Demutualization, Outsider Ownership and Stock Exchange Performance - Empirical Evidence

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Abstract

We employ a balanced panel data set of 28 stock exchanges to disentangle the effects of demutualization and outsider ownership on the operative performance of stock exchanges. For this purpose we calculate in a first step individual efficiency and factor productivity values via DEA. In a second step we regress the derived values against variables that - amongst others - represent the different governance regimes at exchanges in order to determine efficiency and productivity differences between (1) mutuals (2) demutualized but customer-owned exchanges and (3) publicly listed and thus at least partly outsider-owned exchanges. We find evidence that demutualized exchanges exhibit higher technical efficiency than mutuals. However, they perform relatively poor as far as productivity growth is concerned. Furthermore, we find no evidence that publicly listed exchanges possess higher efficiency and productivity values than demutualized exchanges with a customer-dominated structure.

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1 Introduction

Several stock exchanges have been overhauling their corporate governance structure as a result of a more demanding competitive environment. A combination of factors has led to increased pressure on the exchanges' businesses. (1) The changing investment behavior of their (end)customers, now being less home-biased, resulted in increased competition for order flow amongst exchanges. (2) The deregulation of the financial markets, particularly in Europe, by initiatives such as the Single European Market, but also by the Big Bang reforms in UK, opened the path for increased competitive pressure on the incumbent institutions. (3) Yet, the greatest impact on stock exchange competition can be attributed to the developments in information technology and the reduction in communication costs, which resulted in the emergence of new ways to trade securities. Remote membership, electronic order book trading, electronic communication networks, and the internalization of order flow by intermediaries became all viable threats to the traditional floor trading.

The stock exchange in Stockholm was the first to react on this changing environment by restructuring its corporate governance in the early 1990s. As most other exchanges, it was organized as a mutual, which usually comprises a one-member one-vote control structure and a not-for-profit orientation of its venue.[1] In the process of this demutualization, it changed its institutional setting towards a profit-oriented one-share, one-vote structure as we find it in a regular capitalist firm. Several other exchanges followed the suit.

However, one can observe that some exchanges restructured their institution and became profit-oriented, but mostly retained their old shareholders. Hence, this type of reorganization did not involve a change in the *type* of owners, although an internal reallocation of shares and votes may have occurred in order to more closely align the customers' voting power with their respective volume of business. As a consequence, these exchanges basically remained dominated by their customers. Other exchanges have decided to go one step further. They sold a substantial portion of their shares to outsiders via a public listing. Thus, their governance has become more or less dominated by outsiders, i.e. non-customer owners, who foremost have a financial interest in the exchange.[2] Figure 1 demonstrates the growing prevalence of demutualized and listed exchanges vis-à-vis mutual exchanges in the industry. The chart displays this development for the 50 largest stock exchanges for the years 1999 until 2003. The number of exchanges that are organized as mutuals fell from 40 to 25 while the sum of demutualized and publicly listed exchanges rose from 10 to 25 in the same period.

Exchanges undergoing the demutualization process have done so in expectation of improved competitiveness. A survey of exchanges conducted by BTA Consulting and presented by Scullion (2001) reveals the main motives of and expected benefits from demutualization. These are - among others - (1) to tap new sources of

[1] The mutuals' objective function was usually to maximize their members' utility. See part III in Hansmann (1996) for an elaborate analysis of these customer-owned firms.

[2] In her contribution, Aggarwal (2002) describes the various steps of the process and views the public listing of an exchange with a widely dispersed shareholder base as the ultimate step of this restructuring.

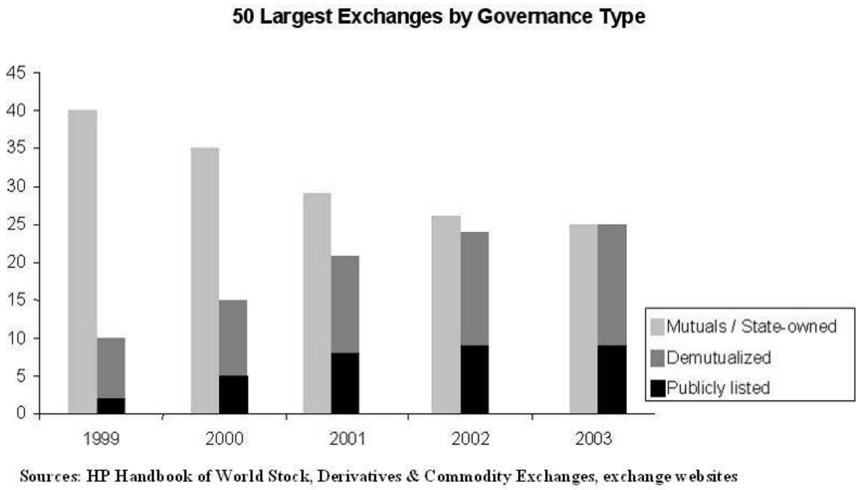

Figure 1: Governance Type of Exchanges 1999-2003.

capital which is possibly needed to modernize their trading systems (2) to pursue business opportunities unconstrained by vested interest issues (3) to achieve better cost control and (4) to increase flexibility, efficiency and competitiveness. Scullion further argues in his contribution that demutualization is now regarded as the key solution to all the problems related with mutual exchanges.[3] In order to achieve the full benefits of demutualization he points out that

> *Demutualisation is not simply [...] turning into a for profit entity owned by members. A truly demutualised exchange would be better placed if it were able to unlock its hidden value for all stakeholders in order to maximise its potential market capitalisation and shareholder value.*[4]

A report published by the OECD takes a similarly positive stance on the effect of outside owners for demutualized exchanges. They note that

> *Being listed on a stock exchange is likely to improve the value of stock exchanges, as exchanges are urged to create value for their own shareholders through improvement of their structure to operate more efficiently.*[5]

Related literature In academia, the demutualization process has been so far predominantly analyzed from a social welfare perspective. The most prominent theoretical contribution is by Hart and Moore (1996) who discusses under which circumstances of competition and broker composition the migration from a mutual towards an outsider-owned for-profit exchange is socially beneficial. Hart and Moore's simple pricing model demonstrates that an outsider-owned governance structure is socially preferable over a mutual structure when there exists a relatively high level

[3] Confer Scullion (2001, p. xxxii).
[4] Confer Scullion (2001, p. xxix).
[5] Confer OECD (2003, p.104).

of competition or a relatively high degree of heterogeneity[6] among members. An empirical contribution is made by Krishnamurti, Sequeira, and Fangjian (2002) who compare the market quality of the Bombay Stock Exchange, a mutual, with that of the National Stock Exchange, a demutualized trading venue. Another strand of literature devotes itself to regulatory issues that emerged, since some of the exchanges undergoing the demutualization process traditionally regulate their trading markets themselves. This raised concerns by industry participants whether the commercial interests of a for-profit exchange would collide with its monitoring effort to ensure fair conduct of trading. Authors such as Pirrong (2000), Karmel (2000) and Elliott (2002), to name a few, have made important contributions in this field.

However, the impact of demutualization and outside ownership on the exchange's performance has so far been scarcely subject to academic literature. This is surprising, since the decision to demutualize and even to go public has far-reaching consequences for the exchanges. Both financial and strategic aspects are relevant. Take for example the costs that are associated with an IPO. According to their annual reports, Deutsche Börse and Euronext paid 36.8 million and 46 million euros for their respective floatation. Although the proceeds received from an IPO naturally more than recouped these costs, the IPO-costs amounted to 3.7% of the new proceeds in Deutsche Börse's case and even to 12.7% for Euronext. Besides these one-off costs there are also additional running costs such as stricter disclosure requirements. A strategic implication is that an exchange can be more easily taken over by other institutions. Thus, the main benefit of demutualization and going public, i.e. improving the exchange's competitiveness and thus its operative performance, should be somehow noticeable.

We are aware of one paper that is directly concerned with the impact of demutualization on stock exchange performance and two further contributions that analyze stock exchange performance in general. The paper directly related to stock exchange performance is by Mendiola and O'Hara (2003) who analyze the share performance and valuation of publicly listed exchanges after their IPO compared to other listed firms and other IPOs. While their results are very interesting in their own right, in particular their finding that there exists a positive link between the fraction of equity sold to outside investors and stock exchange performance, it does not provide a performance comparison with exchanges that are not listed due to the apparent lack of share price information for these exchanges. Furthermore, this approach cannot provide any insights to the performance of an exchange prior to its public listing. Therefore, the use of share prices as indicator of performance is rather limited. As a consequence, a potential method that considers governance differences among exchanges must be able to work with data that is available for all exchanges irrespective of their governance regime. The two other papers we identified are written by Schmiedel and employ frontier efficiency methods in order to derive relative efficiency values of an exchange and which do not incorporate share price information but information on accounting data, staff size and transaction data. For his two papers he makes use of two different methods of frontier analysis.

[6]Hart and Moore refer to heterogeneity in terms of the skewness in the members' size distribution

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 the second paper (Schmiedel (2002)).[7] Schmiedel's findings on stock exchange governance are ambiguous, however. His first paper, which controls for demutualized exchanges within the regression, displays a positive impact of demutualization on cost efficiency[8], whereas his second paper indicates that the mean of productivity gains is higher for mutual exchanges[9].

As already mentioned, the primary focus of Schmiedel's papers is not to elaborate on differences in exchange governance, which is probably also due to the rather limited number of demutualized exchanges in the time period of his analysis (until 1999). Therefore, the aim of our paper is to fill this gap by conducting an efficiency analysis that devotes particular attention on exchange governance and which uses more recent data. As in Schmiedel (2002), we will also employ a non-parametric approach to calculate relative efficiency scores, albeit using a broader set of output variables. Furthermore, in contrast to his proceeding, we will go a step further by regressing the derived estimations of efficiency and productivity against a set of factors mapping the framework in which the respective exchanges are embedded. This procedure will then highlight whether there is a significant impact of different governance structures on the performance of the stock exchanges.

The paper 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 will also be discussed here. Section 4 concludes our paper by summing up our findings and drawing some policy implications.

2 Methodology

This section discusses the methodology used in the paper. The main aim as outlined in section 1 is to isolate the effects of demutualization and outside ownership on stock exchange efficiency and productivity. For that matter we initially provide a brief overview of Data Envelopment Analysis and Malmquist Productivity in section 2.1, as these methods are employed to calculate the exchanges' efficiency and factor productivity values. Readers familiar with the methods may want to skip this section. Section 2.2 describes how specific effects such as different governance regimes can be disentangled via regression analysis. The structure of the employed regressions will be presented in section 2.3.

[7] 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.

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

[9] Confer table 7, the 'Malmquist index'-column for demutualized and cooperative exchanges on page 26.

2.1 Data Envelopment Analysis and Malmquist-Productivity

2.1.1 Data Envelopment Analysis

DEA was introduced by Charnes, Cooper, and Rhodes (1978). Using their linear programming algorithm enables the calculation of relative technical efficiency[10] values for similar entities which process multiple inputs of resources into multiple outputs of products or services. Our focus will be 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.[11] The efficiency of each entity under evaluation is determined by calculating the deviation 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)[12] 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.[13] 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 characteristics of 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.[14]

[10]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)

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

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

[13]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.

[14]VRS allows for differing returns-to-scale characteristics for different levels of input-output combinations. We discuss this issue in further detail in the paragraph "Assumptions on technology".

The DEA-model Consider DMU_1 from a sample of n decision making units. Assume that this DMU uses one type of input and generates one type of output. Then, taking the output-to-input-ratio will not be very informative - save for the fact that a higher ratio generally indicates higher efficiency - unless DMU_1's ratio is compared to efficiency values of the other $n-1$ DMUs. Calculating the ratios for all n DMUs and normalizing them[15] yields *relative* efficiency values that can be interpreted in a meaningful way.

The multiplier and envelopment program The basic DEA input-oriented model[16] introduced by Charnes, Cooper, and Rhodes (1978) is based on the same simple intuition, but generalizes the ratio for the multiple input and multiple output case.[17] They calculate an efficiency ratio by assigning an efficiency-optimized *weighting* scheme to the respective outputs and inputs so that one aggregated 'virtual' output value is divided by one aggregated 'virtual' input value. To be more precise, assume that DMU_1 has an $(m \times 1)$ input vector $X_1 = \{x_{l1}\}$ with $l = 1, ..., m$ and an $(s \times 1)$ output vector $Y_1 = \{y_{r1}\}$ with $r = 1, ..., s$.[18] Further assume that there exists a weighting vector ν for the inputs and a second weighting vector μ for the outputs with corresponding dimensions. Then, the non-linear program

$$\begin{array}{lccll} & \max\limits_{\nu,\mu} & \dfrac{\mu' Y_1}{\nu' X_1} & & \\ s.t. & & \dfrac{\mu' Y_i}{\nu' X_i} & \leq 1 & \forall i = 1, ..., n \\ & & \mu, \nu & \geq 0 & \end{array} \tag{1}$$

states that the efficiency of DMU_1, i.e. the output-input-ratio weighted by the transposed multipliers μ' and ν', is maximized by optimizing the weighting factors subject to the n constraints requiring that none of the DMU's efficiency value exceeds the value of one when the same weighting scheme is used.[19] However, the non-linear program has an infinite number of solutions. By adding the constraint $\nu' X_1 = 1$ to the program, the denominator of the efficiency ratio can be normalized to one so that the program's objective function becomes linear. The linearization of the constraints is accomplished by multiplying $\nu' X_i$ to constraint i $\forall i = 1, ..., n$. The resulting linear 'multiplier' program then has the following form:

[15] This is accomplished by setting a maximum achievable value of one. Hence, perfect efficiency is achieved at a ratio of one while a value of zero indicates absolute inefficiency.

[16] Input-oriented models calculate the DMU's efficiency in terms of the employed quantity of inputs in order to produce a given level of output. Output-oriented models on the other hand determine the efficiency by focusing on the level of produced outputs holding the level of inputs constant. Thus, the choice of the model depends on whether the emphasis is on input reduction or output augmentation. It is reasonable to use an input-oriented model when analyzing the stock exchange industry as the inputs can be influenced more directly by the management than the "outputs" which are predominantly influenced by market demand.

[17] Several refinements of DEA have emerged in the literature. An overview provides chapter 3 of Charnes, Cooper, Lewin, and Seiford (1997).

[18] The observations are all non-negative, i.e. $x_{l1}, y_{r1} \geq 0 \quad \forall l, r$.

[19] The fourth line in equation (1) requires the multipliers to be non-negative. It is assumed that the technology under consideration is convex and has the property of disposability in its strong version.

$$\max_{\nu,\mu} \quad \mu' Y_1 \tag{2}$$
$$\begin{aligned} s.t. \quad \nu' X_1 &= 1 \\ \mu' Y_i &\leq \nu' X_i \quad \forall i = 1, ..., n \\ \mu, \nu &\geq 0 \end{aligned}$$

This program is solved n times, i.e. for each DMU individually. When using matrix notation and employing a $(s \times n)$ matrix of outputs denoted as $\mathbf{Y}$, and a $(m \times n)$ matrix of inputs denoted as $\mathbf{X}$ the program in (2) can be written as:

$$\max_{\nu,\mu} \quad \mu' Y_1 \tag{3}$$
$$\begin{aligned} s.t. \quad \nu' X_1 &= 1 \\ \mathbf{Y}'\mu &\leq \mathbf{X}'\nu \\ \mu, \nu &\geq 0 \end{aligned}$$

The program now yields a unique solution for ν^* and μ^*.[20]

The dual program The *dual* of equation (3), termed as the "envelopment-problem", is usually preferred to the multiplier problem due to lesser calculation effort.[21] It also provides a different point of view to the problem. In particular, the envelopment problem

$$\min_{\theta,\lambda} \quad \theta \tag{4}$$
$$\begin{aligned} s.t. \quad \theta X_1 &\geq \mathbf{X}\lambda \\ Y_1 &\leq \mathbf{Y}\lambda \\ \lambda &\geq 0 \end{aligned}$$

solves for the highest possible radial contraction, i.e. the minimum value of θ, with which the analyzed input vector (X_1) uses at least as many inputs as a linear combination of observations from the reference or best practice set ($\mathbf{X}\lambda$) while producing (Y_1) at most as many outputs as the linear combination of best performing peers ($\mathbf{Y}\lambda$).

Assumptions on technology The presented linear program has a relatively strong assumption about its underlying technology. It restricts the input-output-process to a constant returns-to-scale (CRS) environment. A slightly refined version introduced by Banker, Charnes, and Cooper (1984) mitigates this assumption and calculates efficiency scores in a variable returns-to-scale (VRS) surrounding, i.e. it

[20] Linear programs are solved by the Simplex-Algorithm.

[21] As the number of DMUs ($= n$) is usually larger than the sum of the inputs and outputs ($m+s$) used in the program, the dual needs to calculate $n - (m + s)$ fewer constraint.

allows for differing returns-to-scale characteristics for different levels of input-output combinations. By adding a further constraint to problem (4), namely $\mathbf{1}\lambda = 1$, the reference point of the analyzed DMU is now required to be a *convex* linear combination of efficient DMUs while this was not necessary in the CRS-program.

2.1.2 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.[22]

Consider the left panel of figure 2 (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 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. 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.

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}.[23] They define the productivity index as the geometric mean of two mixed period

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

[23] 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)

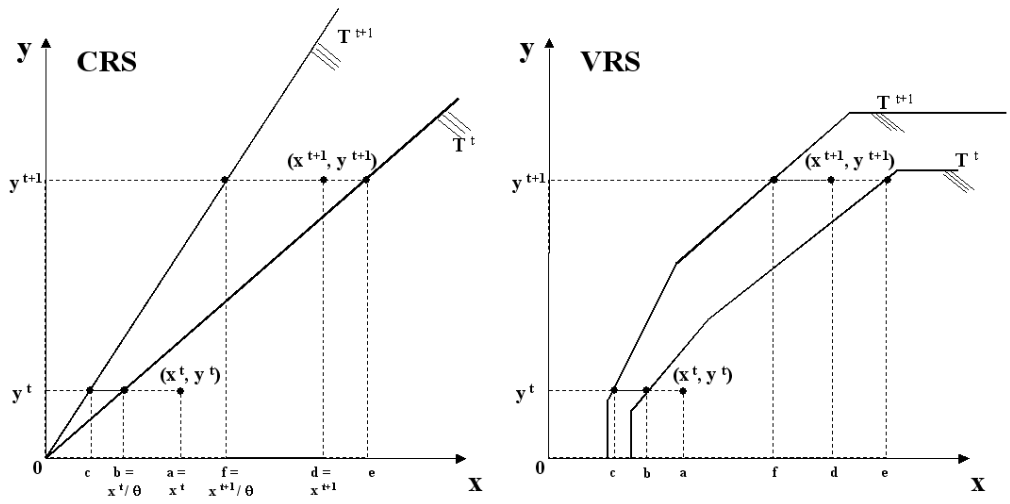

Figure 2: Input-oriented Malmquist approach for CRS and VRS

distance functions[24]:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}} \tag{5}$$

where the first factor uses time period t and the second factor time period $t+1$ as the respective reference technology. Equation (5) can be transformed into equation (6) which uncovers the two decomposed effects stated earlier.

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \cdot \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}} \tag{6}$$

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 2:

$$M(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{0d/0f}{0a/0b}\sqrt{\frac{0d/0e}{0d/0f} \cdot \frac{0a/0b}{0a/0c}} \tag{7}$$

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

[24]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.

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.[25]

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[26], keeping in mind that the required input distance functions are the reciprocal of Farrell's input-oriented technical efficiency measure. Thus,

$$\begin{aligned} [D^t(x_1^t, y_1^t)]^{-1} &= \min_{\theta,\lambda} \quad \theta \\ s.t. \qquad \theta X_1^t &\geq \mathbf{X}^t\lambda \\ Y_1^t &\leq \mathbf{Y}^t\lambda \\ \mathbf{1}\lambda &= 1 \quad (only\ for\ VRS) \\ \lambda &\geq 0 \end{aligned} \tag{8}$$

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 (8). 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 $D_1^{t+1}(x_1^t, y_1^t)$:

$$\begin{aligned} [D^t(x_1^{t+1}, y_1^{t+1})]^{-1} &= \min_{\theta,\lambda} \quad \theta \\ s.t. \qquad \theta X_1^{t+1} &\geq \mathbf{X}^t\lambda \\ Y_1^{t+1} &\leq \mathbf{Y}^t\lambda \\ \mathbf{1}\lambda &= 1 \quad (only\ for\ VRS) \\ \lambda &\geq 0 \end{aligned} \tag{9}$$

and

$$\begin{aligned} [D^{t+1}(x_1^t, y_1^t)]^{-1} &= \min_{\theta,\lambda} \quad \theta \\ s.t. \qquad \theta X_1^t &\geq \mathbf{X}^{t+1}\lambda \\ Y_1^t &\leq \mathbf{Y}^{t+1}\lambda \\ \mathbf{1}\lambda &= 1 \quad (only\ for\ VRS) \\ \lambda &\geq 0 \end{aligned} \tag{10}$$

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

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

2.2 Two-stage approach for assessing efficiency differences

Section 2.1 presented our approach to calculate the DEA-efficiency and Malmquist productivity values. We so far employed input and output variables which we assume are directly related to the operations of an exchange and are thus under the direct control of the responsible management. Additional factors, which cannot be controlled directly by the management, such as different corporate governance schemes, have so far been not incorporated in our analysis. There are two different approaches in the literature that provide a linkage between the "controllable" *operational* and "non-controllable" *framework* factors.

On the one hand, there are refinements to the DEA that allow for the direct inclusion of framework factors. These so-called one-stage approaches either calculate DEA-values for each group of DMUs separately and that are in turn projected on the respective efficient frontier[27] or they calculate the efficiency values for different benchmark frontiers depending in which non-controllable factor environment the respective DMUs are.[28] However, there are shortcomings to this approach. The major drawback is that DEA calculates the efficiency values for each subsample of DMUs separately. As a result the proportion of DMUs that lie on the efficient frontier increases which in consequence dilutes the explanatory power of the method.[29]

The method used here follows a two-stage process. Stage one encompasses the calculation of efficiency and productivity values as outlined in section 2.1 and is based solely on operational inputs and outputs. In the second stage, the resulting values for efficiency and productivity are used as statistical estimators in a regression analysis. These estimators are regressed against framework factors, such as different governance regimes, that may also have influence on exchange efficiency and productivity. The procedure therefore enables us to disentangle the individual effects of these variables and provides a solid basis to judge whether there are significant differences in efficiency and productivity along the varying governance types.

2.3 Regression analysis

Using efficiency scores as dependent variable Using the DEA-scores as estimators of efficiency in a regression analysis entails the problem that they are truncated from above at a maximum value of one. Hence, instead of a regular OLS regression, which would produce biased results, we follow Dusansky and Wilson (1994) and McCarty and Yaisawarng (1993) who apply a Tobit regression in order to deal with truncated observations. Taking our panel data structure into account we use the following general Tobit model:

[27] Confer Charnes, Cooper, and Rhodes (1981) who provide an example for the use of DEA with non-discretionary variables to differentiate between not-for profit and for-profit firms.

[28] See Banker and Morey (1986).

[29] Confer Steinmann (2002, p.34-35). Steinmann also provides further disadvantages of one-stage approaches.

$$
\begin{aligned}
EFF_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} \quad if \quad EFF^*_{i,t} < 1 \qquad (11)\\
EFF_{i,t} &= 1 \qquad\qquad\quad\; if \quad EFF^*_{i,t} \geq 1\\
where \qquad \epsilon_{i,t} &= \alpha_i + \eta_{i,t}
\end{aligned}
$$

Here, $EFF_{i,t}$ is the efficiency value of exchange i in period t derived from the DEA-calculation, $EFF^*_{i,t}$ is the true but unobservable efficiency of exchange i in period t, $X_{i,t} = [1 \quad x']$ is an $((1 \times (K+1))$ vector of K framework variables plus one and β is a $((L+1) \times 1)$ vector of parameters. The error term is decomposed into an time-invariant individual effect of the exchange denoted as α_i and an independent effect $\eta_{i,t}$ which is assumed to be uncorrelated with $X_{i,t}$. Thus, we will employ a random effects model. The $K = 10$ framework variables used in this regression will be introduced and discussed in section 3.2. In total, we regress for $i = \{1, ..., n = 28\} \times t = \{1...T = 5\} = 140$ observations.

Using productivity values as dependent variable In a similar manner, we will regress the framework variables against the results from the productivity analysis. 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 ($\Delta TECH$). Since there is no truncation in the productivity variables, we will employ standard panel regression equations. Thus, we obtain three regression models:

$$
\begin{aligned}
MQ_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} \qquad (12)\\
\Delta EFF_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} \qquad (13)\\
\Delta TECH_{i,t} &= X_{i,t}\beta + \epsilon_{i,t} \qquad (14)\\
where \qquad \epsilon_{i,t} &= \alpha_i + \eta_{i,t} \qquad respectively
\end{aligned}
$$

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. Again, $X_{i,t} = [1 \quad x']$ 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.[30] We will make use of the same $K = 10$ framework variables as in regression (11). Additionally, we will employ the calculated EFF-value of period $t-1$ of each exchange as a further independent variable in order to control for the fact that less efficient

[30]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.

exchanges can potentially improve their productivity by a larger extent than highly efficient exchanges.[31] Since the dependent variables are calculated by comparing two adjacent periods, i.e. MQ_t consumes data from periods t and t-1, we "lose" one period and have therefore four observations per DMU. Thus, we regress for $i = \{1, ..., n = 28\} \times t = \{1...(T-1) = 4\} = 112$ observations.[32]

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.

No.	Exchange	Region	Governance			Avg. World
			Mutual/State	Demutualized	Listed	Market Share
1	BOVESPA	Americas	√	-	-	0.2%
2	Lima	Americas	√	-	-	0.0%
3	NASDAQ	Americas	-	2001	-	25.7%
4	NYSE	Americas	√	-	-	25.1%
5	Toronto TSX	Americas	-	2000	2002	1.1%
6	Budapest	Europe/Africa	-	2002	-	0.0%
7	Copenhagen	Europe/Africa	-	1996	-	0.2%
8	Deutsche Börse	Europe/Africa	-	2000	2001	3.7%
9	Euronext†	Europe/Africa	-	2000	2001	7.7%
10	Hellenic*	Europe/Africa	-	1999	2000	0.2%
11	Istanbul	Europe/Africa	√	-	-	0.1%
12	Johannesburg JSE	Europe/Africa	√	-	-	0.2%
13	London	Europe/Africa	-	2000	2001	10.0%
14	Malta	Europe/Africa	√	-	-	0.0%
15	Oslo	Europe/Africa	-	2001	-	0.2%
16	OM Gruppen	Europe/Africa	-	1993	1998	1.0%
17	SWX Zurich	Europe/Africa	-	2002	-	1.5%
18	Vienna	Europe/Africa	-	1998	-	0.0%
19	Warsaw	Europe/Africa	√	-	-	0.0%
20	Australian	Asia/Pacific	-	1998	1998	0.7%
21	Hongkong	Asia/Pacific		2000	2000	0.7%
22	Jakarta	Asia/Pacific	√	-	-	0.0%
23	Kuala Lumpur	Asia/Pacific	√	-	-	0.1%
24	Phillippine	Asia/Pacific	-	2001	-	0.0%
25	Singapore SGX†	Asia/Pacific	-	1999	2000	0.2%
26	Taiwan	Asia/Pacific	√	-	-	1.8%
27	Thailand	Asia/Pacific	√	-	-	0.1%
28	Tokyo	Asia/Pacific	-	2001	-	4.8%
	Total		11	17	9	**85.2%**

*: Athens Stock Exchange in 1999
†: Pro forma figures for 1999
Sources: HP Handbook of World Stock, Derivatives and Commodity Exchanges, exchange websites, FIBV .

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

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.[33]

[31] Confer our explanation in section 2.1, formula (6) and footnote 25.

[32] In order to employ White-corrected estimators to control for cross-sectional heteroscedasticity we use EViews 5 as statistical package. For the Tobit-regressions we will utilize Stata 8 as EViews does not provide a panel data version for censored data.

[33] 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 World Federation of Stock Exchanges (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.

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.[34] The sample includes 17 demutualized exchanges of which nine entities have also gone public, whereas eleven exchanges remain governed by a mutual structure or are partially state-controlled.[35] Taking the FIBV's fifty largest stock exchanges worldwide as the benchmark, our study includes all exchanges that were publicly listed until 2003. However, the portion of mutuals and demutualized exchanges lies at a mere 50%, respectively. This is due to the lack of comprehensive disclosure requirements for demutualized and mutual exchanges in some countries, which makes the gathering of information on their financial statements impossible. Hence, these two groups are underrepresented.

3.2 Variables

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

3.2.1 Operational variables

In the first stage, the DEA and 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. When considering input variables, it seems plausible 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 ($y^2_{i,t}$).[36] As several exchanges have diversified their businesses into related activities such as derivatives

[34] Trading volume data from (alternative) electronic trading platforms and from banks that internalize customer orders are not taken into account. We acknowledge that these forms of equity trading gained considerable importance in recent years. Nevertheless, it is not possible to include these figures in a comprehensive and coherent fashion.

[35] For convenience reasons, the paper will denote the last type of governance structure merely as 'mutual'.

[36] 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.

	FIRST STAGE: Operational Variables
	Inputs
$\mathbf{x^1_{i,t}}$	Number of staff employed at exchange i in period t
$\mathbf{x^2_{i,t}}$	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
$\mathbf{y^4_{i,t}}$	Revenues from post-trading and software at exchange i in period t (in thousand dollars)

	SECOND STAGE: Framework Variables
	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. (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 (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 to the total number of new foreign listings worldwide (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. (in %)
	Business Model
$\mathbf{OUTSOURCING_{i,t}}$	Dummy variable indicating whether exchange i has outsourced its IT-system in period t.
$\mathbf{HORIZONTAL_{i,t}}$	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.
$\mathbf{FULL\ INTEGRATION_{i,t}}$	Dummy variable indicating whether exchange i is both vertically and horizontally integrated in period t.
	Control Variable for Productivity Regressions
$\mathbf{\Delta EFF_{i,t-1}}$	Corresponding efficiency values (CRS or VRS) of exchange i in period t-1.

Table 2: Variables used in the two-stage process

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.[37] Therefore, variable $y^3_{i,t}$ captures the total *number of derivative contracts* traded on the derivatives markets. Variable $y^4_{i,t}$ represents the *revenues from post-*

[37]As a consequence, some exchanges, that do not provide these type of activities, will display a zero output on these variables in the data set. This contradicts the claim of the DEA literature requiring that all inputs and outputs need to be strictly positive. However, when checking the volatility of the attained results by assigning small positive values to these output variables instead of zeros, the results of DEA do not change. This is due to fact that the DEA-optimization gives a zero weighting on those outputs in any case.

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 as was mentioned earlier in footnote 16. Considering the applied inputs and outputs in this paper, it makes sense to employ 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.

3.2.2 Framework variables

The second stage 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.[38] 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 corporate governance regime (2) the competitive environment and the attractiveness of the exchange's home capital market (3) the exchange's financial flexibility and (4) the exchange's business model.

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. We thus assume that a demutualized but unlisted exchange is more or less controlled by its old stakeholders, i.e. its customers. Exchanges that are publicly listed usually possess a large fraction of outside owners so that we feel comfortable to denote these venues as outsider-dominated. 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 $DEMUT = 1 \wedge LISTED = 1$,

[38] 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 7.2.

i.e. both demutualized and listed.[39] 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 dummies are significantly positive since this would indicate that the "modernized" exchanges, i.e. the demutualized and/or listed venues, outperform mutuals in efficiency and productivity scores. Furthermore, since some authors emphasize the importance of being publicly listed for a successful restructuring[40], we expect a stronger performance by outsider-dominated exchanges.

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. 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 general trends on international equity markets we deduct from each exchange's y-o-y performance the median change of the sample 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 vis-à-vis 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.[41]

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

[40] Confer section 1.

[41] 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.

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 signs: It could have a positive sign when a 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 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.[42] 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 captures the year-on-year change in equity and long-term debt as is stated in the exchanges' balance sheets.[43]

Business model 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

[42] 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.

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

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.

We indicated in section 3.2.1 that several exchanges extended their activities to other areas besides the classic 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 both integrated vertically and horizontally, which we denote in the following as 'fully integrated'. As a consequence, there are varying ways to conduct business in this industry. We believe that we have to control for this aspect, since different configurations may have different effects on exchange efficiency and productivity due to potential economies of scope between the aforementioned activities. Consider for example the combination of a cash and a derivatives market, which could be operated by a single trading system, and therefore save (input) resources. In a similar fashion one could expect economies of scope when combining trading and post-trading services by utilizing straight-through-processing applications.[44] We will therefore employ three dummy variables, denoted as $HORIZONTAL$, $VERTICAL$, and $FULL\ INTEGRATION$, in order to capture the effects of horizontal, vertical and full integration, respectively. Our ex ante expectation concerning the impact of horizontal and/or vertical integration is that it should enhance exchange efficiency and productivity vis-à-vis exchanges that solely operate a cash market.

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.[45] The mean efficiency values are greater in the VRS-case than in the CRS-case since the VRS-efficient frontiers "envelop" the observations more closely. While this effect is relatively moderate for most of the observations, it boosts the efficiency values of some smaller DMUs like the exchanges of Vienna, Budapest and Malta considerably. Furthermore, the VRS-case computes four exchanges, namely Copenhagen, Deutsche Börse, Euronext and Malta, that are fully efficient in all five considered periods, whereas there are only two such cases in the CRS-environment (Copenhagen and Euronext). When focusing on productivity growth, both underlying technolo-

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

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

gies display an overall increase in mean productivity except for the 2001/2002-period where we calculated an overall stagnation in factor productivity. The most remarkable increase is 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 2.3. The table presents the results of White-corrected regressions against DEA-efficiency (EFF), 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 (2-9) for convenience. Overall, the R^2-values of the productivity regressions are reasonable, save for the less appealing values in columns five and nine. For the two Tobit efficiency regressions we display the respective Wald-χ^2-values in columns two and six. 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 productivity regressions in all but one case (column nine), since the p-values display a highly significant rejection of the null-hypothesis. Thus, the use of the fixed effects model is more appropriate.

Influence of competition, financial flexibility, efficiency The results from the variables representing the competitive environment show that a favorable market environment tends to improve the *efficiency* of exchanges. This can be seen at variables $\Delta TRADING$ and $FOREIGN\ LISTING$ in the VRS-setting (column six). They display a significantly positive relationship towards efficiency which implies that exchanges that possess an above sample-median performance in trading volume development and that have a more attractive capital market are on average also more efficient. In the CRS-environment the case is less pronounced since the $\Delta TRADING$ variable is insignificant (column two). The impact of $LIQUIDITY$ on efficiency remains insignificant in both technology settings. The influence of the competition variables on the exchanges' *productivity* is mixed in the CRS-case. An attractive capital market seems to have a positive effect on overall productivity, whereas the contrary holds for higher levels of liquidity. The competition variables in the VRS-setting are 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 five and nine). Thus, additional funds do not seem to have a positive effect on the performance of an exchange.

	Constant Returns-To-Scale				Variable Returns-To-Scale			
	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.133***	0.001	-0.161***	0.187**	0.191***	-0.083***	-0.107***	0.025
Std. Err.	*0.047*	*0.049*	*0.044*	*0.081*	*0.063*	*0.030*	*0.030*	*0.025*
LISTED	0.040	-0.001	-0.083	0.060†	0.091	0.054	-0.068	0.127**
Std. Err.	*0.068*	*0.113*	*0.092*	*0.041*	*0.079*	*0.117*	*0.092*	*0.058*
LIQUIDITY	0.006	-0.032***	-0.002	-0.040	-0.034	-0.021	0.059	-0.063
Std. Err.	*0.031*	*0.011*	*0.022*	*0.034*	*0.043*	*0.054*	*0.063*	*0.087*
ΔTRADING	-0.002	0.008	-0.037	0.060	0.083*	0.040	0.003	0.059
Std. Err.	*0.038*	*0.034*	*0.034*	*0.054*	*0.047*	*0.039*	*0.073*	*0.077*
FOREIGN LISTING	1.804***	0.874†	-0.566	1.609*	2.347***	-0.271	-0.109	-0.218
Std. Err.	*0.388*	*0.61*	*0.848*	*0.900*	*0.687*	*0.868*	*0.503*	*1.007*
ΔLT FINANCE	-0.004	-0.029	0.029	-0.084***	-0.007	-0.026	0.054	$-0.095^{\dagger}$
Std. Err.	*0.033*	*0.069*	*0.071*	*0.018*	*0.041*	*0.073*	*0.048*	*0.060*
OUTSOURCING	0.045	-0.343***	-0.498***	0.187	-0.009	-0.400***	-0.450***	0.099†
Std. Err.	*0.059*	*0.051*	*0.056*	*0.078*	*0.065*	*0.132*	*0.088*	*0.070*
HORIZONTAL	-0.039	$-0.214^{\dagger}$	-0.300**	0.132	0.150**	-0.085	-0.154***	0.053
Std. Err.	*0.068*	*0.154*	*0.134*	*0.098*	*0.076*	*0.129*	*0.050*	*0.098*
VERTICAL	-0.006	-0.153**	-0.247**	0.137	0.180**	-0.128***	-0.116***	-0.010
Std. Err.	*0.086*	*0.065*	*0.120*	*0.138*	*0.085*	*0.048*	*0.044*	*0.053*
FULL INTEGRATION	-0.101	0.029	-0.127	0.147	0.164**	0.145†	-0.041	0.153*
Std. Err.	*0.085*	*0.081*	*0.093*	*0.140*	*0.085*	*0.092*	*0.044*	*0.092*
EFF		-1.096***	-1.003***	-0.096		-0.634***	-1.033***	0.329**
Std. Err.		*0.328*	*0.351*	*0.116*		*0.239*	*0.312*	*0.158*
CONST	0.592***	1.923***	2.032***	0.888***	0.654***	1.674***	1.977***	0.766***
Std. Err.	0.080	*0.189*	*0.151*	*0.047*	0.086	*0.142*	*0.211*	*0.129*
Observations	140	112	112	112	140	112	112	112
Waldχ^2/R^2(adj.)	54.83	0.334	0.417	0.082	55.28	0.285	0.372	-0.070
Hausman Test (p)	-	0.0000	0.0000	0.1097	-	0.0012	0.0000	0.6077

Table 3: Results from the second-stage regression analysis

The control variable EFF shows that *productivity* indeed is lower for exchanges that possess higher efficiency values (columns three and seven). Thus, productivity gains are easier to accomplish for exchanges with lower efficiency values.

Influence of business model From our $OUTSOURCING$ variable we infer that outsourcing has no significant effect on stock exchange *efficiency*, while it significantly reduces overall *productivity* (columns three and seven). Focusing on the sources of this underperformance we observe that this reductions stems primarily from the negative effect on improvements in technical efficiency (columns four and eight), while technological progress seems to increase when an exchange outsources its IT-system. For the latter point,we find weakly significant evidence in column nine.

The influence of the three integration dummy variables on stock exchange *efficiency* is negligible in the CRS-case. In the VRS-setting, all three business configurations seem to be superior to the efficiency of exchanges that merely operate a cash market. However, our robustness checks displayed in appendix D suggest that these findings are not very reliable. Alternations to the model result in a significant change of their respective signs. Hence, we would not want to draw any conclusions with regard to the existence of economies of scope between different activities. On the other hand, our findings on *productivity* are more robust so that some inferences can be made. Here, horizontally integrated exchanges possess a lower productivity value than cash markets-only operators in the CRS-case (column three), which is mainly driven by a weaker performance in efficiency improvements (column four). A similar pattern can be observed for vertically integrated exchanges, which also seems to hold in the VRS-setting. There is evidence that fully integrated exchange have a better performance than cash markets-only venues in the VRS-case (column seven). However, although this outcome is pretty robust to variations in the regression model it is not significant in our bootstrap regressions. Therefore, we take a rather cautious stance regarding conclusions on their comparative performance.

Although some interesting points can 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 two governance variables, which will be discussed in the following.

Influence of governance The $DEMUT$-variable indicates that demutualized exchanges possess *efficiency* levels that are 13 to 19 percentage points higher than that of mutual exchanges depending on the technological setting (confer the $DEMUT$-coefficients in columns two and six). Focusing on the Malmquist-regressions in columns three and seven, 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 this underperformance is explained in both technology settings by a significantly lower value in improvements of technical efficiency (ΔEFF) as can be seen in columns four and eight. According to our estimates demutualized exchanges fare on average 10-16 percentage points worse on this dimension than mutual exchanges. The demutualized exchanges' progress in technology, the second component of productivity, is significantly higher in the CRS-case (column five) by 19 percentage points. As a result, they are able to compensate their underperformance in the first component insofar that the overall productivity converges with that of the mutuals' average performance. In the VRS-case however, such a recoupment is not observable since their improvements in technology is not significantly different from zero (=the mutuals' performance) as can be seen in column nine. As a consequence, the aforementioned resulting aggregate effect for productivity growth is on average lower vis-à-vis the mutuals' performance (column seven).

The $LISTED$-variable, which indicates the additional effects of an outsider-owned governance structure on efficiency and productivity remains largely negligible. The only noticeable significance can be observed in columns five and nine. Here, we find evidence that the observed pattern of demutualized exchanges, i.e. a higher technological progress, can be found for publicly listed exchanges as well. Since the variable measure incremental effects on top of the $DEMUT$-variable, we conclude that this effect is more pronounced for listed stock exchanges, namely by 6 and 12 percentage points, depending on the technological setting.

Interpreting the results of the governance variables The productivity results came a bit surprising to us since we ex ante expected that commercialized exchanges would have a stronger 'drive' to improve productivity in line with their profit-maximizing goal. So why are mutuals doing a better job in improving their technical efficiency while demutualized and listed exchanges are more apt in improving their technology? A plausible economic interpretation is that governance restructuring coincides with changes in operations that lead to temporary (technical) inefficiencies until the new processes are settled and optimized. The stronger rise in technological progress of demutualized (and listed) exchanges vis-à-vis mutuals may indicate increased employment of electronic trading and processing, a potential result from the possibility to abandon an archaic trading floor more easily in a governance structure where traders have a reduced influence on corporate decisions.[46].

In the following, we want to provide some verification that this interpretation seems to have some appeal. First, we want to consider the explanation that the poor performance in improvements in technical efficiency (ΔEFF) of demutualized and listed exchanges could be due to temporary frictions that occur during a restructuring period. One possible way to quantify this is by looking at the variation of the exchanges' most relevant input factors, such as its employee numbers and its assets, over time. If we assume that a stronger variation in these input variables explains operations restructuring, i.e. hiring additional staff for certain new activities and/or reducing employee numbers in unprofitable segments as well buying new businesses and/or selling others, and if we further assume that these extraordinary activities are strongly related to a wider restructuring effort which also includes a governance change, we then should find a higher variation in these factors for demutualized and listed exchanges than for mutual enterprises. To verify our presumption, we pursue the following steps: (1) We calculate the five year (1999-2003) mean and standard deviation for each of the 28 exchanges' staff sizes, tangible assets and total assets. In order to avoid currency-conversion effects on the values of the assets we employ inflation-adjusted home currency book values from the respective balance sheets. (2) By dividing each standard deviation by its corresponding mean, we receive the variation coefficient of each input variable. This gives us a percentage value of 'variability' for each input factor and exchange. (3) We build three subsamples from our sample. The first group consists of exchanges that underwent a demutualization process during the analyzed time frame. In order to have data prior and after the process we focus on those exchanges that demutualized either in 2000 or 2001. These are the following nine exchanges: Toronto, Deutsche Börse, Euronext, London Stock Exchange, Hongkong, NASDAQ, Oslo, Philippine and Tokyo.[47] The second group, which functions as a control group, comprises eleven exchanges that did not change their governance and remained mutuals in the relevant time period. These are: NYSE, Lima, BOVESPA, Istanbul, Johannesburg, Malta, Warsaw, Jakarta, Kuala Lumpur, Taiwan and Thailand. Our third group, which includes Copenhagen, OM Gruppen, Vienna and Australian Stock Exchange, consists of demutualized exchanges that underwent the restructuring prior to our considered time frame. This group should give us some insights whether the

[46]Confer in particular Steil (2002) who analyzes the causes and consequences of a governance change on the exchange's trading technology.

[47]Although some of these exchanges go a step further by going public it is still reasonable to subsume these exchanges under one group as the empirical results showed that both groups exhibit a similar pattern for the ΔEFF and $\Delta TECH$-variables.

variability of input variables is different when the demutualization process lies a few years in the past.[48] (4) We compare the three groups by their respective median variation values.

Figure 3 displays the median variation coefficients of the three inputs and the three subsamples. The sample of demutualized exchanges (black bars) indeed exhibit a higher variability than the sample of mutuals (light grey bars), which therefore confirms our interpretation. Note also that the variability decreases for the third group (dark grey bars), which we denoted as 'Old-Demutualized' here. Thus, assuming that the variability indeed decreases after the demutualization process we would expect that our first subgroup may also experience less variability in the future and therefore stronger improvements in technical efficiency.

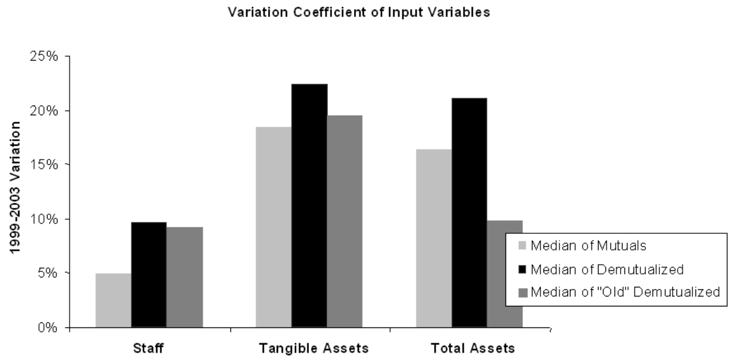

Figure 3: Variation Coefficients of Inputs by Governance Type

The second point we want to explore is whether there is evidence that the demutualization process indeed promotes technology-enhancing measures such as the increased utilization of an electronic order book (EOB). For this purpose we calculate the portion of an exchange's annual equity trading volume processed by an EOB. Using the first and the second subgroup of exchanges as defined before, we can compare these groups' annual median values. Unfortunately, comprehensive information on the EOB is only available for the years 2001 to 2003[49] so that we cannot provide insights to the situation prior to the actual demutualization of the exchanges comprising the first group. Nevertheless, as can be seen from figure 4, we are able to identify an increased use of electronic trading within the demutualized group after their restructuring in 2000 and 2001. Yet, the increase from 60% of total equity volume to 73% within three years is dwarfed by the median values of the mutual group. Here, we observe a slight decline from 100% computerization in 2001 to a still very high figure of 89%. Thus, while we can confirm our notion that demutualized exchanges indeed increasingly substitute their trading floors by computerized trading systems the findings also suggest that there is no confirmation

[48] We did not incorporate the remaining four exchanges of our sample into the analysis since they have either demutualized between 1999 and 2000 or after 2001. Thus, they would have distorted the comparison, for we wanted to highlight the effects of the actual restructuring process.

[49] Confer to the FIBV.

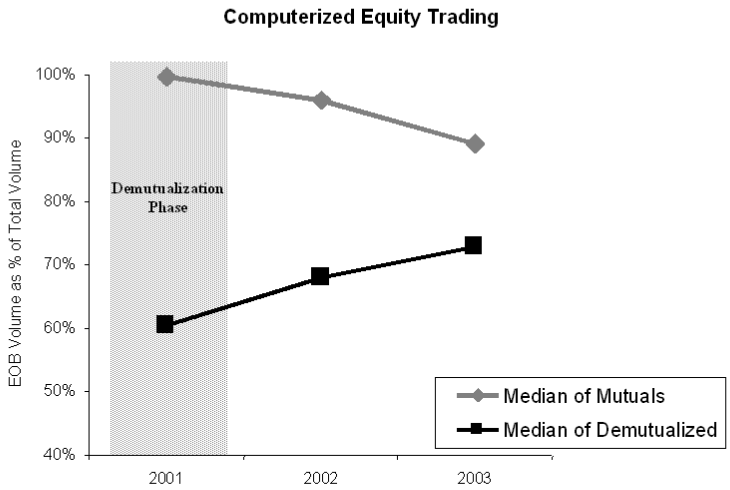

Figure 4: Percentage of Electronic Trading by Governance Type

of the argument brought forward by Steil (2002, p.62-68) that demutualization is a necessary step to overcome the brokers' resistance against an electronic order book. In the contrary, the eleven mutual exchanges under consideration used computerized trading much more intensively than the exchanges in the subsample of demutualized exchanges.[50] The apparent prevalence of a modern trading infrastructure at mutual exchanges would also explain why they perform weaker on the $\Delta TECH$-variable: There just might be no further obvious ways to improve their technology as dramatically as the demutualized exchanges were able to do it, for the latter still heavily used non-electronic trading platforms. Hence, the only way to improve productivity at these mutuals was possible by optimizing existing processes, which may give an alternative reasoning for their higher ΔEFF-values.

Robustness of findings To check the robustness of our results, in particular of our findings on the two governance variables $DEMUT$ and $LISTED$, we conducted several robustness checks. On the one hand, we changed the composition of our regression model in several ways to verify whether this has any significant impact on our governance variables. On the other hand, we verified the validity of our inference by using bootstrapped standard errors for our regressions.[51] In appendix D we present tables 7 and 8 that indicate the results of the alternations to our

[50] They might have even overdone it as we observe a decline between 2001 and 2003. This could be explained by a return to manually executed trading for stock orders that potentially possess a strong market impact as floor brokers may handle certain orders more intelligently than electronic trading systems. Handa, Schwartz, and Tiwari (2004) find evidence for this reasoning at the American Stock Exchange.

[51] 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 90% and 95%-confidence intervals by using the 2.5%, 5% and the 95%, 97.5% percentiles of the distribution, respectively. We also controlled for our panel data structure by using clusters. Confer Bradley and Tibshirani (1993) for an elaborate discussion on bootstrapping.

model. Tables 7.1 and 7.2 display the impact on the governance variables when the variables describing the financial background and business models as well as the competitive situation of an exchange are omitted, respectively. Tables 8.1 and 8.2 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 8.1 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 8.2 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 9 shows our regression results when utilizing the bootstrap method.

Overall, we find that the governance variables' coefficients from our original regression model are very 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. Also the coefficients' significance is hardly affected by regression model variations. The results of our bootstrap-estimates show that the coefficients of the $DEMUT$-variable turn insignificant in the VRS-case which weakens our prior finding that the demutualized exchanges' productivity is significantly worse than that of mutual exchanges.

4 Conclusion

This paper analyzed the efficiency and productivity of the stock exchange industry for the years 1999 to 2003. The chief aim of this research was to provide an empirical contribution to the growing literature on exchange demutualization since some of the points made by other authors rely mostly on anecdotal evidence. Contrary to the statements of some researchers our findings do not support the view that an outsider dominated exchange is a precondition for dealing adequately with increased levels of competition in this industry. Therefore, the case for an IPO, a measure that involves considerable one-off and additional running costs cannot be advocated from a technical efficiency perspective. However, a demutualization process that retains the exchange's customers as its main owners but realigns the ownership structure, for example more in congruence with the customer's respective volume of conducted business, seems promising from a technical efficiency point of view. Assuming that productivity growth will also improve when the restructuring process is completed, this would make this decision even more sensible.

Another point that is commonly advanced in the literature is challenged by this paper: The assumption that a demutualization process is necessary to install modern trading systems cannot be empirically confirmed. In the contrary, the mutual exchanges in our sample have a persistently higher portion of electronic trading than the demutualized and listed exchanges of our sample. Thus, it seems that mutual exchanges are well aware of the necessity to adapt to new trading technologies without changing their governance structure substantially.

We conclude that the rationale behind an IPO seems not primarily driven by efficiency-enhancing motives. An IPO is more likely to be used as a solution vehicle for the diverging interests between (few) large international financial intermediaries and (many) small local brokers. The exchange's old owners possibly viewed a public listing as a catalyst to both maximizing the value of their venue and creating an exit option for those members that were unwilling to bear the costs of a operations restructuring. The fact that most of these IPOs occurred during the bull market until 2000/01, where relatively high sales prices were feasible, further strengthens this argument. Therefore, in anticipation of a substantial appreciation of the value of their voting rights, many small broker gave up their reluctance to demutualize and their hitherto relatively large share of the control structure in favor of cashing out these rights on the securities market. Hence, in the spirit of the theoretical findings by Hart and Moore (1996), we would speculate that the severeness of the conflicting interests among former members of an exchange influenced the respective exchanges' decisions on the appropriate governance regime. Exchanges that possess a relatively homogeneous member structure were able to respond to a changing environment without significantly altering their structure. On the other dimension's end, exchanges with a highly heterogeneous composition could not overcome their conflicts other than providing side payments via an IPO to resolve deadlocks on important decisions concerning the exchange's future strategy.

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

	EFF (CRS)		EFF (VRS)	
	Mean	Std. Dev.	Mean	Std. Dev.
1999	0.613	0.289	0.685	0.287
2000	0.642	0.293	0.724	0.275
2001	0.632	0.271	0.754	0.260
2002	0.610	0.286	0.766	0.297
2003	0.586	0.328	0.666	0.314

	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	HORIZONTAL	VERTICAL
	Sum	Sum	Sum	Sum	Sum
1999	6	2	5	11	4
2000	11	5	7	10	5
2001	15	8	7	10	5
2002	17	9	8	9	4
2003	17	9	7	7	4

	FOREIGN LISTING		LIQUIDITY		FULL INTEGRATION
	Mean	Std. Dev.	Mean	Std. Dev.	Sum
1999	0.026	0.046	0.680	0.535	5
2000	0.031	0.071	1.038	1.103	5
2001	0.028	0.058	0.812	0.746	7
2002	0.028	0.059	0.881	0.772	9
2003	0.013	0.021	0.699	0.518	10

	Δ LT FINANCE		Δ TRADING	
	Mean	Std. Dev.	Mean	Std. Dev.
1998-1999	0.416	0.899	0.130	0.614
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

Efficiency Regression Variables	x^1	x^2	y^1	y^2	y^3	y^4
DEMUT	0.160	0.118	0.110	-0.009	0.223	0.290
LISTED	0.309	0.084	0.085	-0.051	0.308	0.422
LIQUIDITY	0.320	0.394	0.502	0.579	0.163	0.110
ΔTRADING	0.007	-0.003	0.084	0.081	-0.070	-0.057
FOREIGN LISTING	0.363	0.602	0.698	0.866	0.017	-0.018
ΔLT FINANCE	-0.013	-0.065	-0.066	0.011	0.056	0.016
OUTSOURCING	-0.379	-0.172	-0.180	-0.081	-0.189	-0.185
HORIZONTAL	-0.402	-0.327	-0.338	-0.239	0.008	-0.223
VERTICAL	-0.175	-0.185	-0.236	-0.189	-0.138	-0.094
FULL INTEGRATION	0.515	0.120	0.068	-0.074	0.300	0.505
Productivity Regression Variables	x^1	x^2	y^1	y^2	y^3	y^4
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
OUTSOURCING	-0.382	-0.183	-0.176	-0.086	-0.186	-0.207
HORIZONTAL	-0.245	-0.271	-0.249	-0.189	-0.154	-0.132
VERTICAL	-0.242	-0.285	-0.320	-0.215	0.079	-0.099
FULL INTEGRATION	0.443	0.160	0.094	-0.094	0.253	0.477
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 Robustness Checks

7.1	Regressions without financial flexibility and business model variables							
	Constant Returns-To-Scale				Variable Returns-To-Scale			
	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.123***	0.056	-0.132*	0.212***	0.168***	-0.041*	-0.095***	0.057*
Std. Err.	*0.046*	*0.067*	*0.073*	*0.091*	*0.059*	*0.024*	*0.015*	*0.035*
LISTED	-0.005	-0.047	-0.166	0.103***	-0.003	0.005	-0.139	0.156**
Std. Err.	*0.060*	*0.167*	*0.149*	*0.028*	*0.072*	*0.161*	*0.114*	*0.073*
LIQUIDITY	0.006	-0.001	0.033	-0.051*	0.115***	0.016	0.086*	-0.056
Std. Err.	*0.030*	*0.028*	*0.031*	*0.031*	*0.038*	*0.055*	*0.051*	*0.087*
ΔTRADING	-0.010	0.032	-0.019	0.057	-0.012	0.082**	0.027	0.069
Std. Err.	*0.037*	*0.037*	*0.051*	*0.058*	*0.047*	*0.034*	*0.073*	*0.069*
FOREIGN LISTING	1.851***	0.766†	-0.814	1.795*	3.161	-0.526	-0.348	-0.196
Std. Err.	*0.384*	*0.544*	*0.855*	*0.980*	-	*0.795*	*0.470*	*0.996*
EFF		-1.147***	-0.979***	-0.178		-0.623**	-0.981***	0.281***
Std. Err.		*0.307*	*0.334*	*0.139*		*0.274*	*0.311*	*0.113*
CONST	0.564***	1.735***	1.707***	1.058***	0.533	1.513***	1.748***	0.835***
Std. Err.	*0.038*	*0.208*	*0.212*	*0.071*	-	*0.211*	*0.222*	*0.080*

7.2	Regressions without competition variables							
	Constant Returns-To-Scale				Variable Returns-To-Scale			
	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.103	-0.029	-0.135***	0.123**	0.136*	-0.087***	-0.101***	0.012
Std. Err.	*0.100*	*0.042*	*0.021*	*0.057*	*0.084*	*0.025*	*0.031*	*0.023*
LISTED	0.095	-0.008	-0.080	0.048	0.062	0.055	-0.064	0.126*
Std. Err.	*0.096*	*0.105*	*0.097*	*0.045*	*0.093*	*0.106*	*0.094*	*0.068*
ΔLT FINANCE	-0.003	-0.035	0.029	-0.089***	-0.033	-0.019	0.055	-0.086
Std. Err.	*0.035*	*0.068*	*0.066*	*0.032*	*0.044*	*0.073*	*0.054*	*0.063*
OUTSOURCING	0.087	-0.340***	-0.484***	0.172***	0.033	-0.419***	-0.455***	0.073
Std. Err.	-	*0.047*	*0.037*	*0.064*	-	*0.109*	*0.069*	*0.057*
HORIZONTAL	-0.094	-0.142***	-0.263***	0.171	-0.167*	-0.112***	-0.124***	0.020
Std. Err.	*0.111*	*0.057*	*0.108*	*0.133*	*0.094*	*0.044*	*0.051*	*0.054*
VERTICAL	-0.071	-0.204	-0.314***	0.162	0.006	-0.065	-0.163***	0.087
Std. Err.	*0.078*	*0.170*	*0.105*	*0.145*	*0.095*	*0.141*	*0.050*	*0.143*
FULL INTEGRATION	-0.160	0.043	-0.161***	0.209†	-0.237**	0.182***	-0.041	0.209*
Std. Err.	*0.136*	*0.091*	*0.058*	*0.144*	*0.116*	*0.067*	*0.062*	*0.113*
EFF		-1.039***	-1.038***	0.005		-0.648***	-1.033***	0.314*
Std. Err.		*0.300*	*0.303*	*0.054*		*0.22*	*0.317*	*0.165*
CONST	0.668***	1.892***	2.035***	0.843***	0.857***	1.647***	2.026***	0.699***
Std. Err.	*0.087*	*0.184*	*0.148*	*0.055*	*0.097*	*0.128*	*0.234*	*0.159*

Table 7: Robustness check by omitting variables

	Regressions with different competition variables							
8.1	Constant Returns-To-Scale				Variable Returns-To-Scale			
ΔTRADING$_{t-1}$ for t	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.111*	-0.004	-0.157***	0.171**	0.107*	-0.085**	-0.095***	0.006
Std. Err.	*0.060*	*0.041*	*0.037*	*0.072*	*0.057*	*0.038*	*0.033*	*0.028*
LISTED	0.015	0.010	-0.077	0.079**	0.049	0.038	-0.107	0.152**
Std. Err.	-	*0.112*	*0.087*	*0.036*	*0.069*	*0.125*	*0.100*	*0.070*
LIQUIDITY	-0.034	-0.041***	0.011	-0.074*	0.064†	-0.03	0.076*	$-0.099^{\dagger}$
Std. Err.	*0.024*	*0.016*	*0.035*	*0.041*	*0.044*	*0.039*	*0.043*	*0.066*
ΔTRADING	0.020*	0.022	0.015	0.035	0.046	-0.034	-0.078*	0.045
Std. Err.	*0.010*	*0.042*	*0.042*	*0.039*	*0.041*	*0.037*	*0.046*	*0.030*
FOREIGN LISTING	1.154***	0.872†	-0.643	1.687*	3.120***	-0.184	-0.041	-0.166**
Std. Err.	*0.407*	*0.552*	*0.853*	*0.956*	*0.642*	*0.842*	*0.429*	*0.937*
ΔLT FINANCE	0.009	-0.025	0.026	-0.070***	-0.001	-0.025	0.044	-0.081
Std. Err.	*0.031*	*0.062*	*0.076*	*0.024*	*0.040*	*0.077*	*0.047*	*0.040*
OUTSOURCING	0.109	-0.345***	-0.479***	0.162***	0.156***	-0.421***	-0.457***	0.074
Std. Err.	-	*0.050*	*0.041*	*0.052*	*0.062*	*0.11*	*0.057*	*0.063*
HORIZONTAL	-0.017	-0.129***	-0.244**	0.189	-0.140**	-0.149***	-0.192***	0.052
Std. Err.	*0.037*	*0.022*	*0.123*	*0.185*	*0.072*	*0.05*	*0.046*	*0.071*
VERTICAL	-0.008	-0.206	-0.307***	0.158	0.098	-0.081	-0.174***	0.083
Std. Err.	*0.045*	*0.15*	*0.122*	*0.124*	*0.082*	*0.121*	*0.053*	*0.122*
FULL INTEGRATION	-0.088	0.052	-0.146*	0.222	-0.146*	0.152*	-0.100	0.239*
Std. Err.	-	*0.095*	*0.088*	*0.180*	*0.083*	*0.09*	*0.080*	*0.128*
EFF		-1.104***	-1.000***	-0.119		-0.624***	-1.008***	0.313**
Std. Err.		*0.311*	*0.351*	*0.125*		*0.239*	*0.307*	*0.148*
CONST	0.578	1.923***	2.019***	0.902***	0.718***	1.684***	1.985***	0.772***
Std. Err.	-	*0.18*	*0.152*	*0.038*	*0.085*	*0.137*	*0.201*	*0.122*

8.2	Constant Returns-To-Scale				Variable Returns-To-Scale			
ΔLIQUIDITY for ΔTRADING	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.129***	-0.002	-0.156***	0.177**	0.172**	-0.090**	-0.108***	0.015
Std. Err.	*0.048*	*0.044*	*0.042*	*0.076*	*0.078*	*0.038*	*0.037*	*0.030*
LISTED	0.039	0.005	-0.079	0.059†	0.021	0.058	-0.070	0.134**
Std. Err.	*0.073*	*0.107*	*0.088*	*0.040*	*0.085*	*0.114*	*0.094*	*0.061*
LIQUIDITY	0.009	-0.084**	-0.026	-0.049	0.048	-0.065	0.076**	-0.128**
Std. Err.	*0.031*	*0.041*	*0.037*	*0.035*	*0.047*	*0.055*	*0.039*	*0.067*
D LIQUIDITY	-0.021	-0.069**	-0.058	0.024	-0.018	-0.037	0.025	-0.057***
Std. Err.	*0.037*	*0.035*	*0.044*	*0.030*	*0.051*	*0.032*	*0.021*	*0.017*
FOREIGN LISTING	1.796***	1.060*	-0.489	1.655*	3.107***	-0.094	-0.184	0.049
Std. Err.	*0.383*	*0.567*	*0.803*	*0.94*	*0.663*	*0.939*	*0.433*	*1.021*
DELTA LT FINANCE	-0.007	-0.030	0.022	-0.074***	-0.013	-0.020	0.054	$-0.086^{\dagger}$
Std. Err.	*0.033*	*0.067*	*0.077*	*0.021*	*0.041*	*0.071*	*0.053*	*0.055*
OUTSOURCING	0.047	-0.362***	-0.493***	0.165***	0.158**	-0.427***	-0.446***	0.058
Std. Err.	*0.061*	*0.038*	*0.043*	*0.062*	*0.077*	*0.121*	*0.076*	*0.059*
HORIZONTAL	-0.044	-0.149***	-0.257**	0.155	-0.105	-0.115***	-0.116**	0.010
Std. Err.	0.071	0.062	0.120	0.148	0.083	0.044	0.055	0.056
VERTICAL	-0.006	-0.222	-0.320***	0.153	0.071	-0.079	-0.148***	0.06
Std. Err.	*0.084*	*0.166*	*0.132*	*0.119*	*0.09*	*0.126*	*0.057*	*0.116*
FULL INTEGRATION	-0.100	0.047	-0.148**	0.192	-0.165*	0.183***	-0.041	0.210*
Std. Err.	*0.086*	*0.103*	*0.073*	*0.159*	*0.089*	*0.073*	*0.067*	*0.121*
EFF		-1.079***	-0.981***	-0.114		-0.643***	-1.027***	0.315**
Std. Err.		*0.329*	*0.355*	*0.119*		*0.246*	*0.314*	*0.150*
CONST	0.595***	1.957***	2.048***	0.895***	0.701***	1.710***	1.958***	0.820***
Std. Err.	*0.081*	*0.157*	*0.134*	*0.032*	*0.092*	*0.144*	*0.224*	*0.114*

Table 8: Robustness check with varying competition variables

9	Regressions with Bootstrapping (2000 Replications, 5%and 10%-Levels)							
	Constant Returns-To-Scale				Variable Returns-To-Scale			
Bootstrapping	(2) EFF	(3) MQ	(4) ΔEFF	(5) ΔTECH	(6) EFF	(7) MQ	(8) ΔEFF	(9) ΔTECH
DEMUT	0.133*	0.001	-0.161*	0.187**	0.191**	-0.083	-0.107	0.025
Std. Err.	*0.097*	*0.106*	*0.098*	*0.047*	*0.133*	*0.091*	*0.097*	*0.055*
LISTED	0.040	-0.001	-0.083	0.060	0.091	0.054	-0.068	0.127*
Std. Err.	*0.150*	*0.159*	*0.129*	*0.062*	*0.201*	*0.160*	*0.124*	*0.079*
LIQUIDITY	0.006	-0.032	-0.002	-0.040	-0.034	-0.021	0.059	-0.063
Std. Err.	*0.065*	*0.105*	*0.106*	*0.080*	*0.094*	*0.059*	*0.092*	*0.089*
ΔTRADING	-0.002	0.008	-0.037	0.060	0.083**	0.040	0.003	0.059
Std. Err.	*0.049*	*0.066*	*0.066*	*0.059*	*0.060*	*0.057*	*0.091*	*0.074*
FOREIGN LISTING	1.803**	0.874	-0.566	1.609**	2.347*	-0.271	-0.109	-0.218
Std. Err.	*0.914*	*0.926*	*0.873*	*0.906*	*1.336*	*0.880*	*0.983*	*0.896*
ΔLT FINANCE	-0.045	-0.029	0.029	-0.084	-0.007	-0.026	0.054	-0.095*
Std. Err.	*0.037*	*0.123*	*0.091*	*0.060*	*0.067*	*0.076*	*0.061*	*0.059*
OUTSOURCING	0.045	-0.343**	-0.498**	0.187	-0.010	-0.400*	-0.450**	0.099
Std. Err.	*0.097*	*0.240*	*0.190*	*0.145*	*0.158*	*0.282*	*0.228*	*0.138*
HORIZONTAL	-0.039	-0.214**	-0.300*	0.132	0.150*	-0.085	-0.154	0.053
Std. Err.	*0.129*	*0.160*	*0.145*	*0.160*	*0.191*	*0.140*	*0.221*	*0.199*
VERTICAL	-0.006	-0.153	-0.247	0.137	0.180	-0.128	-0.116	-0.010
Std. Err.	*0.208*	*0.294*	*0.211*	*0.162*	*0.408*	*0.300*	*0.238*	*0.167*
FULL INTEGRATION	-0.101	0.029	-0.127	0.147	0.164	0.145	-0.041	0.153
Std. Err.	*0.173*	*0.217*	*0.163*	*0.165*	*0.232*	*0.194*	*0.224*	*0.206*
EFF		-1.096**	-1.002**	-0.096		-0.634**	-1.033**	0.329**
Std. Err.		*0.224*	*0.192*	*0.113*		*0.193*	*0.165*	*0.168*
CONST	0.592**	1.923**	2.032**	0.888**	0.654**	1.674**	1.977**	0.766**
Std. Err.	*0.111*	*0.219*	*0.182*	*0.149*	*0.170*	*0.197*	*0.189*	*0.179*

Table 9: Bootstrap test

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