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Technological development and concentration of stock exchanges in Europe

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Technological development and concentration of stock exchanges in Europe

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Abstract

This paper provides an explanation of technical inefficiencies of financial exchanges in Europe as well as an empirical analysis of their existence and extent. A single-stage stochastic cost frontier approach is employed, which generates exchange inefficiency scores based on a unique unbalanced panel data set for all major European financial exchanges over the period 1985–1999. Overall cost inefficiency scores reveal that European exchanges operate at 20–25% above the efficiency benchmark. The results also affirm that size of exchange; market concentration and quality; structural reorganisations of exchange governance; diversification in trading service activities; and adoption of automated trading systems significantly influence the efficient provision of trading services in Europe. Over the sample period, European exchanges notably improved their ability to efficiently manage their production and input resources.

Key words: Europe, financial exchanges, panel data, technical efficiency

JEL classification numbers: C33, D24, G20, G28, L22, O52

Euroopan pörssien keskittyminen ja tekninen kehitys

Suomen Pankin keskustelualoitteita 21/2001

Heiko Schmiedel
Tutkimusosasto

Tiivistelmä

Tässä tutkimuksessa arvioidaan Euroopan pörssien teknistä tehokkuutta. Lisäksi pohditaan vaihtoehtoisia hypoteeseja, joiden on katsottu selittävän pörssien mahdollista tehottomuutta. Tehottomuuksien mittaamisessa sovelletaan yhden vaiheen stokastisten kustannuspintojen menetelmää. Tutkimuksen ainoalaatuinen havaintoaineisto koostuu Euroopan keskeiset pörssit kattavasta paneelista vuosilta 1985–1999. Tutkimustulosten mukaan Euroopan pörssien kustannukset ovat keskimäärin 20–25 % suuremmat kuin mittapuuna käytetty tehokkuusnormi. Tulokset vahvistavat myös käsitystä, että pörssin koko, markkinoiden keskittyminen ja toimivuus, pörssien hallintajärjestelmien organisointi, kaupankäyntiin liittyvän palvelutoiminnan hajautuminen sekä automaattisten kaupankäyntijärjestelmien käyttöönotto vaikuttavat merkittävästi siihen, miten tehokkaasti Euroopan pörssit tuottavat kaupankäyntiin liittyviä palveluja. Tulokset viittaavat siihen, että Euroopan pörssit ovat tuotantotoiminnassaan kyenneet huomattavasti parantamaan käytettävissä olevien resurssien hallintaa viimeisen viidentoista vuoden aikana.

Asiasanat: Eurooppa, pörssit, paneeliaineisto, tekninen tehokkuus

JEL-luokittelu: C33, D24, G20, G28, L22, O52

Contents

1 Introduction

This study deals with the microstructure of the securities industry in Europe by analysing empirically the existence, extent and explanation of inefficiency effects among all major European financial exchanges. Integration of European financial services and capital markets is believed to have significant long-term benefits arising from improved capital allocation, more efficient intermediation of savings to productive investments, and the strengthening of EU economy (The Committee of Wise Men (2000) and (2001)). This is the major motivation that led monetary and fiscal authority traditionally articulate prime interest in European and global financial market developments. The European security industry experiences a period of great and rapid change, which is driven by three fundamental forces. First, the risk factor of exchange rate changes in the Euro area has been removed with the introduction of a common European currency. Second, the imposition of the Investment Service Directive abandoned considerable restrictions in European financial markets as it provides financial intermediaries with the "single passport" allowing them to benefit from favourable stock trading conditions at any European market regardless of their physical location. Third, in a global context advances in sophisticated communication and information technologies are reducing trading costs and are accelerating the production process of financial services (Hasan, Malkamäki, and Schmiedel (2001)). These far-reaching structural changes in European financial markets stimulate more effectively inter-exchange competition. This paper addresses these developments affecting the structure of European equity markets and it anticipates potential efficiency improvements arising from further consolidation and concentration of the industry.

The paper pursues a number of research issues concerning the microstructure of exchanges: the first is whether providers of trading services are organised efficiently? If this is not the case, what is the level of inefficiency that financial exchanges are facing relative to the best practice exchange and to which extent efficiency gains might arise from consolidation and concentration of stock exchanges in Europe? How does inefficiency among exchanges evolve over time? What determines exchange inefficiency and which are the characteristics explaining inefficiencies in the organisational structure and provision of trading activities?

While efficiency research to date has been extensively carried out in the context of bank performance and determinants of banking efficiencies (Berger and Humphrey (1997)), efficiency effects among exchanges have not been researched so far. Existing evidence relates to economies of scale and score in stock exchanges (Hasan and Malkamäki (2001)). As noticed by Hasan and Malkamäki (2001), a plausible explanation for this neglected research field is the unavailability of consistent panel data on key balance sheet items across stock exchanges. The purpose of this paper is to fill this gap in the literature and to contribute to the discussion about the future of stock exchanges by estimating technical efficiencies of European stock exchanges in a stochastic frontier framework. Domowitz and Steil (1999) claim that traditional literature on financial market structures mainly focuses on explicit trading rules, mechanisms, and on their impact on the price discovery process, but less work has been carried out on the economics of exchanges themselves. To have a better understanding of the functioning of the security trading industry this paper examines the organisation of financial exchange markets from a supply-sided perspective. Following Arnold, Hersch, Mulherin, and Netter (1999) as well as Domowitz and Steil (1999) stock exchanges are considered herein as operative firms which offer trading products and embody particular technologies. The key hypothesis of this analysis is that although inefficiency effects in the provision of trading services by European stock exchanges might have declined over time, inefficiencies still remain on a considerable high level.

A unique unbalanced panel data set is constructed, consisting of all major European financial exchanges over the time period 1985–1999. Using a single-stage econometric frontier approach (Kumbhakar and Lovell (2000)), Coelli, Rao and Battese (1998)), the paper estimates simultaneously stochastic frontier functions incorporating inefficiency effects of European stock exchanges and examines potential correlates helping to explain deviations from the efficient frontier.

The overall findings exhibit evidence that European exchanges' inefficiency scores are 20–25 per cent higher than the predicted benchmark. Improvements in efficiency among exchanges over the sample period are to be found in association with a number of exchange-specific characteristics. The results indicate that size of exchanges, market concentration and quality, diversification in other trading activities, emergence of sophisticated trading technologies, as well as changes of exchanges governance structures play a dominant role in the efficient provision of trading services in European stock exchange industry.

In order to benefit from a fully integrated European financial services and capital market, the results support the need for a more efficient security-trading infrastructure and for consolidation of the present fragmented security trading landscape at the European level. In this respect, one major challenge for European financial regulators will be to create and ensure a stable European regulatory system that is flexible enough to adjust adequately to future technological and market developments. First advances in this discussion has been achieved by a recent agreement on a new legislative process for European security markets based on the reports of the Committee of Wise Men (2001). Against the background of recent trends in the global and European economic environment, future nation-wide and cross-border consolidation, alliances and mergers, take-overs of financial exchanges are likely to be forthcoming in Europe.

The structure of the remainder is as follows. In section 2, the discussion of prior empirical and theoretical literature on financial markets structure provides the background for this study. Section 3 highlights recent developments in stock and derivative exchange industry. The stochastic frontier methodology and the functional specifications of the frontier models employed in this paper are defined in section 4. Section 5 describes the data set and deals with the selection of relevant variables. The empirical results are presented and discussed in section 6. The paper ends by drawing conclusions in section 6.

2 Relevant literature

In the literature on efficiency, a considerable amount of research has been carried out about the empirical estimation of financial institution efficiency, primarily in the context of depository institutions as well as firms in the insurance industry. Berger and Humphrey (1997) survey the results of 130 studies of financial institution efficiency covering 21 countries based on five different frontier efficiency approaches. Overall evidence of the reviewed studies suggests efficiency estimates near 80 per cent using both, parametric and non-parametric, frontier techniques. Although extensive evidence exists on different types of financial institutions, no study can be detected so far which benchmarks empirically the relative performance of financial exchanges.

In a broader context, some studies examine important changes in global financial markets evaluating causes, consequences, and future prospects for financial sector consolidation and emphasise the relevance of geographic patterns of financial activities (Berger, Demsetz and Strahan (1999)), The Committee of Wise Men (2001), Group of Ten (2001), OECD (2001). In particular, a recent OECD study (2001) describes the forces shaping structural changes in financial markets. The authors anticipate the development towards a future single global market by the mean of interconnected national equity markets as a potential outcome of rapidly proceeding market globalisation and technological advances. They argue in favour of a remaining coexistence of national local trading places for less-liquid financial products. However, problems may arise as their role is no longer unchallenged by international rival markets and thus the importance of smaller, marketplaces is expected to diminish over time.

Consistent with these developments, Gehrig (2000) models the implications of technological advances for the location of financial activities. Distinguishing between complex local and straightforward generally available information, he argues that the latter can easily be transferred through electronic networks while the former requires face-to-face interactions, i.e. when individuals make contracts bearing confidential contents. These two informational categories have different repercussions on financial centres. Certain financial services in particular those activities of the value chain consisting of a high degree of simple and standardised information can be shifted to lower-cost peripheral regions. In contrast, non-standardised financial activities that depend on complex information exchanges between market participants are best performed in front offices with an immediate local access to market information. Following Gehrig (2000) the relevance of geography for financial activities will persist even for stock exchanges at the national level conditionally on their ability of aggregating local non-standardised complex information.

A similar viewpoint derives from studies that emphasise the location of information as being a central element for the distribution of international capital flows and trading performances. Brennan and Cao (1997) construct a model of international equity portfolio flows based on the assumption of geographic information asymmetries between domestic and foreign investors. In the case that domestic investors enjoy a cumulative information advantage over foreign investors about their domestic market, investors tend to purchase foreign assets in periods when the return on foreign assets is high and tend to sell when the return is low. Considering a gravity model, Portes and Rey (2000) explore determinants of cross-border asset transaction in major equity markets. The results show that bilateral gross asset flows are especially suited to market size and distance as a proxy for informational asymmetries. Other information variables that bear explanatory power include proxies for information transmission, insider trading, and transaction technology. According to their findings, a negative relationship between asset trade and distance is strongly associated with informational asymmetries. Hau (2001) investigates international informational barriers across the trading population. He reports that geographical information asymmetries are main determinants of trading performance differences.

Related to the financial centre literature, Martin and Rey (2000) analyse on a theoretical level the effects of financial integration on asset flows, risk diversification and the breath of financial markets. In particular, they focus on the impact of cross-border listings on the cost of capital and on financial geography when financial markets become integrated implying a decline in transaction costs. Depending on the underlying cost structure of cross-border listings or equity trade, their model suggests that financial integration encourages the issue of shares on the largest markets of the integrated area. If financial integration implies decreasing fixed cost of issuing abroad within the integrated area smaller economies are then also likely to gain market shares and to benefit from financial integration.

In recent years there has been a sharp increase in the trading of foreign stocks as investors realise the necessity for international diversification and as foreign companies seek to broaden their shareholder base and raise capital (Domowitz, Glen, Madhavan (1998)). Evidence on cross-border listing decisions supports the view that geography in finance still maters. Pagano, Röell, and Zechner (1999) examine companies' cross-listing decisions from a firm-specific perspective. They observe the overall tendency that European companies have increasingly listed abroad, especially on U.S. exchanges over the considered time period, while listings of U.S. companies in the EU have declined. They find evidence that European companies listing on the transatlantic exchange reveal characteristics of high-growth, export-oriented, and high-tech industries. Apart from a few common features concerning size, high-foreign sale, and high R&D expenditure, inter-Europe cross-listing companies appear to differ considerably from those, being present on U.S. stock markets. In a subsequent empirical analysis, Pagano, Randl, and Röell (2001) demonstrate that European companies prefer to be cross-listed in more liquid and larger markets, as well as in markets with a relative high number of listed companies of the same industry. Furthermore, cross-listing decisions also seem to be positively related to markets offering better investor protection, more efficient courts and bureaucracy.

There is only little research available that addresses international comparisons of financial exchanges themselves. In contrast to classical financial market studies, Domowitz and Steil (1999) emphasise important effects of advances in automated trading technologies on operating costs and the organisational structure of an exchange, rather than focusing on transactions costs that traders face. By modelling aspects of the organisation of financial exchanges, Pirrong (1999) concludes that the existence of scale economies in the provision of trading infrastructure encourages co-operation and consolidation among financial trading services. In an earlier study on scale economies in security markets, Doede (1967) reports that the average operating costs of stock exchanges are a declining function of trading volume. In a closely related study Demsetz (1968) observes that bid-ask spreads are a declining function of the rate of transaction volume. Both approaches indicate evidence on economies of scale in exchange operations and in the market making of a particular security, respectively. In a game-theoretic framework, Di Noia (2001) addresses possible effects of cross-network externalities on competition and consolidation in the European stock exchange industry. It is demonstrated that competition may lead to inefficient equilibria while an implicit merger may have a Pareto optimal outcome and result in higher profitability of both exchanges. The implicit merger model shows that specialisation in listing or trading services among exchanges is likely. By analysing the effects of U.S. exchange mergers on trading volume and execution costs, Arnold, Hersch, Mulherin, and Netter (1999) find that merging exchanges attracted market share and experienced narrower bid-ask spreads.

Malkamäki and Topi (1999) analyse driving forces of the changes in the market structures for financial exchanges and securities settlement systems. They argue that economies of scale and scope and network effects will foster cross-border competition among exchanges. Furthermore, Hasan and Malkamäki (2001) investigate empirically the existence of economies of scale and scope among exchanges providing separate perspectives of different regions. They find evidence indicating substantial higher economies of scale and scope in North American and European exchanges in comparison to Asian and South American exchanges. Comparing descriptive statistics of total costs to total revenues of eleven European stock exchanges over 1993–1994, Cybo-Ottone, Di Noia, and Murgia (2000) observe that efficiency differences are likely to exist across the sample exchanges. However, these studies do not provide empirical support for the determination of efficiency levels among exchanges and factors that may explain variations from the efficient reference.

Against the background of the ongoing consolidation of the financial sector, rapid technological developments, a changing regulatory environment pointing towards increasing competition and concentration of stock exchanges, this study is important for a better understanding of financial exchanges functioning and structure. In particular for the European area, these developments appear to be quite acute. However, the reviewed literature lacks a comprehensive panel based benchmark analysis for European security industry. This paper attempts to fill this gap. Adopting a supply-sided viewpoint, this study presents novel insights in the efficient organisation and structure of exchange markets in Europe. The purpose of the paper is to consider whether and if so to what extent inefficiency problems exist in European exchanges. In addition, the paper asks how exchanges' relative efficiency has evolved over time and which factors might explain deviations from the efficient benchmark. Using a unique panel data set for all major European exchanges for the period 1985–1999, this paper employs multi-product, translog cost frontier functions, in which the technical inefficiency effects are modelled in terms of exchange-specific characteristics.

3 'Co-ompetition' among financial exchanges

The term 'co-ompetition' is used in order to describe the trend of increasing co-operation and competition among exchanges pointing towards concentration of stock exchanges in Europe as a potential outcome of continuing globalisation, innovations in communication and trading technologies, as well as deregulation.

Against this background, financial exchanges reorganise their operations and form alliances in order to leverage themselves in a stronger competitive position. The figure A-1 illustrates the complexity and inter-connections of Europeans current securities trading landscape. It seems evident that financial exchanges follow different ways to cope with investor's demands of lower trading costs, improved liquidity and immediate access to international trading. Consistent with OECD (2001), four different models of inter-exchange co-operation can be identified from figure A-1. A first strategy is promoted by NASDAQ. The basic idea is to establish branches with local partners using a common technology to have access to regional markets. Prominent examples are NASDAQ Europe, NASDAQ Canada, and NASDAQ Japan. The objective is to build up inter-connected hubs for a global electronic 24/7 marketplace. A second type includes mergers among exchanges, i.e. the recent merger Paris, Brussels, and Amsterdam under the name Euronext, or the ill-fated London Stock Exchange and Deutsche Börse merger attempt. Here the purpose is to achieve actively economies of scale by concentrating trading on one stock exchange with a common trading system. A third strategy is the attempted hostile take-over bid pursued by the Swedish OM Group for the London Stock Exchange. Finally, a fourth design of exchange co-operation is portrayed by the New York Stock Exchange. This attempt seeks to interconnect leading equity exchanges in a Global Equity Market (GEM) by the means of a shared common electronic interface.

In derivative markets, Globex Alliance and Eurex have already pooled trading activities in a de facto interconnected single electronic trading platform. Globex Alliance as a world global electronic trading system offers remote trading access to its interconnected member exchanges. Under the Globex Alliance, participants of the Chicago Mercantile Exchange (CME), Euronext (formerly ParisBourse, Singapore Exchange Derivatives Trading (SGX), Brazil's Bolsa de Mercadorias & Futuros (BM&F), Spains MEFF, and the Bourse de Montréal benefit from remote access to all the Alliance markets by a single electronic trading system.

The Eurex exchange was jointly launched by the German Deutsche Börse AG and the Swiss Exchange by the merger of the formerly DTB Deutsche Terminbörse und SOFFEX (Swiss Options and Financial Futures Exchange) in 1996. Eurex provides direct electronic access to a wide range of derivative products. In terms of trading volume, the rapid emergence of Eurex relative to UK based London International Financial Futures Exchange (LIFFE), affirms that cost efficiency and the importance of network economics play a dominant role in the efficient microstructure of trading systems.

There are also substantial economic forces of fragmentation at work, which limit the extent of consolidation of financial institutions within Europe. In a recent study, Berger, DeYoung and Udell (2001) claim that efficiency barriers, in particular distances between nations, linguistic and cultural differences, or implicit rules against foreign institutions, may inhibit the creation of an EU-wide single market for financial services and institutions. Although the Single Market

Programme and European Monetary Union remove some of these restrictions for EU nations and for the EMU member countries, the remaining obstacles may make it difficult to exploit all advantages of potential efficiency gains arising from a consolidated EU market for financial services.

Despite ongoing formation of alliances, ultimately mergers, or letter of intents to create joint and specialised market segments, further concrete progress in the consolidation process is required and is likely to be forthcoming in Europe. In the following, the paper evaluates potential efficiency gains that may occur from future changes in the organisation of European exchange markets.

4 Methodology

The stochastic frontier analysis (SFA) literature makes significant contributions to the econometric modelling of production and the estimation of technical efficiency of firms. Econometric SFA models incorporate a two-component error structure. One part of the error term is associated with traditional random and uncontrollable factors, and the second component captures individual firm deviations or errors due to factors within the control of management, such as technical and allocative efficiency. By estimating the ratio of the variability for the two separated error terms, the level of technical inefficiency for each observation in the sample can be quantified.[1]

4.1 Stochastic cost frontier

In terms of the specific estimation technique in this paper, different stochastic cost frontiers using panel data and incorporating technical inefficiency effects are formulated, following Battese and Coelli (1995). The most notable features of this stochastic cost frontier approach are that it accommodates unbalanced panel data, or pooled time-series, cross-sectional data, and that it estimates in a single stage both the cost frontier and the coefficients of firm-specific variables that may explain deviations from the efficient cost frontier.

Several studies adopt a two-stage approach, in which a stochastic frontier is estimated in the first stage, and obtained efficiencies are then regressed against a vector of firm-specific variables in a second stage. However, one of the reasons to argue against the two-step formulation is that the underlying assumptions are clearly inconsistent with those of the stochastic frontier estimation. For example, it is assumed in the first stage that the inefficiencies are independent and identically distributed, but this assumption is contradicted in the second-stage regression, in which predicted efficiencies are assumed to a have a functional relationship with the firm specific characteristics. More recent studies address this problem and adopt a single stage approach, in which explanatory variables are incorporated directly into the inefficiency error component. This approach assumes that the inefficiency error component is a truncation at zero of a normal distribution with the mean being dependent on a vector of firm-specific variables.

[1] Kumbhakar and Lovell (2000), Coelli, Rao, and Battese (1998) provide a survey of literature on econometric approaches to efficiency estimation.

Battese and Coelli (1995) propose a model that allows for panel data and in which inefficiency effects are defined to be an explicit function of some firm-specific factors and a random error. All relevant parameters are estimated in a single-stage maximum-likelihood procedure.

The preferred model of a stochastic frontier cost function for panel data is defined as follows

$$TC_{it} = X_{it}\beta + \varepsilon_{it} \quad \text{and} \quad i = 1,...,N \text{ and } t = 1,...,T \tag{4.1}$$

where TC_{it} denotes the logarithm of the total cost of production for the i–th firm (i = 1, ..., N) for the t–th time period (t = 1, ..., T), X_{it} is a $(1 \times K)$ vector whose values are functions of inputs, outputs and other explanatory variables associated with the i–th observation at the t–th period of observation, β represents a $(K \times 1)$ vector of unknown parameters to be estimated, and ε_{it} is a disturbance term.

$$TC_{it} = X_{it}\beta + v_{it} + u_{it} \quad \text{and} \quad i = 1,...,N \text{ and } t = 1,...,T \tag{4.2}$$

The disturbance term, ε_{it}, in equation (4.1) can be decomposed into two influences as defined in equation (4.2). The v_{it}'s are assumed to be independent and identically distributed $N(0, \sigma_v^2)$ random errors, which have normal distribution with mean zero and unknown variance σ_v^2, the u_{it}'s are non-negative unobservable random variables accounting for the cost of inefficiency in production and are assumed to be independently distributed. The latter is obtained by truncation at zero of the normal distribution with mean, $z_{it}\delta$, and variance σ_u^2, that is $N^+(\mu_{it}, \sigma_u^2)$, where $\mu_{it} = z_{it}\delta$, z_{it} represents a $(1 \times M)$ vector of firm-specific variables that are allowed to vary over time, and δ an $(M \times 1)$ vector of unknown coefficients of the firm-specific inefficiency variables.

The information that the error term, ε_{it}, contains on u_{it} can be extracted by using the conditional mean of the inefficiency term, given the composed error term, as originally proposed by Meeusen and van den Broeck (1977) and Aigner, Lovell, and Schmidt (1977). Accordingly, the best operational predictor of the inefficiencies is the mean of this conditional distμribution for the half-normal model, which is defined as

$$E(u_i|\varepsilon_i) = \frac{\sigma_u^2\sigma_v^2}{\sigma^2}\left[\frac{\phi(\varepsilon_i\lambda/\sigma)}{1-\Phi(\varepsilon_i\lambda/\sigma)} - \left(\frac{\varepsilon_i\lambda}{\sigma}\right)\right] \tag{4.3}$$

where the total variance is $\sigma_s \equiv (\sigma_v^2 + \sigma_u^2)^{1/2}$, $\lambda \equiv \sigma_u / \sigma_v$, $\phi(.)$ and $\Phi(.)$ are the standard normal density and the cumulative normal density function, respectively.[2]

For the Battese and Coelli (1995) frontier model, the null hypothesis, that technical inefficiency effects are absent from the model, can be conducted by

[2] Battese and Coelli (1995) use the parameterisation of Battese and Corra (1977) involving the parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2 / \sigma_s^2$. Further details are presented in the appendix of Battese and Coelli (1993).

testing the null and alternative hypotheses, $H_0 : \gamma = 0$ with $\gamma \equiv \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ versus $H_1 : \gamma > 0$. Under the null hypothesis that the second-order coefficients and the cross terms in the translog function are zero tests whether the Cobb-Douglas frontier is an adequate representation of the data. Also, the null hypothesis that the technical inefficiency effects are not influenced by the level of the explanatory variables can be tested by $H_0 : \delta = 0$ against $H_1 : \delta > 0$, where δ denotes the vector of coefficients of the exchange-specific inefficiency variables included in the expression, $z_{it}\delta$. These formal hypotheses tests are performed using generalised likelihood-ratio statistics.

To obtain maximum likelihood estimates of a common efficiency frontier and of the technical inefficiency effects model of Battese and Coelli (1995), two further a priori specifications are therefore required. These comprise the selection of an appropriate underlying cost function and the identification of the firm-specific variables.

4.2 Multiproduct cost function

A commonly used translog functional form is employed to examine the underlying cost structure and to benchmark the performance of European stock and derivative exchanges. The translog cost model has the appealing virtues that it accommodates multiple outputs and that it is flexible enough to provide a second-order approximation to any well-behaved underlying cost frontier at the mean of the data (Kumbhakar and Lovell (2000)). The general functional form of the translog cost function is defined as

$$\begin{aligned}
\ln TC_{it}(Q_{it}, P_{it}, X_{it}, T) = {} & \alpha_0 + \sum_h \alpha_h \ln Q_{hit} + \frac{1}{2}\sum_h \sum_j \alpha_{hj} \ln Q_{hit} \ln Q_{jit} \\
& + \sum_k \beta_k \ln P_{kit} + \frac{1}{2}\sum_k \sum_l \beta_{kl} \ln P_{kit} \ln P_{lit} \\
& + \sum_k \sum_h \eta_{hk} \ln P_{kit} \ln Q_{hit} + \xi_x \ln X_{it} + \frac{1}{2}\xi_{xx} (\ln X_{it})^2 \qquad (4.4) \\
& + \sum_h \kappa_h \ln Q_{hit} \ln X_{it} + \sum_k \lambda_k \ln P_{kit} \ln X_{it} + \tau_t T + \frac{1}{2}\tau_{tt} T^2 \\
& + \sum_h \rho_h \ln Q_{hit} T + \sum_k \psi_k \ln P_{kit} T + \omega_t \ln X_{it} T + v_{it} + u_{it}
\end{aligned}$$

The total costs, TC_{it}, depend on the vector of output, Q_{it}, the vector of factor prices, P_{it}, the stock market performance, X_{it}, and a time variable, T, for each exchange i and time period t.[3] The technical inefficiency effects are captured by the inefficiency term u_{it}, as discussed above. Finally, to control for measurement errors and cost determinants beyond the control of management, the second random term v_{it} is added.

To ensure symmetry and linear homogeneity in input prices, equation (4.4) is reformulated by imposing the usual restrictions

[3] See section 5 for detailed information on the data and variables.

$\alpha_{hj} = \alpha_{jh}$ and $\beta_{kl} = \beta_{lk}$

$$\sum_k \beta_k = 1 \quad \sum_l \beta_{kl} = 0 \quad \sum_k \delta_{hk} = 0 \quad \sum_k \lambda_k = 0 \quad \sum_k \delta_k = 0.$$

This normalisation is achieved by scaling total costs, price of capital, and input cross terms by the price of labour input, arbitrarily chosen. The translog cost function is then defined as

$$\begin{aligned}
\ln \overline{TC}_{it}(Q_{it}, \overline{P}_{it}, X_{it}, T) = & \\
& \alpha_0 + \sum_h \alpha_h \ln Q_{hit} + \frac{1}{2}\sum_h \sum_j \alpha_{hj} \ln Q_{hit} \ln Q_{jit} \\
& + \sum_k \beta_k \ln \overline{P}_{kit} + \frac{1}{2}\sum_k \sum_l \beta_{kl} \ln \overline{P}_{kit} \ln \overline{P}_{lit} \\
& + \sum_k \sum_h \eta_{hk} \ln \overline{P}_{kit} \ln Q_{hit} + \xi_x \ln X_{it} + \frac{1}{2}\xi_{xx} (\ln X_{it})^2 \\
& + \sum_h \kappa_h \ln Q_{hit} \ln X_{it} + \sum_k \lambda_k \ln \overline{P}_{kit} \ln X_{it} + \tau_t T + \frac{1}{2}\tau_{tt} T^2 \\
& + \sum_h \rho_h \ln Q_{hit} T + \sum_k \psi_k \ln \overline{P}_{kit} T + \omega_t \ln X_{it} T + v_{it} + u_{it}
\end{aligned} \tag{4.5}$$

where $h, j = 1,\ldots,n$ and $k, l = 1,\ldots, p-1$ and $\overline{TC}_{it} = TC_{it} / P_{pit}$, $\overline{P}_{kit} = P_{kit} / P_{pit}$, $\overline{P}_{l} = P_{lit} / P_{pit}$.

5 Data and variables

The data used in this study come from a variety of sources, including annual reports of European exchanges, various issues of the International Federation of Stock Exchanges (FIBV), IMF International Financial Statistics (IFS), and information from exchanges Internet sites. Most of the data were collected from annual balance sheets, income statement reports, and Internet pages of all major operating stock and derivative exchanges in Europe covering a 15-year time period (Annual Reports 1985–1999). In some cases, additional information was obtained from the exchanges by correspondence. Also various issues of the MSCI Handbook served as an important source to obtain information on exchange-specific characteristics. Although reporting schemes and information content of the financial accounts vary across time and exchange, however, a consistent data set has been constructed including all necessary information on key balance sheet and income statement items for 28 individual exchanges, of which 17 exchanges over the period from 1985–1999 finally entered the estimations.[4] All national currencies are converted into U.S. $ and are inflation adjusted using data from IFS. All variables other than qualitative proxies are expressed in natural logarithms.[5]

As mentioned earlier, financial exchanges are herein regarded as operative firms. Given the model details in section 4, financial exchanges can thus be characterised as incurring operating costs, TC, while producing two different outputs, Q, using two inputs, P, operating in a performing market environment, X. In terms of the cost structure, total costs are measured as the amount of dollar value in thousands of operating expenses excluding financial and extra ordinary items.

The outputs of exchanges used in this study are taken from various issues of the FIBV Annual Yearbooks (1985–1999). Following Hasan and Malkamäki (2001) financial exchanges are treated as a type of firm that produces two different operative transaction services. First, exchanges facilitate trade processing and matching by providing a centralised trading place or electronic trading systems. Second, financial exchanges are also engaged in the monitoring of listed companies and maintenance of the marketplace attempting to ensure that transactions are fairly and efficiently executed. The output concerning trade processing can be proxied by using trading statistics, namely the number and value of executed trades. Proxies for the output regarding the listing procedure of companies are the number and value of companies listed on a particular exchange. In line with Hasan and Malkamäki (2001), the number of listed companies and the value of transactions are identified to be the most appropriate output variables.[6]

The input variables for the study include two direct measures of inputs, namely the price of capital and the price of labour. The price of capital is measured by taking the sum of capital expenditure, i.e. office expenses, IT and systems costs, and equipment scaled by the book value of net total office premises and equipment. The price of labour is calculated as the total expenditures on employees divided by the number of full-time equivalent employees at the end of the year.

In addition, the stock market index performance is treated as netput to control explicitly in the translog function for the performance of the individual stock market. In order to obtain parametric measures of technical characteristics of the underlying technology, the above-discussed model accounts the possibility of technical change. This is achieved by including a linear time trend variable, its square, and interactions of the other factor inputs and outputs (Coelli, Rao, and Battese (1998)).

All exogenous variables in this paper considered as potential correlates to inefficiency are related in various aspects to exchange size, market concentration,

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[4] An overview of the panel data sample is provided in table A-1 in the appendix. Not all years are available for all exchanges. Exchanges with missing variables have been eliminated from the original database and some observations have been omitted when failing a standard set of criteria for data quality.

[5] See table A-2 for data definition and summury statistics.

[6] When regressing total cost on the number and value of transactions and listed companies respectively, the number of listed companies and the value of transactions perform best in terms of regression fit. The estimation results are not reported here, since they are consistent with those found in Hasan and Malkamäki (2001). There might also exist multicollinearity between the output variables (see also section 6). The estimation focuses on two output proxies, the number of listed companies and the value of trades.

institutional organisation, governance structure, and the ability to adopt new innovative trading technologies.

The first exchange characteristics control for size effects on efficiency. As a direct measure of exchanges size, the variables, ASSET and CAPITAL, are included in the regressions. These variables represent the total of financial and non-financial assets and the total capital of the i–th exchanges for the t–th time period respectively. It may be argued that larger exchanges have a better ability to manage exchanges operations. Hence, a negative relationship between exchange size and inefficiency would be intuitive. The exchange industry is highly competing to attract market shares and concentrate trading, so it is important to determine efficiency effects of market concentration and market quality. Several variables, CONCAP, CONTRADE and VELO are included to control for the degree of market concentration and market quality. Here, negative coefficients of these variables are expected. Additionally, the paper considers whether exchange's age, AGE, is related to efficiency. Following the bank efficiency literature (Berger and Mester (1997)), one plausible explanation is that exchanges with many years in the trading service business occupy relatively better position on the learning curve.

The stochastic frontier model for the technical inefficiency effects of European stock exchange industry also includes a set of binary explanatory variables. Some exchanges have expanded their operations to derivative and settlement business. The first dummy variable, DER, is intended to capture efficiency differences between stock exchanges that are also involved in derivatives and securities settlement operations. In the case that an exchange is engaged in these activities the variable takes a value of one and zero otherwise. It may be argued that the pooling of diverse trading services and vertical integration of clearing and settlement activities is inversely related to the overall level of inefficiency, thus *a priori* a negative coefficient is expected.

The next two trading technology variables, ETRADE and REMOTRADE, are measured by dummy variables to take recent technological innovations and advances in computerised new trading facilities as well as sophisticated cross-border securities trading systems into account. These variables are termed as first and second-generation technologies in electronic equities trading. The first-generation variable models the switchover from manual to automated execution of orders. From exchanges annual reports it can be inferred that screen based trading systems across Europe have been mainly implemented in the 1990's. The advent of new electronic trading facilities should be related to increasing trading efficiencies in the securities industry compared to earlier manual processes. Hence, a negative coefficient is postulated.

Second-generation technologies incorporate further evolution and competition between security trading systems. Several European stock exchanges launched cross-boarder electronic trading networks, but some, like the Madrid Stock Exchange, do not allow to remote membership. Concerning the proxy of remote access it is less obvious to predict any particular direction, in which the level of exchange efficiency is determined. Hence, two possible contradicting hypotheses are formulated. It can be argued that exchanges increase efficient trading and benefit from offering remote membership, since remote-trading facilities are an important element of expanding networks and a remedy to enhance liquidity associated to network effects (Domowitz and Steil (1999)). In this case a negative coefficient could be hypothesised. Alternatively, developments in more sophisticated cross-border trading environments made exchanges facing high initial investment and implementation cost, especially in the end of the 1990's. Although one might expect higher efficiency in order processing and execution from the creating of cross-border trading systems along time, significant cost increases can take place in the short run. Overall, no a priori coefficient is anticipated.

The fourth variable, OWNER, incorporates the ownership structure of stock exchanges. In pre-automation times, financial exchanges have mostly been organised as national monopolies owned by their members, i.e. member-firm brokers and dealers. Traditionally, these exchange members operated necessarily as transaction intermediaries for those with only limited trading access and thereby gaining monopolistic profits from exchange transactions (Domowitz and Steil (1999)). The situation in an automated market is different, where the increase in competition among exchanges and other electronic networks requires exchanges to become more efficient and profitable in all their activities. If an automated exchange can still be organised following the traditional mutual concept, it is doubtful that such a governance structure is optimal and adaptive enough in times of intensifying competition among stock exchanges. The importance of an adequate governance structure has led a number European exchanges to demutualise with the effect of diminishing member firm's influence over commercial activities of the exchange (see Domowitz and Steil (1999) for further discussion on this issue). Some prominent examples for exchange demutualisations are Stockholm (1993), Copenhagen (1996), Amsterdam (1997), and Iceland (1999). Given the need for profitable and efficient strategic governance decision making in a dynamic competitive environment, the transformation of exchange governance structure seems to result in a more market efficient organisation than its mutual counterpart. Thus, the ownership variable, taking the value one if an exchange has demutualised and zero otherwise, should be negatively related to exchange inefficiency level.

Summary statistics over the period 1985–1999 and definitions of all relevant variables in the stochastic frontier and in the inefficiency model are displayed in table A-2. The data sample covers a wide range of financial exchanges in terms of size, trading statistics and other characteristics.

6 Empirical results

Before running regression analysis, rank-order correlation has been computed first in order to address potential multicollinearity problems that may exist between the considered variables. Table A-3 portrays the correlation of the relevant variables involved in the different models. Each cell of the upper triangular half of the matrix contains the coefficient correlation for 28 exchanges in Europe. The lower triangular matrix provides correlation for the 17 in-sample exchanges for which efficiency estimates are calculated. The correlation matrix provides useful insights for the model specifications using different exchange-specific characteristics and variables. The correlation matrix indicates that the four output variables in the stochastic cost frontier models, NCOM, VTRADE, VCOM, and NTRADE are strongly related to each other, as expected. To limit collinearity among these variables, the paper concentrates in further estimations exclusively on the outputs

NCOM and VTRADE, as already mentioned earlier. Concerning variables in the inefficiency model, strong association also applies to the market concentration proxies, CONCAP and CONTRADE. Hence, only the former enters the regression estimation and the latter is used to check robustness to substitute for CONCAP. The correlation coefficients among the dummy variables apparently suggest no severe multicollinearity problems.

The maximum likelihood estimates of the translog stochastic cost functions for the pooled sample in equation (4.5), as well as the parameters for the technical inefficiency effects, are portrayed in table A-4a and A-4b. Asymptotic standard errors are also reported in the table. All coefficients reveal the expected signs, except the variable AGE.

Different model specifications and sub-samples were analysed to test the robustness of the regression results. In the first model, a translog cost frontier model is estimated comprising two inputs and outputs, as well as a stock market performance variable and a time trend in linear terms. To determine the efficiency effects of the selected exchange-specific characteristics in this model, the panel data structure requires focusing on the sub-sample period 1993–1999. In the second model, the translog functional form is extended by the cross- and squared terms of the performance measure and by non-neutral technical change. Variations in the inefficiency model allow enlarging the time dimension and making conclusions about the development of inefficiency of European exchanges over the 15-year time period 1985–1999.

Formal statistical tests are conducted to check significance of the estimated models. The different hypothesis tests are presented in table 1. All values of the test statistic that exceed the critical value in this table are significant at the 5 percent level. Given the specifications of the translog frontier of model I, the tests of hypotheses in the first part of table 1 indicate that the Cobb-Douglas frontier is rejected as an adequate representation, and the hypothesis of no technical change is also rejected. However, the hypothesis of no performance effect cannot be rejected, given the specifications of the translog frontier. Therefore, the preferred frontier specification is model Ib.

Table 1. **Generalised likelihood-ratio tests of hypotheses for parameters of the stochastic frontier cost function for European Stock Exchanges**

Null hypothesis	Log-likelihood	λ	$\chi^2_{0.95}$-value	Decision
complete model I	–5.90			
H_0: $\alpha_{ij} = 0$ i,j = 1,2,6,10,11	–13.02	14.24	12.59	Reject H_0
H_0: $\alpha_{10} = 0$	–5.41	0.98	3.84	Accept H_0
H_0: $\alpha_{11} = 0$	–14.42	17.05	3.84	Reject H_0
H_0: $\gamma = 0$	–13.43	15.06	13.40	Reject H_0
H_0: $\delta_{Ii} = 0$ i = 1,...,5	–13.44	15.07	11.07	Reject H_0
complete model II	–25.97			
H_0: $\alpha_{ij} = 0$ i,j = 1,2,6,10,15	–66.35	77.64	25.00	Reject H_0
H_0: $\alpha_i = 0$ i = 10,...,14,20	–35.27	18.60	12.59	Reject H_0
H_0: $\alpha_i = 0$ i = 15,...,20	–35.56	16.05	12.59	Reject H_0
H_0: $\gamma = 0$	–34.93	17.90	11.91	Reject H_0
H_0: $\delta_{IIi} = 0$ i = 1,...,4	–34.00	16.05	9.49	Reject H_0

Notes: The generalised likelihood-ratio test statistic is calculated as $\lambda = -2\{\ln[L(H_0)] - \ln[L(H_1)]\}$ where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses, H_0 and H_1, respectively. The test statistic has approximately chi-square distribution with degrees of freedom equal to the number of restrictions involved. The likelihood ratio statistic for the test involving $\gamma = 0$ is asymptotically distributed as a mixed chi-square distribution. The critical value for this test is obtained from table 1 of Kodde and Palm (1986). Values of the test statistic that exceed the critical value in this table are significant at the 5 per cent level.

The last section of table 1 presents tests of various null hypotheses, given the specifications of the stochastic frontier with inefficiency effects defined by model II. The first null hypothesis of the second model, H_0: $\alpha_{ij} = 0$, i,j = 1,2,6,10,15, that the Cobb-Douglas frontier is an appropriate model approximation of European stock exchanges, is clearly rejected by the data. Also, the second null hypothesis, H_0: $\alpha_i = 0$, i = 10,...,14,20, specifying that stock exchange performance does not determine the stochastic frontier model is rejected by the data. Likewise, the third null hypothesis, H_0: $\alpha_i = 0$, i = 15,...,20, suggesting that there is no technical change in European stock exchanges is also rejected at the five per cent level.

Given the specifications of model II, the preferred frontier model is thus the frontier with technical change.[7]

The estimated parameters of the inefficiency models are of particular interest to this study. Under the cost frontier formulation in model I, the overall findings indicate that the size of an exchange is negatively associated to inefficiency. As expected, larger institutions appear to have better abilities to manage overall trading service operations. The results for the second group of variables conform to their a priori expected sign. It is shown that market concentration and market quality are inversely correlated to inefficiency. The substitution of the variable CONCAP by CONTRADE alters only slightly the results in the way that overall inefficiency increases 4.3 per cent. Given the specified frontier model I, it is found that exchange's age affect negatively the efficient provision of trading services. At first sight, this finding appears to be counter-intuitive. A potential explanation of this finding is that more recently established exchanges may benefit from sharing trading service experiences from those exchanges with more years in business, possibly due to technological diffusion.

Given the second inefficiency model, the coefficient of the variable, DER, reveals a negative sign indicating that exchanges that integrate derivative and settlement activities seem to have significantly better capabilities in managing overall costs.

The negative ETRADE coefficient implies that the switchover from floor-based to automated trading helped stock exchanges to reduce cost inefficiencies. Interestingly, concerning the variable remote access, REMOTRADE, a significant positive association related to cost inefficiency is observed. As earlier mentioned, this result confirms the hypothesis that exchanges incurred recently high initial establishment costs to offer remote membership access, which in turn do not lower inefficiencies in the short run, though efficiency gains in the long run are intuitive.

Finally, the negative coefficient for the variable, OWNER, confirms statistically significant higher efficiency associated with recent transformations of exchanges governance structure from a mutually owned into a for-profit investor-owned companies, which is termed as demutualisation. It supports the view that the ownership has a direct impact on the management and that a for-profit exchange can operate more efficiently in order to respond and to adjust adequately to technological advances and changes in the regulatory and economic environment.

One striking result of the model estimations is that the γ coefficient indicate that residual variation is partly due to the inefficiency effect, u_{it}. In both cases, the null hypothesis that inefficiency effects are absent from the model, $\gamma = 0$, is

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[7] It can be argued that the production technology may also depend on whether the exchanges are involved in derivative and settlement activities. Hence, if they do not follow the same cost function, it is not proper to pool derivative and stock exchanges. In order to test for pooling for stock and derivative exchanges, the translog cost frontier in equation (4.5) was extended by binary variables taking the value of one if the exchanges is engaged in these businesses and zero otherwise. The models were estimated with the included dummy variables. The LR-test for the null hypothesis did not exceed the critical value of the chi-square distribution at the five per cent level indicating that the structure of the cost functions does not differ significantly, and that the data for derivative and stock exchanges in the sample could be pooled.

Although differences in the cost structure for derivative and stock exchanges are statistically insignificant, evidence is found that diversification in the provision of trading activity matters when explaining inefficiencies among exchanges.

rejected at the 5 per cent level of significance. Furthermore, the one-sided generalised likelihood-ratio tests of H_0: $\delta_{Ii} = 0$, $i = 1,...,5$, and H_0: $\delta_{IIi} = 0$, $i = 1,...,4$, reveal statistics, which exceed the 5 per cent critical value respectively. Hence, as mentioned by Battese and Coelli (1995), this proves that the joint effects of the exchange specific characteristics on the inefficiencies of trading service production are significant, although the individual effects of one or more of the variables may not have a statistically significant impact.

The technical inefficiency scores of European financial exchanges under the different model specifications were predicted. In respect to model Ia and Ib, the mean technical inefficiency scores were found to be 0.2601 and 0.2114 respectively. Although the models IIa and IIb are statistical different, technical inefficiencies of European financial exchanges were estimated alternatively under the translog frontier specification with and without technical change. Descriptive statistics as well as individual mean inefficiency scores of each exchange under the above-discussed model specifications IIa and IIb are reported in table 2. Observing the predicted inefficiency scores over the entire sample and period, the combined estimate indicates that an average financial exchange in Europe experiences a cost inefficiency score of 0.2888 under the preferred frontier specification. A closer look on five-year sub-samples makes evident that the average level of cost efficiency has improved over time. Concerning the five-year sub-samples 1985–1989, 1990–1994, 1995–1999, the mean cost-inefficiency scores decreased considerably over time and came down from 0.4520, 0.3223, to the lowest score of 0.2302 reported in the second half of the 1990s.

Furthermore, inefficiency scores have been calculated for three different panels. The classification of the exchanges has been made according to the value of market capitalisation of the respective stock market. For example, the first panel includes the five leading European markets, namely Amsterdam, Frankfurt, Madrid, London, and Paris, while the others comprise medium and smaller exchanges. The evidence reveals average inefficiency scores for the top 5, medium, and smallest exchanges of 0.2329, 0.3059, and 0.3319 respectively. These scores suggest that larger exchanges operate more efficiently relative to the group of smaller exchanges. In the first part of table 2, disaggregated results provide information on the inefficiency level of the individual stock exchanges. When interpreting the ranking of the inefficiency scores, one should bear in mind that the estimates are valid only given the specific stochastic frontier formulations.

Table 2. **Ranking and descriptive statistics of inefficiency scores of European exchanges**

Exchange	Model IIa	Exchange	Model IIb
Swiss Exchange	0.0345	Euronext Brussels	0.0293
Euronext Brussels	0.0408	Swiss Exchange	0.0295
Euronext Amsterdam	0.0466	Budapest Stock Exchange	0.0310
Budapest Stock Exchange	0.0466	Euronext Amsterdam	0.0314
Deutsche Börse AG	0.0719	Deutsche Börse AG	0.0922
Barcelona Stock Exchange	0.0845	Barcelona Stock Exchange	0.1024
Copenhagen Stock Exchange	0.1915	Helsinki Stock Exchanges	0.1684
Tallinn Stock Exchange	0.1955	Bourse de Luxembourg	0.2027
Bolsa de Madrid	0.2235	Iceland Stock Exchange	0.2139
Bourse de Luxembourg	0.2606	Tallinn Stock Exchange	0.2156
Helsinki Stock Exchanges	0.3365	Bolsa de Madrid	0.2221
Euronext Paris	0.3924	Copenhagen Stock Exchange	0.2267
OM Stockholm Exchange	0.4136	Euronext Paris	0.2459
Iceland Stock Exchange	0.4258	London Stock Exchange	0.2495
Oslo Bors	0.4489	Oslo Bors	0.2535
London Stock Exchange	0.4629	OM Stockholm Exchange	0.2652
Wiener Börse	0.5288	Wiener Börse	0.6356
1985–1989	0.4520	1985–1989	0.2245
1990–1994	0.3223	1990–1994	0.1753
1995–1999	0.2302	1995–1999	0.1891
combined 1985–1999	0.2888	combined 1985–1999	0.1885
top 5[a)]	0.2329	top 5[a)]	0.1461
medium[a)]	0.3059	medium[a)]	0.1935
smallest 5[a)]	0.3319	smallest 5[a)]	0.2478

Notes: The estimates in this table are average and individual inefficiency scores of European financial exchanges over the time period 1985–1999. The coefficients are listed in ascending order so that those stock exchanges with the lowest inefficiency level are ranked first. Note that an accurate interpretation of these scores is valid only under the specific stochastic frontier formulations. a) the grouping of the stock exchanges is constructed according to the value of capitalisation of the respective market.

Overall, there is little effect on the average level or dispersion of cost inefficiency across the model variation, although the preferred model with non-neutral technical change in the stochastic frontier exhibits some higher inefficiency scores. A breakdown of the estimated cost efficiencies on exchange- individual level also shows that the ranking of exchanges according to their efficiency is also robust to model variations.

Aggregated results expose decreasing inefficiency over time. The histograms in figure A-2a and A-2b depict the distribution of exchanges with their corresponding technical inefficiency scores over the entire time period. Both graphs reveal an asymmetric distribution of technical inefficiency scores pointing towards efficiency progress over time. It is apparent that most of the exchanges have predicted inefficiencies in the interval 0.3000 observed in the period 1985–1989. However, the majority of stock exchanges were able to improve substantially technical efficiencies over the last decade, so that most observations can be found in the inefficiency range close to 0.1000 in the last five-year time interval.

It can be summarised from empirical evidence that changes in the governance structure, market concentration and quality, as well as developments in new trading technologies are associated with improved cost efficiency among European stock exchanges. Disaggregated results exhibit a better ability of larger exchanges to manage costs in a more efficient manner relative to their smaller competitors. In addition, evidence reveals that diversification in trading activities experience higher cost efficiency.

7 Conclusions

Despite important structural changes in modern global and European financial exchange markets mainly due to technological developments, a changing regulatory environment, and continuing globalisation, relatively little is known about the impact of such forces acting on the efficient organisation of these markets. The paper provides novel insights in the microstructure of European financial exchanges and extents related empirical work in this area in several ways. The innovation includes the use of a translog stochastic frontier model to quantify technical efficiency effects among financial exchanges. Moreover, the present study employs a single stage approach to estimate inefficiency effects. Furthermore, the study evaluates the organisation of exchange institution efficiency in a European context, since increasing competition among stock exchanges is a recent and quite acute phenomenon, especially in Europe. The paper makes also a first attempt to analyse potential correlates helping to explain variations from the efficient frontier. The estimations are based on a unique unbalanced panel data set considering all major European financial exchanges during the years 1985–1999.

Overall evidence suggests that, on average, European financial exchanges operate at a 20–25 per cent higher cost level compared to the efficient benchmark exchange. The estimates also indicate that European exchanges have experienced steady improvements in their relative technical efficiency scores over the sample period. Nevertheless, it was found that in more recent years trading service providers in Europe still operate at a significant less efficient level than the predicted benchmark. Graphical evidence on the distribution of inefficiency scores over the sample period is consistent with the finding of substantially increasing but persisting differences in technical efficiency among European exchanges. Moreover, sub-sample results show that large exchanges outperform their smaller counterparts in terms of higher efficiency. With the incorporation of efficiency effects, the paper also contributes to examine the relationship between exchange institution efficiency and organisational form. Accordingly, the presented evidence suggests that exchanges operating efficiency is related to size effects, ownership form, trading quality and market concentration, integration of other trading activities, and first generation automated trade execution technologies, though no efficiency enhancing effect was found for the years in business and second generation cross-border trading facilities at the current stage.

What can be inferred from the presented results concerning future prospects for an integrated common European security market? One plausible implication in the light of the ongoing discussion about the fragmented European exchange industry is that the formation of mergers or alliances among exchanges may have a beneficial effect on the market if they enhance efficiency improvements and permit exchanges to take advantage of scale economies. As well, the creation of alliances among exchanges would also enable co-operating exchanges to share high establishment and development cost of new electronic trading technologies which might lead to greater system efficiency. The trend towards concentration of exchange markets in Europe is well paving its way, but considerable room for improvement remains to attain an efficient market organisation of the European trading landscape. In this respect, regulators are challenged to create and ensure a stable European regulatory system that is flexible enough to adjust adequately to future technological and market developments. First initiatives in this direction have already been achieved by a recent agreement on a new legislative process for the European securities market based on the reports of the Committee of Wise Men (2001).

References

Aigner, D.J. – Lovell, C.A.K. – Schmidt, P. (1977) **Specification and Estimation of Frontier Production, Profit and Cost Functions.** Journal of Econometrics, 6, 21–37.

Annual Reports (1985–1999) **Annual Reports of 28 European Stock Exchanges.**

Arnold, T. – Hersch, P. – Mulherin, J.H. – Netter, J. (1999) **Merging Markets.** Journal of Finance, 52, 655–681.

Battese, G.E. – Coelli, T.J. (1993) **A Stochastic Frontier Production Function incorporating a Model for Technical Efficiency Effects.** Working Papers in Economics and Applied Statistics 69, University of New England, Armidale.

Battese, G.E. – Coelli, T.J. (1995) **A Model for Technical Inefficiency in a Stochastic Frontier Production Function for Panel Data.** Empirical Economics, 20, 325–332.

Battese, G.E. – Corra, G.S. (1977) **Estimation of a Production Frontier Model: with Application to the Pastoral Zone of Eastern Australia.** Australian Journal of Productivity Analysis, 3, 153–169.

Berger, A.N. – Demsetz, R.S. – Strahan, P.E. (1999) **The Consolidation of the Financial Services Industry: Causes, Consequences, and Implications for the Future.** Journal of Banking and Finance, 23, 135–194.

Berger, A.N. – Humphrey, D.B. (1997) **Efficiency of Financial Institutions: International Survey and Directions for Future Research.** European Journal of Operational Research, 98, 175–212.

Brennan, M.J. – Cao, H.H. (1997) **International Portfolio Investment Flows.** Journal of Finance, 52, 1851–1880.

Coelli, T.J. – Rao, D.S.P. – Battese, G.E. (1998) **An Introduction to Efficiency and Productivity Analysis.** Kluwer Academic Publishers, Boston, Massachusetts 02061.

Cybo-Ottone, A. – Di Noia, C. – Murgia, M. (2000) **Recent Development in the Structure of Securities Markets.** Brookings-Wharton Papers on Financial Services, 2000.

Demsetz, H. (1968) **The Cost of Transacting.** Quarterly Journal of Economics, 82, 33–53.

Di Noia, C. (2001) **The Stock-Exchange Industry: Network Effects, Implicit Mergers, and Remote Access.** European Financial Management 7, 1, 39–72.

Domowitz, I. – Glen, J. – Madhavan, A. (1998) **International Cross-Listing and Order Flow Migration: Evidence from an Emerging Market.** Journal of Finance, 53, 2001–2027.

Doede, R. (1967) **The Monopoly Power of the New York Stock Exchange.** Unpublished Ph.D. Dissertation, University of Chicago.

Domowitz, I. – Steil, B. (1999) **Automation, Trading Costs, and the Structure of the Trading Services Industry.** Brookings-Wharton Papers on Financial Services, 1–52.

FIBV (1985–1999) **Annual Reports 1985–1999.** International Federation of Stock Exchanges, Paris.

Gehrig, T. (2000) **Cities and the Geography of Financial Centres.** In Huriot, J.M. – Thisse, J.F (eds.) *Economics of Cities – Theoretical Perspectives.* Cambridge, MIT University Press, 415–444.

Group of Ten (2001) **Report on Consolidation in the Financial Sector.** Basel.

Hau, H. (2001) **Geographic Patterns of Trading Profitability in Xetra.** European Economic Review, 45, 757–769.

Hasan. I. – Malkamäki, M. (2001) **Are Expansions Cost Effective for Stock Exchanges?** A Global Perspective. Journal of Banking and Finance, forthcoming.

Hasan, I. – Malkamäki, M. – Schmiedel, H. (2001) **Technology, Automation and Productivity of Stock Exchanges: An International Perspective.** Bank of Finland Discussion Paper, mimeo.

International Monetary Fund (various issues). **International Financial Statistics.** Washington.

Kumbhakar, S.C. – Lovell, C.A.K. (2000) **Stochastic Frontier Analysis.** Cambridge University Press.

Malkamäki, M. – Topi, J. (1999) **Strategic Challenges for Exchanges and Securities Settlement.** Bank of Finland Discussion Paper, 4/99.

Martin, P. – Rey, H. (2000) **Financial Integration and Asset Returns.** European Economic Review, 44, 1327–1350.

Meeusen, Y.M. – van den Broeck, J. (1977) **Efficiency Estimation from Cobb-Douglas Production Functions with Composed Errors.** International Economic Review, 18, 435–444.

MSCI (1995–2000) **Handbook of World Stock, Derivative, and Commodity Exchanges.** Mondo Visione, UK.

OECD (2001) **Future Prospects for National Financial Markets and Trading Centres.** OECD, Paris.

Pagano, M. – Randl, O. – Röell, A.A. (2001) **What makes Stock Exchanges Succeed? Evidence from Cross-Listing Decisions.** European Economic Review, 45, 770–782.

Pagano, M. – Röell, A.A. – Zechner, J. (1999) **The Geography of Equity Listing: Why do Companies List Abroad?** Centre for Studies in Economics and Finance, Working Paper No. 28.

Pirrong, C. (1999) **The Organization of Financial Exchange Markets: Theory and Evidence.** Journal of Financial Markets, 2, 329–357.

Portes, R. – Rey, H. (2000) **The Determinants of Cross-Border Equity Flows: The Geography of Information.** CEPR Discussion Paper 2225.

The Committee of Wise Men (2001) **Final Report of The Committee of Wise Men on the Regulation of European Securities Markets.** Brussels.

Appendix

Table A-1. **Summary of panel data set**

Exchange	Years
Euronext Amsterdam	1989–1999
Athens Stock Exchange	1997–1999
Barcelona Stock Exchange	1992–1995
Bolsa de Bilbao	1992–1999
Bolsa de Madrid	1995–1999
Bolsa de Valencia	1989–1990, 1992–1999
Euronext Brussels	1991–1999
Copenhagen Stock Exchange	1992–1999
Deutsche Börse AG	1991–1999
Helsinki Stock Exchanges	1985–1999
Istanbul Stock Exchange	1995–1999
Bolsa de Valores de Lisboa/Porto	1997–1998
London Stock Exchange	1989–1999
Ljubljana Stock Exchange	1990–1999
Bourse de Luxembourg	1993–1999
Malta Stock Exchange	1992–1999
Oslo Bors	1987–1999
Euronext Paris	1990–1999
OM Stockholm Exchange	1985–1999
Swiss Exchange	1996–1999
Wiener Börse	1993–1999
Warsaw Stock Exchange	1993–1999
Irish Stock Exchange	1996–1998
Tallinn Stock Exchange	1996–1999
Budapest Stock Exchange	1997–1999
Prague Stock Exchange	1992–1999
Iceland Stock Exchange	1989–1999
Riga Stock Exchange	1996–1999

Table A-2. **Summary statistics for variables in the stochastic frontier and employed as potential correlates of inefficiency for European exchanges, 1985–1999**

Variable		Definition	Mean	Standard Deviation
TC	TC (thousands US $)	Total operating expenses of the i–th exchange in the t–th time period	47583	84315
Q_1	NCOM	Number of companies listed on the i–th exchange in the t–th time period	399	555
Q_2	VTRADE (millions US $)	Total value of shares traded on the i–th exchange in the t–th time period	211000	658000
Q_3	VCOM (millions US $)	Total number of issued shares of domestic companies on the i–th exchange in the t–th period multiplied by their respective prices at a given time	323000	1360000
Q_4	NTRADE	Total number of trades dealt on the i–th exchange in the t–th time period	5759	10869
P_1	PRICE CAPITAL (%)	Total capital expenditures, i.e. office expenses, IT and systems costs, and equipment, scaled by the book value of net total office premises and equipment of the i–th exchange in the t–th time period	2.2725	2.1868
P_2	PRICE LABOUR (thousands US $/ employee)	Total expenditures on employees divided by the number of employees for the i–th exchange in the t–th time period	69.8381	33.6582
X	SMI (%)	Stock index performance of the i–th exchange and the t–th time period	136.45	235.81
T	TIME	Time trend		
Z_{I1}	ASSET (thousands US $)	Total of financial and non-financial assets of the i–th exchange in the t–th time period	152943	518463
Z_{I2}	CAPITAL (thousands US $)	Total capital of the i–th exchange in the t–th time period	56716	92101
Z_{I3a}	CONCAP(%)	Market concentration of five per cent of the most capitalised domestic companies compared with the total market capitalisation of domestic companies on the i–th exchange in the t–th time period	56.72	13.92

Table A-2 (continued) **Summary statistics for variables in the stochastic frontier and employed as potential correlates of inefficiency for European exchanges, 1985–1999**

Variable		Definition	Mean	Standard Deviation
Z_{I3b}	CONTRADE (%)	Market concentration of the five per cent most traded domestic companies compared with the total turnover value of domestic companies on the i–th exchange in the t–th time period (only employed to test robustness to substitute for Concap)	58.71	16.27
Z_{I4}	AGE (years)	Number of years the i–th exchange is in business	129	95
Z_{I5}	VELO (%)	Turnover velocity is the annualised ratio between turnover of domestic shares and their market capitalisation for the i–th exchange in the t–th time period	72.61	36.69
Z_{II1}	DER	Dummy, equals one if the i–th exchange is involved in derivative activities in the t–th time period, otherwise zero	0.18	0.39
Z_{II2}	ETRADE	Dummy, equals one if the i–th exchange has switched from materialised to automated trade execution, otherwise zero	0.23	0.42
Z_{II3}	REMOTRADE	Dummy, equals one if the i–th exchange allows remote access, otherwise zero	0.02	0.13
Z_{II4}	OWNER	Dummy, equals one if the exchange has demutualised, otherwise zero	0.08	0.27

Note: All currencies are converted into uniform U.S. $ measures and all variables other than the qualitative proxies are expressed in natural logarithms.

Table A-3. **Coefficient correlation matrix for European financial exchanges**

	TC	PR. LABOUR	PR. CAPITAL	NCOM	VTRADE	VCOM	NTRADE	ASSET	CAP	CONCAP	CONTRADE	AGE	EXCH	SMI	DER	OWNER	ETRADE	REMOTRADE	VELO
TC	1	0.3325	0.3122	0.6376	0.8785	0.8497	0.7069	0.3389	0.6603	0.5738	0.5129	0.6280	0.4870	0.0749	0.4275	–0.2050	0.2253	0.4505	0.3236
PR. LABOUR	0.2707	1	0.3563	0.0342	0.3303	0.3276	0.2619	0.1695	0.2827	0.2917	0.4969	0.2568	0.1838	–0.1241	0.3841	0.1408	0.2007	0.2814	0.2103
PR. CAPITAL	0.2862	0.2361	1	–0.0125	0.3092	0.2022	0.4215	0.0725	0.1455	0.0791	0.5170	0.4477	0.5290	–0.1493	0.2048	0.1601	0.1952	0.3444	0.3022
NCOM	0.6285	–0.0855	–0.0803	1	0.7565	0.7407	0.3290	0.2737	0.5597	0.4201	0.4283	0.6403	0.4165	–0.1063	0.2022	–0.3496	0.0237	0.0718	0.1550
VTRADE	0.8830	0.2451	0.2528	0.7455	1	0.9310	0.6703	0.3115	0.6315	0.5884	0.5879	0.6732	0.5200	–0.0798	0.3747	–0.2731	0.2033	0.3460	0.3300
VCOM	0.8536	0.2191	0.1213	0.7290	0.9267	1	0.6769	0.5604	0.7247	0.6106	0.5549	0.5653	0.3019	–0.0677	0.3174	–0.2236	0.1604	0.2074	0.1406
NTRADE	0.7197	0.3033	0.4848	0.3403	0.7070	0.7234	1	0.6107	0.5873	0.4552	0.5014	0.6105	0.4367	0.1757	0.1815	–0.2952	0.2258	0.3472	0.4664
ASSET	0.3286	0.1287	0.0371	0.2575	0.2939	0.5537	0.6298	1	0.6378	0.3031	0.3051	0.2751	–0.0544	–0.0126	–0.0907	–0.1570	0.0505	–0.0012	–0.0317
CAPITAL	0.6541	0.2215	0.0936	0.5432	0.6157	0.7136	0.6137	0.6318	1	0.5247	0.5162	0.4439	0.1826	–0.0372	0.0706	–0.1361	0.1504	0.3969	0.1096
CONCAP	0.5817	0.3056	0.0756	0.4246	0.6083	0.6353	0.4687	0.3047	0.5270	1	0.6150	0.3591	0.2539	0.0717	0.4513	–0.2654	0.3711	0.1260	0.3262
CONTRADE	0.5083	0.4050	0.4485	0.4064	0.5672	0.5208	0.5725	0.2924	0.5081	0.6813	1	0.6987	0.5820	–0.1096	0.4573	–0.0228	0.4539	0.2530	0.4401
AGE	0.6303	0.1403	0.3995	0.6411	0.6669	0.5444	0.6560	0.2638	0.4382	0.4131	0.6699	1	0.7921	–0.1034	0.3719	–0.2708	0.3174	0.3478	0.5025
EXCH	0.4862	0.1398	0.5167	0.4050	0.5093	0.2795	0.4614	–0.0704	0.1650	0.2641	0.5788	0.8050	1	–0.0995	0.5733	–0.2950	0.2882	0.3101	0.6283
SMI	0.1074	0.1241	0.1371	–0.1676	0.0583	0.1721	0.1459	0.1561	0.1388	0.1294	0.1257	–0.1548	–0.1238	1	–0.0460	–0.0314	0.1784	–0.0304	0.2789
DER	0.4067	0.3186	0.1409	0.1643	0.3372	0.2697	0.1937	–0.1222	0.0278	0.4614	0.4249	0.3417	0.5647	0.2319	1	–0.1247	0.4111	0.1054	0.2703
OWNER	–0.2655	0.0157	0.0886	–0.4173	–0.3530	–0.3139	–0.3080	–0.1924	–0.1912	–0.3001	–0.1159	–0.3634	–0.3398	0.3150	–0.1919	1	–0.0109	0.2021	–0.2541
ETRADE	0.2125	0.1949	0.2105	0.0111	0.2049	0.1595	0.1941	0.0489	0.1618	0.4384	0.4982	0.2929	0.3066	0.3382	0.4387	–0.0256	1	0.2704	0.3908
REMOTRADE	0.4428	0.2549	0.3253	0.0478	0.3270	0.1796	0.3595	–0.0167	0.3829	0.1216	0.2303	0.3373	0.2991	0.1059	0.0780	0.1774	0.2843	1	0.1966
VELO	0.3789	0.3937	0.4747	0.2175	0.4351	0.2331	0.4473	–0.0058	0.1793	0.4114	0.6289	0.6113	0.7498	0.0096	0.3687	–0.2300	0.3411	0.2531	1

Table A-4a. **Maximum-likelihood estimates for parameters of translog stochastic cost frontier function for European stock exchanges**

Variable	Parameter	Model Ia Coeff.	Model Ia Std. Error	Model Ib Coeff.	Model Ib Std. Error
Cost frontier model					
constant	α_0	–0.57751	1.55780	–0.25472	2.41705
$\ln Q_1$	α_1	–1.09787	0.94573	–0.78178	0.77644
$\ln Q_2$	α_2	0.03550	0.29413	0.07756	0.24715
$\ln Q_1 \ln Q_1$	α_{11}	0.21935	0.14497	0.18521	0.13706
$\ln Q_2 \ln Q_2$	α_{22}	0.05243	0.01794	0.04904	0.01734
$\ln Q_1 \ln Q_2$	α_{12}	–0.06711	0.10398	–0.07320	0.08522
$\ln P_1$	β_1	1.55569	0.88643	1.05791	0.76731
$\ln P_1 \ln P_1$	β_{11}	0.23353	0.08534	0.23195	0.08825
$\ln P_1 \ln Q_1$	η_1	0.01177	0.15573	0.03933	0.15458
$\ln P_1 \ln Q_2$	η_2	–0.22214	0.07747	–0.20313	0.07551
$\ln X_1$	ξ_x	0.03607	0.03136	–	–
T	τ_t	–0.00736	0.14421	0.03366	0.02645
Inefficiency model					
constant	δ_0	0.23859	1.18526	0.14735	0.90650
Z_{I1}	δ_1	–0.41243	0.07815	–0.29894	0.10277
Z_{I2}	δ_2	–0.02873	0.07156	0.00735	0.06092
Z_{I3}	δ_3	–0.26162	0.31307	–0.32451	0.30219
Z_{I4}	δ_4	1.14005	0.27975	0.99337	0.30068
Z_{I5}	δ_5	–0.13427	0.10907	–0.16590	0.09546
sigma squared	$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.09561	0.01965	0.08237	0.01607
gamma	$\gamma = \sigma_u^2 / \sigma_s^2$	0.38450	0.11658	0.20794	0.14444
no. obs.		63		63	
loglikelihood function		–5.90068		–5.40985	
mean inefficiency		0.2601		0.2114	

Table A-4b **Maximum-likelihood estimates for parameters of translog stochastic cost frontier function for European stock exchanges**

Variable	Parameter	Model IIa Coeff.	Model IIa Std. Error	Model IIb Coeff.	Model IIb Std. Error
Cost frontier model					
constant	α_0	3.71391	1.00412	1.96470	1.01886
$\ln Q_1$	α_1	1.81288	0.84271	1.19762	1.13282
$\ln Q_2$	α_2	0.49716	0.32433	0.64152	0.45613
$\ln Q_1 \ln Q_1$	α_{11}	0.10823	0.13342	0.16075	0.13217
$\ln Q_2 \ln Q_2$	α_{22}	–0.01045	0.02125	–0.01066	0.01937
$\ln Q_1 \ln Q_2$	α_{12}	–0.05995	0.10259	–0.08023	0.09584
$\ln P_1$	β_1	1.06772	0.41018	1.08693	0.46058
$\ln P_1 \ln P_1$	β_{11}	–0.07049	0.03812	–0.06180	0.03492
$\ln P_1 \ln Q_1$	η_1	–0.17459	0.11332	–0.12612	0.09616
$\ln P_1 \ln Q_2$	η_2	0.03619	0.05642	–0.00333	0.05158
$\ln X_1$	ξ_x	–3.92987	0.65299	–2.95774	0.72699
$\ln X_1 \ln X_1$	ξ_{xx}	0.09878	0.23958	0.27263	0.14021
$\ln X_1 \ln Q_1$	κ_1	–0.43630	0.31639	–0.24917	0.20767
$\ln X_1 \ln Q_2$	κ_2	0.13930	0.14546	0.06463	0.09431
$\ln X_1 \ln P_1$	λ_1	–0.40349	0.12904	–0.16338	0.10177
T	τ_t	0.00653	0.16601	–	–
TT	τ_{tt}	–0.00632	0.00568	–	–
$T\ln Q_1$	ρ_1	0.02539	0.05327	–	–
$T\ln Q_2$	ρ_2	–0.01323	0.02568	–	–
$T\ln P_1$	ψ_1	0.05991	0.02340	–	–
$T\ln X_1$	ω_t	0.10790	0.08211	–	–
Inefficiency model					
constant	δ_0	0.38874	0.12887	0.19896	0.34351
Z_{II1}	δ_1	–0.88022	0.29144	–0.78877	0.67600
Z_{I12}	δ_2	–0.29637	0.23761	–0.48444	0.29189
Z_{I13}	δ_3	1.06091	0.33806	1.10336	0.34520
Z_{I14}	δ_4	–0.56487	0.26699	–0.07395	0.35019
sigma squared	$\sigma_s^2 = \sigma_v^2 + \sigma_u^2$	0.10433	0.02873	0.12268	0.09744
gamma	$\gamma = \sigma_u^2 / \sigma_s^2$	0.25945	0.23094	0.15896	0.82624
no. obs.		109		109	
loglikelihood		–25.97486		–35.55705	
mean inefficiency		0.2888		0.1885	

Figure A-1. **Network of European Stock and Derivative Exchanges**

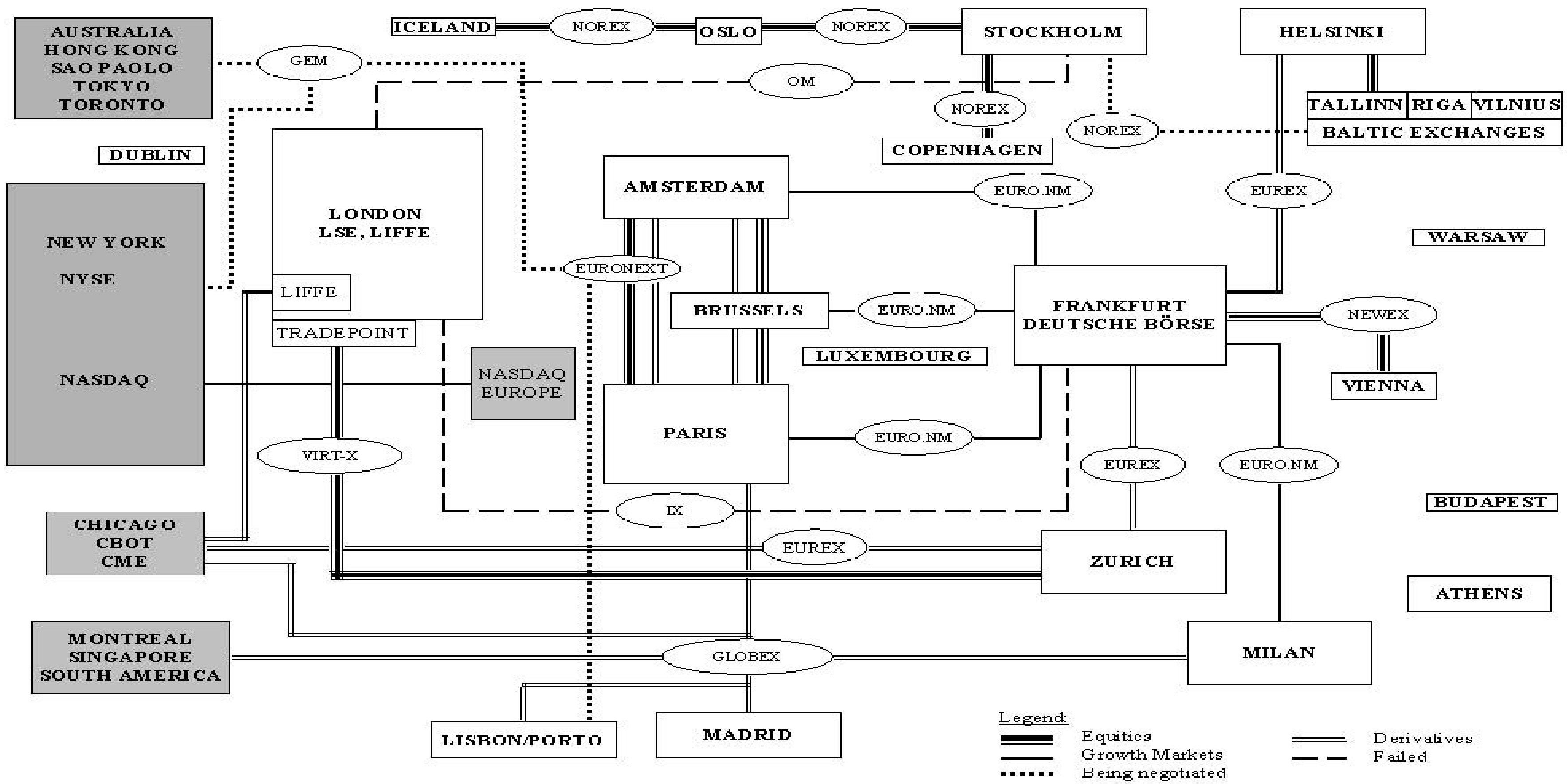


Figure 2a. **Distribution of sample cost inefficiencies of European stock exchanges by 5-year time intervals (Model IIa: with technical change)**

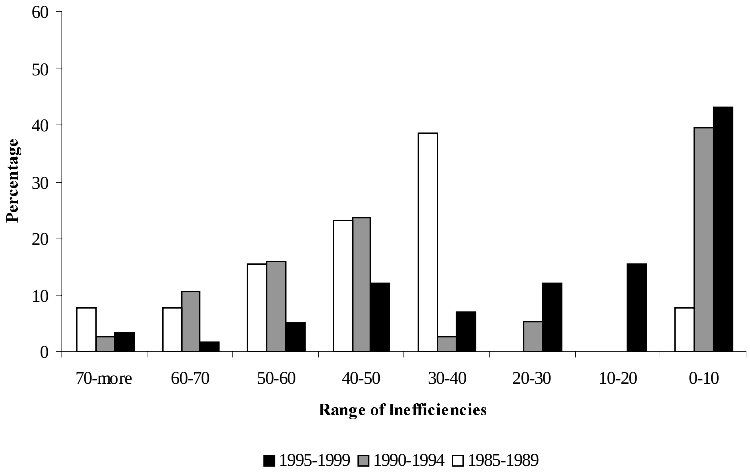
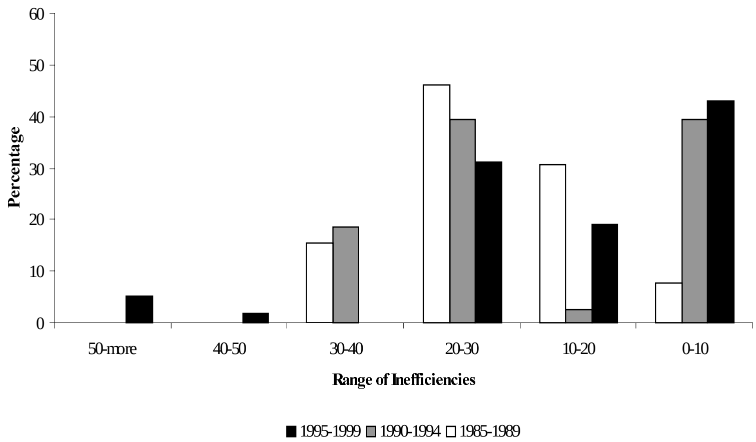


Figure 2b. **Distribution of sample cost inefficiencies of European stock exchanges by 5-year time intervals (Model IIb: without technical change)**



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