in the bootstrapped regressions of table 10. Therefore, we consider the former variable's coefficient as likely to be significantly negative whereas the latter variable's coefficient is likely to be insignificant.

4 Conclusion

This paper discussed the ongoing trend of business diversification within the stock exchange industry for the years 1999 to 2003 and sought to measure potential differences in productivity growth that are attributable to differing business models. We noticed that most of the integration activity in these years was conducted by profit-oriented, demutualized exchanges, whereas mutual exchanges largely focused on their existing operations, save for a few entities that diversified into derivatives trading activities. We presume that the reason for these different patterns lie in the diverging ownership structures and the resulting objective functions of the exchanges. While profit-oriented, particularly publicly listed stock exchanges, substantially rely on revenues from related business activities such as post-trading services, derivatives trading or software sales, we find no evidence that the integration of these activities also leads to better results in efficiency and productivity compared to exchanges that focus on cash market operations. Although some potential for efficiency improvements should be possible due to economies of scope between certain activities, this cannot be observed. Counterproductive effects such as increased business process complexity seem to dominate the overall effect on efficiency

(1993) for an elaborate discussion on bootstrapping.

and productivity leading to a worse performance as opposed to cash market-only operators. Interestingly, exchanges that combine derivatives trading, post-trading *and* software sales do not seem to fare worse. Here, the complexity of the different (usually IT-based) business processes are apparently better managed, resulting in productivity growth that can match that of the cash market-focused providers. Although we present a rationale why this could be related to its in-house competence in software development, future research is necessary to develop a deeper understanding for the relevance of IT-competence in the stock exchange industry.

Our analysis exclusively focused on the relative efficiency and productivity of exchanges with and without related activities. This analysis therefore also touches the much discussed topic whether vertical integration is beneficial or detrimental to social welfare. As indicated in the introduction, a significant outperformance of a vertically integrated business model would have provided proponents of this business model a plausible justification. However, we find no evidence for such a phenomenon. Yet, our analysis falls short of providing evidence that vertical integration is indeed less efficient, as it remains to be analyzed how these exchanges perform relative to two entities providing cash trading and post-trading, separately.

A Descriptive Statistics

Operational Variables

INPUTS	x1		x2	
	Staff (No. Employed)		Tangible Assets ($ 000)	
	Mean	Std. Dev.	Mean	Std. Dev.
1999	558.5	494.4	52,131	74,936
2000	591.0	503.3	58,622	85,873
2001	615.0	529.7	69,657	94,969
2002	682.3	720.6	74,925	104,044
2003	658.1	696.8	79,959	107,562

OUTPUTS	y1		y2		y3		y4	
	Listing (No. of companies)		Cash Trading (Volume in $ 000 000)		Derivatives Trading (No. of contracts in 000)		Settlement/Software ($ 000)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1999	858.1	1071.1	1,432,736	2,629,916	26,430	76,181	20,228	45,169
2000	876.3	1056.7	1,942,741	4,208,753	33,024	89,092	27,044	56,448
2001	817.5	924.7	1,359,079	2,842,350	47,298	124,285	31,500	65,918
2002	797.9	868.3	1,248,960	2,446,333	63,260	174,780	46,235	111,907
2003	901.2	1007.3	1,219,142	2,321,408	74,936	198,740	66,019	179,856

Resulting Dependent Variables for the Second Stage

	MQ (CRS)		ΔEFF (CRS)		ΔTECH (CRS)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1999-2000	1.067	0.263	1.088	0.293	0.761	0.273
2000-2001	1.021	0.288	1.034	0.295	0.992	0.079
2001-2002	0.994	0.188	0.967	0.222	1.049	0.168
2002-2003	1.141	0.259	0.938	0.261	1.248	0.203

	MQ (VRS)		ΔEFF (VRS)		ΔTECH (VRS)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
1999-2000	1.086	0.240	1.105	0.271	0.997	0.138
2000-2001	1.009	0.241	1.104	0.343	0.992	0.079
2001-2002	0.998	0.123	0.993	0.187	1.049	0.168
2002-2003	1.077	0.213	0.893	0.191	1.248	0.203

Independent Framework Variables of the Second Stage

	DEMUT	LISTED	OUTSOURCING
	Sum	Sum	Sum
1999	6	2	5
2000	11	5	7
2001	15	8	7
2002	17	9	8
2003	17	9	7

	HORIZONTAL	VERTICAL	HORI-VERTICAL	FULL INTEGRATION
	Sum	Sum	Sum	Sum
1999	10	5	5	1
2000	7	6	5	3
2001	6	5	7	4
2002	6	4	6	6
2003	8	5	7	5

	FOREIGN LISTING		LIQUIDITY	
	Mean	Std. Dev.	Mean	Std. Dev.
1999	0.026	0.046	0.680	0.535
2000	0.031	0.071	1.038	1.103
2001	0.028	0.058	0.812	0.746
2002	0.028	0.059	0.881	0.772
2003	0.013	0.021	0.699	0.518

	Δ LT FINANCE		Δ TRADING	
	Mean	Std. Dev.	Mean	Std. Dev.
1999-2000	0.165	0.271	0.030	0.515
2000-2001	0.286	0.392	-0.006	0.292
2001-2002	0.095	0.240	0.035	0.275
2002-2003	0.079	0.273	0.101	0.388

Table 4: Descriptive Statistics for Employed First and Second Stage Variables

B First Stage Results

	Constant-Returns-To-Scale								
	DEA Technical Efficiency					Malmquist Prod. Index			
	1999	**2000**	**2001**	**2002**	**2003**	**99-00**	**00-01**	**01-02**	**02-03**
NASDAQ	1.00	1.00	0.78	0.64	0.72	1.00	0.79	0.81	1.23
NYSE	0.45	0.49	0.66	0.60	0.49	1.00	0.95	0.97	0.95
Toronto TSX	0.74	0.79	0.53	0.72	1.00	0.97	0.71	1.43	1.80
Lima	0.87	1.00	1.00	1.00	0.81	1.06	1.06	1.04	1.05
BOVESPA	0.34	0.50	0.61	0.89	1.00	1.44	1.37	1.23	1.32
Hellenic	0.55	1.00	0.45	0.28	0.35	1.68	0.44	0.78	1.69
Budapest	0.23	0.24	0.47	0.48	0.66	1.10	1.86	0.65	1.50
Copenhagen	1.00	1.00	1.00	1.00	1.00	1.00	0.92	1.00	1.00
Deutsche Börse	1.00	1.00	1.00	0.70	1.00	1.00	1.00	0.83	1.64
Euronext	1.00	1.00	1.00	1.00	1.00	1.05	1.00	1.00	1.00
Istanbul	0.17	0.20	0.20	0.14	0.11	1.06	0.92	0.74	1.07
Johannesburg JSE	1.00	0.81	0.72	0.72	0.41	0.88	0.83	0.89	0.73
London	0.83	0.97	1.00	1.00	1.00	0.98	1.06	1.00	1.01
Malta	0.41	0.22	0.18	0.17	0.14	0.69	0.82	1.22	1.09
Oslo	0.67	0.71	0.70	0.50	0.37	1.01	0.96	0.69	0.97
OM Gruppen	0.91	0.60	1.00	1.00	1.00	1.01	1.67	0.98	1.00
SWX Zurich	0.69	1.00	0.78	1.00	1.00	1.59	0.84	1.08	1.08
Vienna	0.36	0.37	0.36	0.44	0.26	0.98	0.97	1.25	1.01
Warsaw	0.31	0.32	0.24	0.23	0.18	0.92	0.80	0.96	1.07
Australian	0.90	0.93	0.82	0.85	0.65	1.01	0.94	1.13	1.12
Hongkong	0.42	0.76	0.70	0.54	0.45	1.79	0.88	1.02	1.14
Jakarta	0.33	0.32	0.37	0.48	0.69	0.91	1.05	1.15	1.28
Kuala Lumpur	0.39	0.36	0.43	0.23	0.21	0.92	1.16	0.69	1.26
Philippine	0.45	0.52	0.46	0.44	0.26	1.07	0.95	0.99	1.04
Singapore SGX	1.00	0.57	0.66	0.50	0.26	0.58	1.08	1.06	0.69
Taiwan	0.23	0.28	0.30	0.33	0.24	1.10	1.07	1.16	1.04
Thailand	0.38	0.37	0.38	0.37	0.32	0.97	0.98	0.95	0.95
Tokyo	0.50	0.64	0.90	0.84	0.81	1.08	1.51	1.12	1.22
Mean	0.61	0.64	0.63	0.61	0.59	1.07	1.02	0.99	1.14
Standard Deviation	0.29	0.29	0.27	0.29	0.33	0.26	0.29	0.19	0.26

	Variable-Returns-To-Scale								
	DEA Technical Efficiency					Malmquist Prod. Index			
	1999	**2000**	**2001**	**2002**	**2003**	**99-00**	**00-01**	**01-02**	**02-03**
NASDAQ	1.00	1.00	1.00	1.00	0.72	1.00	0.90	0.94	1.00
NYSE	0.57	0.63	1.00	1.00	0.49	1.31	0.93	0.97	0.98
Toronto TSX	1.00	1.00	0.56	1.00	1.00	1.00	0.58	1.00	1.52
Lima	0.99	1.00	1.00	1.00	1.00	1.03	1.06	1.03	1.03
BOVESPA	0.36	0.53	0.64	0.94	1.00	1.41	1.26	1.22	1.25
Hellenic	0.67	1.00	0.45	0.28	0.37	1.51	0.45	0.75	1.66
Budapest	0.44	0.77	1.00	1.00	1.00	1.32	1.24	1.00	1.01
Copenhagen	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.00	1.00
Deutsche Börse	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.37
Euronext	1.00	1.00	1.00	1.00	1.00	1.03	1.00	1.00	1.00
Istanbul	0.19	0.22	0.25	0.16	0.13	1.09	0.84	0.74	0.97
Johannesburg JSE	1.00	1.00	1.00	1.00	0.45	0.95	0.94	1.00	0.54
London	0.85	0.97	1.00	1.00	1.00	0.99	1.02	1.00	1.00
Malta	1.00	1.00	1.00	1.00	1.00	0.90	0.96	0.99	0.98
Oslo	0.83	0.76	0.73	0.54	0.51	0.95	0.96	0.73	1.05
OM Gruppen	0.92	0.60	1.00	1.00	1.00	1.00	1.66	0.98	1.00
SWX Zurich	0.70	1.00	0.79	1.00	1.00	1.54	0.85	1.08	1.08
Vienna	0.53	0.57	0.62	0.68	0.63	1.00	0.95	1.16	1.02
Warsaw	0.32	0.32	0.25	0.24	0.24	0.92	0.81	1.00	1.12
Australian	0.94	1.00	1.00	1.00	0.66	1.04	0.98	1.04	1.07
Hongkong	0.43	0.76	0.71	0.59	0.46	1.78	0.88	1.04	1.15
Jakarta	0.35	0.32	0.72	0.82	0.69	0.91	1.37	1.15	1.26
Kuala Lumpur	0.39	0.37	0.44	0.29	0.22	0.92	1.14	0.78	1.23
Philippine	0.53	0.52	0.47	0.45	0.42	1.04	0.96	1.00	1.02
Singapore SGX	1.00	0.58	0.66	0.50	0.27	0.59	1.08	1.06	0.70
Taiwan	0.26	0.33	0.46	0.49	0.25	1.15	1.04	1.16	1.04
Thailand	0.39	0.38	0.42	0.46	0.32	0.97	1.00	0.97	0.96
Tokyo	0.51	0.64	0.93	1.00	0.81	1.08	1.46	1.11	1.12
Mean	0.68	0.72	0.75	0.77	0.67	1.09	1.01	1.00	1.08
Standard Deviation	0.29	0.27	0.26	0.30	0.31	0.24	0.24	0.12	0.21

Table 5: First Stage Results

C Correlation Matrix

1st and 2nd Stage Variables	x^1	x^2	y^1	y^2	y^3	y^4
HORIZONTAL	-0.242	-0.285	-0.320	-0.215	0.079	-0.099
VERTICAL	-0.249	-0.262	-0.241	-0.182	-0.149	-0.145
HORI-VERTICAL	0.127	0.001	0.025	-0.153	-0.098	0.050
FULL INTEGRATION	0.482	0.225	0.105	0.042	0.471	0.620
OUTSOURCING	-0.382	-0.183	-0.176	-0.086	-0.186	-0.207
DEMUT	0.188	0.109	0.074	-0.022	0.221	0.351
LISTED	0.386	0.116	0.041	-0.058	0.299	0.494
LIQUIDITY	0.403	0.439	0.531	0.597	0.193	0.187
ΔTRADING	0.035	-0.062	0.035	-0.038	-0.071	-0.075
FOREIGN LISTING	0.403	0.670	0.749	0.892	0.020	-0.013
ΔLT FINANCE	0.069	-0.048	0.063	0.071	0.197	0.119
EFF (CRS)	0.266	0.167	0.347	0.313	0.358	0.333
EFF (VRS)	0.162	0.157	0.304	0.313	0.289	0.250

Table 6: Correlation matrix for first and second stage variables

D Tobit Regressions on Efficiency

	Technology	
	CRS	VRS
HORIZONTAL	-0.059	-0.087
Std. Err.	*0.066*	*0.092*
VERTICAL	0.017	0.103
Std. Err.	*0.084*	*0.084*
HORI-VERTICAL	-0.064	-0.163*
Std. Err.	*0.070*	*0.087*
FULL INTEGRATION	-0.043	-0.107
Std. Err.	*0.084*	*0.106*
OUTSOURCING	0.074†	0.134*
Std. Err.	*0.052*	*0.077*
DEMUT	0.125***	0.166***
Std. Err.	*0.044*	*0.062*
LIQUIDITY	0.010	0.033
Std. Err.	*0.026*	*0.038*
ΔTRADING	0.000	0.049
Std. Err.	*0.045*	*0.046*
FOREIGN LISTING	1.805***	3.327***
Std. Err.	*0.425*	*0.717*
ΔLT FINANCE	-0.007	-0.008
Std. Err.	*0.033*	*0.040*
CONST	0.584***	0.698***
Std. Err.	*0.069*	*0.100*
Observations	140	140
Wald χ^2	51.18	62.85

Table 7: Results from Tobit-regressions on efficiency values (random effects model)

E Robustness Checks

Regressions without governance variables

8.1	Constant Returns-To-Scale (2) MQ	(3) ΔEFF	(4) ΔTECH	Variable Returns-To-Scale (5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	-0.197	-0.289***	0.095	-0.070	-0.182***	0.102
Std. Err.	*0.153*	*0.112*	*0.071*	*0.117*	*0.048*	*0.111*
VERTICAL	-0.441***	-0.524***	0.086	-0.426***	-0.366***	-0.046
Std. Err.	*0.113*	*0.112*	*0.109*	*0.107*	*0.092*	*0.083*
HORI-VERTICAL	-0.329***	-0.363***	0.045	-0.226***	-0.207***	-0.041
Std. Err.	*0.102*	*0.056*	*0.115*	*0.055*	*0.043*	*0.085*
FULL INTEGRATION	-0.160	-0.366***	0.183†	-0.041	-0.235**	0.154
Std. Err.	*0.129*	*0.021*	*0.116*	*0.088*	*0.106*	*0.167*
OUTSOURCING	-0.237***	-0.443***	0.229***	-0.274***	-0.411***	0.186**
Std. Err.	*0.045*	*0.017*	*0.057*	*0.104*	*0.058*	*0.083*
LIQUIDITY	-0.017	-0.001	-0.028	-0.014	0.059	-0.053
Std. Err.	*0.024*	*0.046*	*0.054*	*0.024*	*0.066*	*0.093*
ΔTRADING	0.020	-0.022	0.052	0.054*	0.015	0.063
Std. Err.	*0.029*	*0.027*	*0.050*	*0.031*	*0.073*	*0.078*
FOREIGN LISTING	0.661	-0.093	0.859	-0.233	0.196	-0.517
Std. Err.	*0.603*	*0.835*	*0.695*	*0.515*	*0.752*	*1.120*
ΔLT FINANCE	-0.060	0.091†	-0.166***	-0.032	0.106***	-0.151*
Std. Err.	*0.098*	*0.062*	*0.032*	*0.095*	*0.031*	*0.090*
EFF	-0.996***	-1.047***	0.058	-0.577***	-1.058***	0.410***
Std. Err.	*0.310*	*0.314*	*0.126*	*0.197*	*0.272*	*0.155*
CONST	1.957***	2.046***	0.931***	1.698***	2.009***	0.756***
Std. Err.	*0.167*	*0.152*	*0.068*	*0.122*	*0.211*	*0.128*

Regressions without financial flexibility and competition variables

8.2	Constant Returns-To-Scale (2) MQ	(3) ΔEFF	(4) ΔTECH	Variable Returns-To-Scale (5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	−0.217†	-0.325***	0.121*	-0.088	-0.191***	0.096
Std. Err.	*0.135*	*0.105*	*0.069*	*0.132*	*0.054*	*0.113*
VERTICAL	-0.502***	-0.475***	-0.024	-0.486***	-0.302***	-0.184**
Std. Err.	*0.108*	*0.126*	*0.052*	*0.093*	*0.126*	*0.083*
HORI-VERTICAL	-0.349***	-0.381***	0.048	-0.230***	-0.204***	-0.042
Std. Err.	*0.085*	*0.054*	*0.098*	*0.047*	*0.030*	*0.092*
FULL INTEGRATION	-0.204***	-0.297***	0.069	-0.056	-0.144	0.052
Std. Err.	*0.053*	*0.081*	*0.101*	*0.049*	*0.148*	*0.142*
OUTSOURCING	-0.230***	-0.427***	0.223***	-0.303**	-0.412***	0.149***
Std. Err.	*0.076*	*0.048*	*0.047*	*0.133*	*0.081*	*0.058*
DEMUT	-0.013	-0.165***	0.173***	-0.079*	-0.130***	0.056***
Std. Err.	*0.051*	*0.020*	*0.060*	*0.041*	*0.031*	*0.021*
LISTED	0.021	-0.055	0.062**	0.076	-0.051	0.140*
Std. Err.	*0.139*	*0.117*	*0.027*	*0.139*	*0.110*	*0.077*
EFF	-0.988***	-0.963***	-0.028	-0.565***	-0.969***	0.328**
Std. Err.	*0.252*	*0.250*	*0.047*	*0.201*	*0.304*	*0.161*
CONST	1.972***	2.079***	0.901***	1.711***	2.064***	0.728***
Std. Err.	*0.132*	*0.122*	*0.012*	*0.094*	*0.232*	*0.151*

Table 8: Robustness check by omitting variables

Regressions with different competition variables

9.1	Constant Returns-To-Scale			Variable Returns-To-Scale		
ΔTRADING$_{t-1}$ for t	(2) MQ	(3) ΔEFF	(4) ΔTECH	(5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	$-0.191^{\dagger}$	-0.340***	0.182*	-0.133	-0.297***	0.162
Std. Err.	*0.131*	*0.095*	*0.101*	*0.122*	*0.065*	*0.164*
VERTICAL	-0.445***	-0.518***	0.120	-0.553***	-0.513***	-0.032
Std. Err.	*0.064*	*0.078*	*0.120*	*0.089*	*0.126*	*0.165*
HORI-VERTICAL	-0.323***	-0.399***	0.108	-0.259***	-0.280***	0.008
Std. Err.	*0.098*	*0.049*	*0.139*	*0.071*	*0.070*	*0.126*
FULL INTEGRATION	$-0.151^{\dagger}$	-0.328***	0.187	-0.099	$-0.314^{\dagger}$	0.184
Std. Err.	*0.105*	*0.063*	*0.136*	*0.089*	*0.220*	*0.26*
OUTSOURCING	-0.246***	-0.416***	0.196***	-0.314***	-0.417***	0.142**
Std. Err.	*0.078*	*0.052*	*0.033*	*0.125*	*0.048*	*0.064*
DEMUT	-0.009	-0.187***	0.205**	-0.102*	-0.129*	0.028**
Std. Err.	*0.042*	*0.052*	*0.089*	*0.058*	*0.068*	*0.012*
LISTED	0.013	-0.059	0.065*	0.046	-0.077	0.134*
Std. Err.	*0.132*	*0.100*	*0.035*	*0.134*	*0.107*	*0.078*
LIQUIDITY	$-0.026^{\dagger}$	0.029	-0.079*	-0.014	0.095**	-0.100
Std. Err.	*0.016*	*0.041*	*0.042*	*0.026*	*0.044*	*0.073*
ΔTRADING	0.002	-0.009	0.035	-0.064***	-0.117**	0.053
Std. Err.	*0.031*	*0.032*	*0.028*	*0.023*	*0.051*	*0.048*
FOREIGN LISTING	0.684	-0.876	1.763*	-0.385	-0.218	-0.195
Std. Err.	*0.653*	*1.017*	*1.016*	*0.814*	*0.401*	*0.989*
ΔLT FINANCE	-0.058	0.011	-0.077**	-0.040	0.065	$-0.113^{\dagger}$
Std. Err.	*0.07*	*0.081*	*0.037*	*0.081*	*0.057*	*0.077*
EFF	-0.997***	-0.908***	-0.110	-0.508**	-0.948***	0.367***
Std. Err.	*0.294*	*0.349*	*0.151*	*0.229*	*0.309*	*0.151*
CONST	1.964***	2.070***	0.903***	1.756***	2.077***	0.750***
Std. Err.	*0.169*	*0.153*	*0.011*	*0.125*	*0.236*	*0.152*

9.2	Constant Returns-To-Scale			Variable Returns-To-Scale		
ΔLIQUIDITY for ΔTRADING	(2) MQ	(3) ΔEFF	(4) ΔTECH	(5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	-0.211	-0.351***	0.162*	-0.092	-0.200***	0.107
Std. Err.	*0.163*	*0.134*	*0.086*	*0.133*	*0.062*	*0.124*
VERTICAL	-0.476***	-0.530***	0.079	-0.472***	-0.343***	-0.121
Std. Err.	*0.13*	*0.135*	*0.083*	*0.136*	*0.123*	*0.095*
HORI-VERTICAL	-0.338***	-0.408***	0.096	-0.232***	-0.218***	-0.026
Std. Err.	*0.114*	*0.075*	*0.131*	*0.073*	*0.034*	*0.103*
FULL INTEGRATION	-0.153	-0.319***	$0.151^{\dagger}$	-0.033	-0.192	0.127
Std. Err.	*0.115*	*0.068*	*0.105*	*0.109*	*0.166*	*0.206*
OUTSOURCING	-0.256***	-0.424***	0.194***	-0.311**	-0.397***	0.126**
Std. Err.	*0.073*	*0.053*	*0.040*	*0.146*	*0.087*	*0.065*
DEMUT	-0.011	-0.189***	0.204**	-0.098**	-0.125**	0.028**
Std. Err.	*0.039*	*0.051*	*0.090*	*0.049*	*0.056*	*0.013*
LISTED	0.019	-0.049	$0.051^{\dagger}$	0.070	-0.043	$0.122^{\dagger}$
Std. Err.	*0.127*	*0.101*	*0.032*	*0.136*	*0.123*	*0.078*
LIQUIDITY	-0.080**	-0.023	-0.049	-0.059*	0.078*	-0.122*
Std. Err.	*0.038*	*0.042*	*0.038*	*0.037*	*0.041*	*0.074*
ΔLIQUIDITY	-0.076**	$-0.070^{\dagger}$	0.029	$-0.038^{\dagger}$	0.020	-0.050***
Std. Err.	*0.039*	*0.048*	*0.027*	*0.026*	*0.018*	*0.02*
FOREIGN LISTING	0.866	-0.707	1.694*	-0.278	-0.304	-0.027
Std. Err.	*0.637*	*0.963*	*0.996*	*0.842*	*0.454*	*1.093*
ΔLT FINANCE	-0.062	0.007	-0.075**	-0.042	0.060	-0.111
Std. Err.	*0.072*	*0.083*	*0.037*	*0.083*	*0.071*	*0.083*
EFF	-0.969***	-0.886***	-0.105	-0.534**	-0.981***	0.375**
Std. Err.	*0.316*	*0.358*	*0.141*	*0.233*	*0.323*	*0.161*
CONST	2.007***	2.106***	0.900***	1.763***	2.014***	0.812***
Std. Err.	*0.140*	*0.132*	*0.011*	*0.123*	*0.227*	*0.124*

Table 9: Robustness check with varying competition variables

Regression with Bootstrapping (2000 Replications, 5%, 10% and 15%-Level)						
	Constant Returns-To-Scale			Variable Returns-To-Scale		
Bootstrapping	(2) MQ	(3) ΔEFF	(4) ΔTECH	(5) MQ	(6) ΔEFF	(7) ΔTECH
HORIZONTAL	**-0.199****	**-0.321****	**0.132**	$-0.098^{\dagger}$	**-0.206**	**0.098**
Std. Err.	*0.135*	*0.143*	*0.176*	*0.123*	*0.225*	*0.172*
VERTICAL	$-0.447^{\dagger}$	**-0.507****	**0.072**	$-0.457^{\dagger}$	$-0.348^{\dagger}$	**-0.101**
Std. Err.	*0.417*	*0.290*	*0.220*	*0.393*	*0.323*	*0.174*
HORI-VERTICAL	**-0.331****	**-0.381****	**0.065**	**-0.243****	**-0.222**	**-0.043**
Std. Err.	*0.203*	*0.163*	*0.201*	*0.184*	*0.235*	*0.185*
FULL INTEGRATION	**-0.164**	**-0.300****	**0.115**	**-0.058**	**-0.194**	**0.092**
Std. Err.	*0.162*	*0.162*	*0.176*	*0.163*	*0.228*	*0.198*
OUTSOURCING	**-0.239****	**-0.427****	**0.213***	$-0.290^{\dagger}$	**-0.399****	**0.155***
Std. Err.	*0.154*	*0.154*	*0.132*	*0.227*	*0.207*	*0.120*
DEMUT	**-0.007**	**-0.190****	**0.210****	**-0.093***	**-0.124****	**0.035**
Std. Err.	*0.092*	*0.080*	*0.050*	*0.073*	*0.079*	*0.051*
LISTED	**0.011**	**-0.055**	**0.051**	**0.064**	**-0.041**	**0.115***
Std. Err.	*0.174*	*0.149*	*0.070*	*0.179*	*0.132*	*0.083*
LIQUIDITY	**-0.017**	**0.011**	**-0.041**	**-0.012**	**0.065**	**-0.057**
Std. Err.	*0.117*	*0.114*	*0.081*	*0.072*	*0.095*	*0.084*
ΔTRADING	**0.019**	**-0.036**	**0.067***	**0.046**	**0.003**	**0.066**
Std. Err.	*0.067*	*0.066*	*0.057*	*0.057*	*0.092*	*0.076*
FOREIGN LISTING	**0.649**	**-0.810**	**1.641****	**-0.468**	**-0.247**	**-0.285**
Std. Err.	*1.012*	*0.923*	*0.951*	*0.915*	*0.949*	*0.933*
ΔLT FINANCE	**-0.06**	**0.015**	$-0.084^{\dagger}$	**-0.047**	**0.060**	**-0.117****
Std. Err.	*0.122*	*0.098*	*0.065*	*0.068*	*0.064*	*0.060*
EFF	**-0.993****	**-0.917****	**-0.085**	**-0.531****	**-0.984****	**0.379****
Std. Err.	*0.254*	*0.228*	*0.120*	*0.176*	*0.171*	*0.164*
CONST	**1.958****	**2.079****	**0.894****	**1.721****	**2.030****	**0.757****
Std. Err.	*0.224*	*0.200*	*0.177*	*0.193*	*0.204*	*0.168*

Table 10: Bootstrap test

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