Forthcoming in the Journal of International Financial Markets, Institutions & Money

September 13, 2017

Economies of Scale and Scope in Financial Market Infrastructures[♣]

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Abstract

This article confirms the existence of substantial economies of scale in trading and post-trading financial market infrastructures (FMI), using the panel data of thirty stock exchanges, twenty-nine clearing houses, and twenty-three central securities depositories from thirty-six countries. We show that economies of scale are positively related to size and vertical and horizontal integration of FMI providers. Economies of scale are significantly higher in North America than in other regions. When analyzing economies of scope, we show that the efficiency of FMI providers increases with vertical (but not horizontal) integration and with a focus on a narrow range of asset classes. We also analyze implications for systemic risk.

Keywords: clearing houses, central securities depositories, stock exchanges, economies of scale, economies of scope, vertical integration, horizontal integration, systemic risk

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[♣] The authors would like to thank two anonymous referees and the participants at the 1st INFINITI Conference on International Finance Asia-Pacific in Ho Chi Minh City for their valuable comments and suggestions. Shaofang Li appreciates the financial support of the Fundamental Research Funds for the Central Universities (grant number 2242016S20016). All errors remain our own.

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1. Introduction

Financial market infrastructures (FMI) serve as a backbone for efficient and resilient financial markets. After the execution of a financial transaction on a stock exchange, several post-trade processes referred to as clearing and settlement are carried out. Clearing and settlement typically involves a clearing house and a central securities depository (CSD) and ensures that the obligations in trade are honored as agreed upon with as little execution risk for the counterparties and as efficiently as possible. FMI are increasingly seen as a crucial support for smooth functioning of the real economy.

The landscape of FMIs has changed dramatically in light of consolidation of stock exchanges, clearing houses, and CSDs. For example, Euroclear, the Belgium-based CSD, became the largest international CSD in the world through acquisitions of CSDs in France, the Netherlands, the UK, Belgium, Finland, and Sweden in 2001, 2002, 2007, and 2008. Merger activities between stock exchanges include the Euronext merger in 2000, the OMX merger in 2003, the NYSE-Euronext merger in 2007, the NASDAQ-OMX merger in 2007, and the merger between the London Stock Exchange and Borsa Italiana in 2007. Mergers between clearing houses, CSDs, and stock exchanges have created some of the largest FMI conglomerates.[1] In light of antiglobalization forces (e.g., the Brexit process and President Donald Trump's protectionist rhetoric), there is a possibility that further integration dynamics might be put on hold or even reversed. Understanding the consequences of consolidation is thus crucial in predicting the efficient and stable road ahead for FMI and for financial systems at large.

This article analyzes whether economies of scale and scope exist in the trading and post-trading FMI. We employ the translog cost function to examine the existence of

[1] See the formation of Clearstream through the merger of Cedel International and Deutsche Borse in 2002, the acquisition of Central Depository Services Ltd. by the Bombay Stock Exchange in 2010, and the acquisition of LCH.Clearnet by the London Stock Exchange in 2013.

economies of scale and data envelopment analysis (DEA) to estimate the efficiency of FMI. Our sample comprises eighty-two institutions, including thirty stock exchanges, twenty-nine clearing houses, and twenty-three CSDs from Europe, North America, the Asia-Pacific region, South America, and Africa from 2000 to 2015.

We aim to contribute to the existing literature in three ways. First, our focus is on both trade and post-trade FMI. This allows us to analyze the existence of economies of scale in increasingly integrated FMI, in which separation of trade and post-trade FMI becomes increasingly difficult. The past studies have looked at different industries separately when estimating economies of scale or scope (e.g., Hasan and Malkamäki (2001), Hasan et al. (2003), Schmiedel et al. (2006), Van Cayseele and Wuyts (2007), Beijnen and Bolt (2009)). The problem with analyzing CSDs, clearing houses, and stock exchanges separately is that such an approach may result in mis-estimation of economies of scale and scope. For example, the analysis could focus on stock exchanges only and estimate economies of scale on the basis of the sample of stock exchanges that do not diversify into other activities such as CSDs or clearing houses. However, such an analysis would cover mostly small stock exchanges and leave out bigger and potentially more efficient stock exchanges that diversify into custody, settlement, or clearing, resulting in an underestimated economies of scale. Alternatively, one could analyze together stock exchanges only and stock exchanges that diversify into other activities. In such a way, there is a missing reference point to estimate how diversification into other activities affects the scale economies and efficiencies. For example, the analysis that would not consider the additional business of diversified stock exchanges would overestimate their costs. To add the reference point and to estimate the effect of diversification into custody, clearing, and settlement, we need to add to the sample the clearing houses and CSDs. Therefore, our data cover all FMI providers—vertically integrated and non-vertically integrated stock exchanges, CSDs, and clearing houses.

Second, we evaluate the existence of economies of scope within FMI. We investigate the benefits of vertical integration (i.e., merger of a clearing house or a CSD with a stock exchange) and horizontal integration (i.e., merger of two FMI providers of the same type). We also analyze whether it is more efficient for an FMI to provide services for a broad range of asset classes or if it is preferable to focus on a narrow range of asset classes.

Third, we analyze whether efficiency of FMIs affect systemic risk in the financial system and the level of development of the financial system. Well-functioning FMI is crucial for stability and efficiency of the financial system at large (CPSS-IOSCO, 2012). In addition, several regulators have required derivatives to be cleared under central clearing house with the intention to limit the systemic risk in the opaque derivatives market (as suggested by e.g. Acharya and Bisin, 2014, Li and Marinc, 2016a). However, broadening the range of products covered by the FMI providers may result in the concentration of systemic risk in the FMI (Heath, et al., 2016). We analyze whether consolidation of FMI providers and broadening of the product coverage of the FMI providers is associated with a higher systemic risk in the financial system.

The results confirm the existence of substantial economies of scale in FMI. Using the multiple-inputs and multiple-outputs model to measure mean cost scale elasticity, we find that the operating cost increases only by 21.54% if the number of transactions and the value of transactions are doubled. We also show that economies of scale increase with the institution size and with vertical and horizontal integration. The expansion of clearing houses, CSDs, and stock exchanges strengthens cost savings, especially for large institutions. Economies of scale seem to be most pronounced in the North American markets compared to other regions.

We partially confirm the existence of economies of scope across trading and post-trading

FMI. More specifically, we find that the efficiency of FMI providers is positively related to vertical integration but negatively to horizontal integration. This implies that economies of scope exist across different types of FMI providers. However, FMI providers that focus on a narrow range of asset classes are more efficient than FMI providers that focus on a broad range of asset classes. This indicates that diseconomies of scope exist across services provided for a broad range of asset classes.

We find some evidence that the efficiency of the FMI is negatively related to the systemic risk within the financial systems. The expansion of services of FMI providers to the broad range of asset classes is positively related to the systemic risk. However, the established relations are only weakly significant and further research is needed to confirm results.

The article is organized as follows. Section 2 reviews the functioning of FMI and the existing literature on economies of scale and scope in FMI. Section 3 describes the methodology and the data. Section 4 presents the empirical results. Section 5 investigates the factors affecting economies of scale and efficiency. Section 6 concludes the article.

2. Literature Review

2.1 The Functioning of FMI

FMI are crucial for smooth functioning of financial markets. We follow Lee (2010), who defines FMI as exchanges, clearing houses, and CSDs,[2] with the key functions that they provide as listing, trading, information dissemination, clearing, and settlement (see also Ferrarini and Saguato, 2015; Milne, 2016).

Exchanges operate a trading system in which securities or derivatives are traded among market participants. Two main functions of exchanges are data dissemination, in which pre-

[2] This definition of FMI is not universal. In the Swiss Financial Market Infrastructure Act, FMI are defined broadly as trading venues, central counterparties, CSDs, trade repositories, and payment systems. Others define FMI more narrowly as post-trade service providers only (see CPSS-IOSCO, 2012).

and post-trade data regarding prices and trade quantities are generated, and order execution, in which orders of market participants are transformed into trades.

After a security is transacted on a stock exchange, the trade has to be cleared and settled by the post-trade services institutions. The trading of securities on a stock exchange involves the transfer of ownership from the seller to the buyer of the relevant instruments as well as a reciprocal transfer of funds in payment. Clearing and settlement services guarantee that these transactions are performed safely and efficiently (Giddy et al., 1996; Schaper, 2008). Broadly, clearing refers to the process in which the buyer of a security and its seller establish their respective obligations (i.e., who owes what to whom and when). More narrowly, clearing is used for central counterparty clearing, in which a central counterparty clearing house interposes itself between counterparties and effectively becomes the "seller to every buyer and the buyer to every seller" (see CPSS-IOSCO, 2012). A clearing house deals with the logistical progress of matching and recording the transactions executed by a stock exchange, and provides a guarantee to the buying and selling counterparties to remove counterparty risk (Bernanke, 1990; Roe, 2013; Wendt, 2006). The clearing of trades can occur on either gross or net positions. If the trading partners or participants agree to offset net positions, then a process of netting takes place, in which a large number of individual positions or obligations are netted into a smaller number of positions or obligations (Van Cayseele and Wuyts, 2007).

After the clearing process is finished, the settlement of the transaction has to be executed. Settlement implies the transfer of money from the buyer to the seller, and simultaneous delivery of the securities from the seller to the buyer. The settlement process not only involves the clearing house, but also the local and international CSDs. The role of CSDs or international CSDs is to provide a mechanism to hold securities and to affect transfer between accounts by book entry. The main objective of CSDs is to centralize securities in either immobilized or dematerialized form that will permit the book entry transfer function to operate for the settlement of transactions (Milne, 2016; Van Cayseele and Wuyts, 2007).

2.2 Global Forces Reshaping FMI

FMI are on the verge of a deep transformation due to IT developments, changes in the regulatory environment, and removal of barriers to competition, with stark differences across countries.

IT developments are perceived as a major change driver in FMI. IT developments generally increase efficiency in the financial industry but may also increase the transaction nature of financial services, associated with higher economies of scale and competition (see Boot, 2014; Marinč, 2013). FMI providers that successfully implement efficient IT systems can improve their profitability and risk management.[3] IT developments and IT-driven standardization of services and products can also be used to pursue cross-border growth strategies. Cybersecurity presents an additional challenge to FMI providers, potentially giving an advantage to larger institutions with more resources to counter potential cyberattacks.

Another dominant force reshaping FMI is the continuously evolving regulatory landscape. Regulators have increased their attention to stability by imposing additional regulatory requirements on FMI (through the Dodd-Frank Act, Basel III, MiFID II, EMIR, CRD IV, and CSD Regulations), potentially with a downward pressure on cost efficiency. In addition, the regulators aim to lower systemic risk in financial systems by expanding the scope of FMI to cover previously unregulated financial products. For example, the majority of financial derivatives need to be centrally cleared. Broadening the scope might increase revenues of

[3] Hasan et al. (2003) find that investments in standardization and new technologies increase the productivity of stock exchanges. Knieps (2006) argues that implementation of new systems and further developments in settlement technology improve cost effectiveness in the post-trade markets. IT developments promote integration of financial markets in the euro area (see, e.g., Hasan and Malkamäki, 2001; Schmiedel et al., 2006), reduce the importance of location for the efficiency of transactions, and foster a single market, especially if regulatory barriers are also removed (see Gehrig and Stenbacka, 2007). IT serves as a competitive factor in the post-trading industry (Schaper and Chlistalla, 2010).

FMI providers but may also affect costs. On the one hand, FMI providers are evaluating whether sufficient economies of scope exist across services for a broad range of asset classes or whether is it better to focus on a narrow range of asset classes. On the other hand, the regulators are evaluating implications for systemic risk.

The regulatory barriers to competition among FMI providers are declining. In Europe, interoperability of clearing houses is already enacted by EMIR and will continue for settlements through TARGET2-Securities (T2S) infrastructure and CSD Regulations. Several other countries (e.g., Australia) are considering whether to open up borders to competition in the post-trade services by allowing entry of international providers or by creating bilateral links (e.g., the Hong Kong Shanghai Stock Connect initiative enables investors in each market to trade shares in the other market using local FMI providers; see Ray and Jaswal, 2015).[4]

FMI differ across the main capital markets. The US market is heavily concentrated. The Depository Trust Company, Fixed Income Clearing Corporation, and National Securities Clearing Corporation operate under the Depository Trust & Clearing Corporation, and they clear and settle the majority of the securities in the US. In contrast, the European FMI are still heavily fragmented along national lines.[5] Although substantial consolidation is occurring due to technological and regulatory pressures, political factors may halt further integration. For example, unless an agreement is reached after Brexit, the UK financial firms might lose passporting rights to sell financial products in the EU,[6] with clearing of euro-denominated financial products (currently mostly handled by the LCH, which is controlled by the LSE)

[4] Van Cayseele (2004), Holthausen and Tapking (2007), Milne (2007), Juranek and Walz (2010), Serifsoy and Weiß (2007), and Li and Marinč (2016b) investigate competition in the clearing and settlement industry.

[5] In an action plan on building a capital markets union, the European Commission (2015) stresses that barriers to efficient cross-border clearing and settlement still exist despite progress in integration such as establishing a level playing field through common European regulation.

[6] The UK could request an equivalence decision pursuant to MiFID II/MiFIR. CRD IV contains no provisions for third-country equivalence. See https://www2.isda.org/functional-areas/legal-and-documentation/uk-brexit/.

moving to continental Europe.

In light of increased competition and lower entry barriers, but increased political and regulatory risks, FMI providers need to evaluate the benefits of horizontal integration among the same FMI providers or vertical integration across different FMI providers.

2.3 Evidence on Scale and Scope Economies in FMI

Several empirical and theoretical studies evaluate economies of scale and scope in FMI.[7] Hasan and Malkamäki (2001) confirm the existence of economies of scale and scope among stock exchanges. The degree of economies of scale and scope vary across size and world regions. Hasan et al. (2003) show that organization structure, market competition, and investment in technology-related developments influence the cost and revenue efficiency of stock exchanges (see also Hasan and Schmiedel, 2004; Dicle and Levendis, 2013). Serifsoy (2007) compares the technical efficiency and factor productivity of exchanges with various business models. Exchanges that diversify into related activities are less efficient but exhibit stronger factor productivity growth than exchanges that remain focused on the cash market.

Economies of scale and scope can also be traced by analyzing the aftermath of mergers. Nielsson (2009) investigates the effects of the Euronext stock exchange merger on listed firms and finds asymmetric liquidity gains form the merger. The positive effects are seen only for large firms and firms with foreign sales, but not for small or medium-sized firms and for domestically oriented firms (see also Pownall, Vulcheva, and Wang, 2014). The price response of public stock exchanges to mergers and acquisitions is positive and larger for horizontal and cross-border integration compared to vertical and domestic integration (Hasan et al., 2012a, 2012b). Charles et al. (2016) confirm that mergers of stock exchanges

[7] In banking, recent empirical work has identified some economies of scale stemming potentially from IT development but found less evidence on the existence of economies of scope (see Boot, 2016 for a review). Berger, Hasan, and Zhou (2010) find diseconomies of scope in Chinese banking. Acharya, Hasan, and Saunders (2006) show that diversification of bank assets might lead to lower returns and riskier loans. See also Lepetit et al. (2008), Choi, Francis, and Hasan (2010), Meslier et al. (2016), Meslier, Tacneng, and Tarazi (2014).

significantly increase the information efficiency of the market. Francis, Hasan, and Sun (2008) show that mergers and acquisitions are especially beneficial for US acquirers if their targets are from local segmented financial markets. Their findings indicate that the integration of local segmented financial markets into the world capital markets alleviates financial constraints of local firms.

Several studies confirm the existence of economies of scale in the clearing and settlement industry in the US and Europe. Van Cayseele and Wuyts (2007) show that economies of scale exist in European clearing and settlement, and Schmiedel et al. (2006) find that the level of economies of scale varies by the size of a clearing and settlement institution.

Consolidation through vertical and horizontal mergers in clearing and settlement systems reflects a delicate link between economies of scale and scope and competition issues. Köppl and Monnet (2007) argue that vertical integration between settlement institutions and exchanges can prevent efficiency gains that could be obtained by horizontal consolidation between clearing and settlement institutions. Vertical mergers between exchanges and clearing and settlement institutions might lead to potential anticompetitive concerns. Tapking and Yang (2006) show that vertical integration of domestic service providers may be desirable if domestic investors are not inclined to invest in foreign securities (see also Pirrong, 2007). Rochet (2006) finds that the welfare effect of a vertical integration depends on the tradeoff between efficiency gains and lower competition at the custodian level (see also Kauko, 2007; Cherbonnier and Rochet, 2010; Droll, Podlich, and Wedow, 2016).

In summary, we have identified the factors that shape the FMI as technological development, the scope of services that an FMI provider offers (i.e., services for a broad range or a narrow range of asset classes), a region in which the FMI provider operates, and the market structure in FMI expressed through variables such as the size of an FMI provider, vertical integration, and horizontal integration. We hypothesize that these factors also affect the level of scale economies and scope economies in FMI.

3. Methodology and Data Statistics

Now, we describe how we estimate economies of scale, efficiency, and the factors that drive economies of scale and efficiency in FMI. In addition, we present the sources and simple summary statistics of our data.

3.1 Estimation of Economies of Scale

For the estimation of economies of scale, we follow Hasan and Malkamäki (2001), Schmiedel et al. (2006), Van Cayseele and Wuyts (2007), and Davies and Tracey (2014), and employ the translog cost function (Berndt, 1991), in which scale economies vary with the level of output. The general functional form of the multiple-product translog cost function is

$$\ln TC_{it} = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln Q_{it}^m + \sum_{n=1}^{N} \beta_n \ln P_{it}^n + \frac{1}{2}\sum_{m=1}^{M}\sum_{k=1}^{M} \alpha_{mk} (\ln Q_{it}^m * \ln Q_{it}^k) + \frac{1}{2}\sum_{n=1}^{N}\sum_{l=1}^{N} \beta_{nl} (\ln P_{it}^n * \ln P_{it}^l) + \sum_{m=1}^{M}\sum_{n=1}^{N} \omega_{mn} (\ln Q_{it}^m * \ln P_{it}^n) + \rho_1 t + \varepsilon_{it} \quad (1)$$

where TC_{it} is the total operating cost of institution *i* at time *t*.

We estimate two specifications of a regression model in (1). First, we estimate a multiple-inputs and multiple-outputs model in which we set $M = N = 2$ in (1) and use the number of transactions (NT_{it}, denoted as Q_{it}^1) and value of transactions (VT_{it}, denoted as Q_{it}^2) as the output factor variables Q_{it}^m.[8] Following Hasan and Malkamäki (2001) and Schmiedel et al. (2006), we use the variable GDP *per capita* ($GDPPC_{it}$, denoted as P_{it}^1) to measure the labor cost for different countries at different years, and use the ratio of the country-specific share of information and communication technology expenditure to GDP (ICT_{it}, denoted as P_{it}^2) to measure the technology investments, as the input factor price variables P_{it}^n.[9]

[8] In our main analysis, we follow Schmiedel (2001, 2002), Davies and Tracey (2014), and Beccalli et al. (2015), and use the logarithms of the values of the input and output variables and drop the observations of FMIs with zero output variables, in order to avoid the estimation bias. As a robustness check in Appendix B, we also consider FMIs with zero output variables.

[9] Instead of $GDPPC_{it}$ and ICT_{it} we could use technology and office expense and personnel expense as the input factor price

We include the time trend variable *t* to control for technology development (see also Hou, Wang, and Li, 2015). We estimate the translog cost function in (1) by employing both the fixed effect estimation and stochastic frontiers analysis (*SFA*). The robust standard errors are clustered at the firm level (see Appendix for details). Cost scale elasticities are calculated as

$$e_{Q^1}(Q_{it}^1, Q_{it}^2) = \frac{\partial \ln TC}{\partial \ln Q^1} = \alpha_1 + \alpha_{11}\ln Q_{it}^1 + \alpha_{12}\ln Q_{it}^2 + \sum_{\mathrm{n}=1}^2 \omega_{1n}\ln P_{it}^n \quad (2)$$

$$e_{Q^2}(Q_{it}^1, Q_{it}^2) = \frac{\partial \ln TC}{\partial \ln Q^2} = \alpha_2 + \alpha_{22}\ln Q_{it}^2 + \alpha_{12}\ln Q_{it}^1 + \sum_{\mathrm{n}=1}^2 \omega_{2n}\ln P_{it}^n \quad (3)$$

where regression coefficients α_i, α_{mk}, and ω_{mn} are obtained from multiple-inputs and multiple-outputs specification of (1) with $M = N = 2$. The inverse function of economies of scale $ES2_{it}$ at point (Q^1, Q^2) of the output set is computed by the sum of the cost scale elasticities with respect to both outputs

$$\frac{1}{ES2_{it}} = \sum_{m=1}^2 \frac{\partial \ln TC}{\partial \ln Q^m} = e_{Q^1}(Q_{it}^1, Q_{it}^2) + e_{Q^2}(Q_{it}^1, Q_{it}^2) \quad (4)$$

Second, we estimate a single-input and single-output model in which we set $M = N = 1$ in (1) and use the number of transactions (NT_{it}, denoted as Q_{it}^1) as a single output, and GDP *per capita* ($GDPPC_{it}$, denoted as P_{it}^1) as a single input. The inverse function of economies of scale $ES1_{it}$ at point Q^1 of the output set is computed by the cost scale elasticity with respect to the single input

$$\frac{1}{ES1_{it}} = \frac{\partial \ln TC}{\partial \ln Q^1} = \alpha_1 + \alpha_{11}\ln Q_{it}^1 + \omega_{11}\ln P_{it}^1 \quad (5)$$

where regression coefficients α_1, α_{11}, and ω_{11} are obtained from single-input and single-output specification of (1) with $M = N = 1$.

3.2 Estimation of Efficiency

We also apply the frontier analysis by using DEA (following Cooper et al., 2004; Cummins et

variables. However, FMI frequently do not report these data. As a robustness check, we include variable $STAFF_{it}$ (denoted as P_{it}^3), which is defined as the ratio of personnel expenses divided by the total assets, as another measure of labor cost. In addition, we focus on the subsample of FMI that reports the value of personnel expense. The results remain qualitatively the same (see Table A3 in the Appendix).

al., 2010) to estimate technical, cost, revenue, and profit efficiency for each firm in our sample.[10] Efficiency scores range between 0 and 1, where a value of 1 indicates that firms are fully efficient, and values smaller than 1 indicate that firms are not fully efficient.

The technical efficiency (TE_{it}) of a given firm is defined as the ratio of the input usage of a fully efficient firm producing the same output vector as the given firm to the input usage of the given firm. Technical efficiency (TE_{it}) is a product of two parts: pure technical efficiency (PTE_{it}), which measures the efficiency relative to the variable returns to scale frontier, and scale efficiency (SE_{it}), which measures the distance between the variable returns to scale frontier and the constant returns to scale frontier.

Cost efficiency is defined as the ratio of the costs of a fully efficient firm with the same output quantities and input prices of a given firm to the given firm's actual costs. Cost efficiency can be decomposed into technical efficiency (TE_{it}) and allocative efficiency (AE_{it}), which describes how well the firm chooses the optimal mix of inputs. Cost efficiency relative to the constant returns to scale (CE_{it}) is defined as the product of pure technical, scale, and allocative efficiency, $CE_{it} = PTE_{it} * SE_{it} * AE_{it}$. We also estimate the cost efficiency under variable returns to scale (VCE_{it}) and cost efficiency under constant returns to scale purged of scale efficiency ($CEScope_{it}$, defined as $CEScope_{it} = CE_{it} / SE_{it} = PTE_{it} * AE_{it}$).

Revenue efficiency is defined as the ratio of the revenues of a given firm to the revenue of a fully efficient firm with the same input vector and output prices. We estimate the revenue efficiency under both constant returns to scale (RE_{it}) and variable returns to scale (VRE_{it}). We also estimate revenue efficiency under constant returns to scale purged of scale efficiency ($REScope_{it}$, defined as $REScope_{it} = RE_{it} / SE_{it}$). Finally, profit efficiency (PE_{it}) is defined as

[10] Alternatively, we could employ stochastic frontier analysis (e.g., as in Fang, Hasan, and Marton, 2011). We prefer DEA because it avoids potential specification errors that can occur due to the improper specification of cost or revenue function. DEA is also computed for an individual firm and does not require distributional assumptions.

the profit that could be obtained if the firm were fully efficient.

For estimating efficiency under the DEA model, we use the following inputs and outputs. The inputs include GDP *per capita* ($GDPPC_{it}$) as a proxy for the price of labor and the ratio of the country-specific share of information and communication technology expenditure to GDP (ICT_{it}) as a proxy for the price of technology investment. Outputs used are the number of transactions (NT_{it}) and the value of transactions (VT_{it}) processed by FMI provider *i* in year *t*. For estimating cost, revenue, and profit efficiency, we employ total operating cost (TC_{it}), total operating income (TR_{it}), and total profit (TP_{it}), respectively, as proxies for cost, revenue, and profit variables.

We estimate cost, revenue, technical, scale, allocative, and profit efficiency under both constant returns to scale (CCR model; Charnes et al., 1978) and variable returns to scale (BCC model; Banker et al., 1984; Lozano-Vivas, Pastor, and Hasan, 2001). As in Cummins et al. (2010), we employ the input orientation for estimating technical efficiency in the cost minimization problem, and the output orientation for the revenue and profit maximization problem.

3.3 Determinants of Economies of Scale and Scope

We analyze which factors affect economies of scale and scope using the following regression

$$Y_{it} = \varphi_0 + \sum_k \varphi_k \, Controls_{itk} + \sum_j \varphi_j \, F_{itj} + \varepsilon_{it} \quad (6)$$

Dependent variable Y_{it} represents either a measure of cost scale elasticity $\frac{1}{\mathrm{ES1}_{it}}$ based on a single-input and single-output model from (5) or cost scale elasticity $\frac{1}{\mathrm{ES2}_{it}}$ based on a multiple-inputs and multiple-outputs model from (4), in which higher values indicate lower economies of scale, or an indicator of efficiency (TE_{it}, PTE_{it}, CE_{it}, $CEScope_{it}$, VCE_{it}, RE_{it}, $REScope_{it}$, VRE_{it}, SE_{it}, AE_{it}, or PE_{it}).

We are interested in how several factors F_{itj} affect economies of scale and efficiency. We analyze the effect of institution size (logarithm of total assets, denoted by $Size_{it}$), the institution type (*Dummy clearing house*$_i$ equals one if the FMI provider is a clearing house and zero otherwise, and *Dummy CSD*$_i$ equals one if the FMI provider is a CSD and zero otherwise), the effects of horizontal mergers between the same types of institutions (*Horizontally integrated*$_{it}$), and the effects of vertical mergers between different types of institutions (*Vertically integrated*$_{it}$). More specifically, the dummy variable *Vertically integrated*$_{it}$ equals one if the FMI provider is or has become vertically integrated with another FMI provider (i.e., if a clearing house or CSD is vertically integrated with a stock exchange) and zero otherwise. The dummy variable *Horizontally integrated*$_{it}$ equals one from the year the FMI provider merged with the same type of FMI provider onwards, and zero otherwise.

We also analyze the impact of the geographic location (*Dummy North America*$_i$, *Dummy Europe*$_i$, and *Dummy Asia-Pacific*$_i$), and the degree of specialization of the FMI providers (*Broad range of asset classes*$_i$) on the economies of scales and efficiency measures. The dummy variable *Broad range of asset classes*$_i$ equals zero if the FMI provider offers services only for bonds and equities securities, and equals one if the FMI provider also offers services for other instruments such as derivatives and commodities.

As control variables $Controls_{itk}$, we include *GDP growth*$_{it}$ and *Inflation*$_{it}$ in a country to account for the changes of economic cycles. We also add *Interest rates*$_{it}$ and *Stocks trade ratio*$_{it}$, defined as the value of stocks traded to GDP, to control for the changes in monetary policy and the size of the security market in a given country. To control for the risk-taking of the institutions, we follow Hughes and Mester (1993) and include the logarithm of equity to asset ratio, denoted as $ln\ EOA_{it}$. In an additional specification, we also include the logarithm of ICT_{it} and a time trend t to capture the effect of technological development. The definitions of the variables are presented in Table 1. We estimate the regression in (6) by using the feasible generalized least squares (FGLS). To deal with residuals that may be correlated across time we include dummy variables for each time period and then estimate standard errors allowing for heteroscedastic standard errors in firm dimension.

3.4 Data Collection

We collect the data from several sources. The financial information of CSDs and clearing houses was collected from the Bankscope database and annual reports, and the data for stock exchanges was acquired from annual reports. The data for the total number and value of transactions for clearing houses and CSDs are obtained from Bank for International Settlement Statistics on Payment and Settlement Systems, and data for stock exchanges are collected from the World Federation of Exchanges Annual Yearbooks. Macroeconomic data are taken from the IMF International Financial Statistics (IFS) and the World Bank Database. The information on merger and acquisition activities is obtained from the Zephyr database. All of the data were collected in national currencies, converted into US dollars and inflation-adjusted. Table 1 lists data sources per each variable.

Our sample consists of eighty-two institutions, including thirty stock exchanges, twenty-nine clearing houses, and twenty-three CSDs, amounting to 653 firm-year observations, from regions including Europe, North America, the Asia-Pacific region, South America, and Africa between 2000 and 2015. Table A4 in Appendix lists the FMI providers in our data and their institutional characteristics.

<Insert Table 1 here>

3.5 Data Statistics

Table 2 provides descriptive statistics. The average values of total operating cost and total operating income are $256.9 million and $348.9 million, respectively. Regarding the output variables, the average number of transactions per institution per year is 1.306 billion and the average total value of the transactions per institution per year is $66.620 trillion. Regarding the input variables, the average value of *GDPPC* is $32,200, the average *ICT* is 1.66%, and the average value of personnel expense per institution per year is $78.8 million. The average value of equity to total assets, *EOA*, is 31.5%.

<Insert Table 2 here>

Based on the type of FMI provider, we can split our sample into subsamples of stock exchanges, clearing houses, and CSDs. Even though clearing houses are the biggest in terms of average total assets (stock exchanges have medium assets and CSDs have the smallest total assets), they generate the lowest total operating cost and operating income (followed by the CSDs and the stock exchanges). The average number and value of transactions per institution per year are the highest for clearing houses, followed by CSDs, and the lowest for stock exchanges. Clearing houses are also the most leveraged among the FMI providers (with *EOA* of only 7.93%), followed by CSDs (with *EOA* of 27.37%) and stock exchanges (with *EOA* of 52.58%). Clearing houses incur the lowest personnel expenses, followed by stock exchanges and CSDs.

We also divide our sample based on specialization. FMI providers that focus on a broad range of asset classes have higher operating costs, operating income, personnel expenses, and total assets, but a lower number and value of transactions than FMI providers that focus on a narrow range of asset classes.

Finally, we split our sample according to different types of integration. The results show that horizontally integrated FMI providers have higher operating costs, operating income, and personnel expenses, but lower total assets, and a lower number and value of transactions than non-horizontally integrated FMI providers. Vertically integrated FMI providers have not only higher operating costs, operating income, and personnel expenses, but also a higher number and value of transactions than non-vertically integrated FMI providers.

4. Empirical Results

In this section, we first present the main performance indicators of the FMI providers. Second, we perform the translog analysis and estimate the economies of scale in FMI. Third, we employ DEA to estimate efficiency scores and analyze economies of scope in FMI.

4.1 Simple Performance Indicators

We overview several simple performance indicators of the total sample, CSDs, stock exchanges, and clearing houses from Europe, North America, the Asia-Pacific region, and South America and Africa in Table 3. Table 3 also provides the performance ratios of the subsamples based on the institution size, specialization, and type of integration. We can observe that the performance indicators vary considerably across the size, type of institution, geographic location, specialization, and type of integration.

<Insert Table 3 here>

As an indicator of cost efficiency, we compute cost per trade, defined as the total operating cost divided by number of transactions, *TC/NT*. It represents an estimate of the average unit cost of settling a trade in the market. The average *TC/NT* is \$423.77 for CSDs, \$63.16 for stock exchanges, and \$38.71 for clearing houses. Another variable that discerns cost efficiency is the cost per value of transaction, *TC/VT*. Stock exchanges exhibit the highest *TC/VT*, with an average *TC/VT* of \$0.0033, followed by CSDs, with an average *TC/VT* of \$0.0007, and clearing houses, with the lowest average *TC/VT* of \$0.000009. As a profitability indicator, we compute operating income per trade, *TR/NT*, and operating income per value of transaction, *TR/VT*. The average *TR/NT* of CSDs is the highest and is around three times that of *TR/NT* of stock exchanges, and twelve times that of *TR/NT* of clearing houses. The average *TR/VT* is the highest for stock exchanges, followed by CSDs and clearing houses.

We are interested in how the size of an FMI affects simple cost performance indicators. The average *TC/NT* and *TR/NT* is much higher for large FMI providers than for small ones. To understand this, note that large FMI providers in our sample include the NASDAQ, New York Stock Exchange, TMX Group, Deutsche Boerse, London Stock Exchange, Euroclear Bank, Clearstream International, the Depository Trust Company, and Tokyo Stock Exchange. Most of them provide cross-border services, which are generally costlier than domestic transactions (see Giovannini Group, 2002; De Carvalho, 2004; Schmiedel and Schönenberger, 2005). In contrast, the largest FMI providers have a much lower value of *TC/VT* and *TR/VT* compared to the smallest ones, potentially because they process most of the high-value transactions.

We graphically depict the relationship between the number of transactions and *TC/NT* in Figure 1 and the relationship between the value of transactions and *TC/VT* in Figure 2. Figure 1 and Figure 2 indicate that, with the increasing number of transactions and the value of transactions, the cost per trade and the cost per value of transaction are decreasing. These findings persist across the subsamples of clearing houses, CSDs, and stock exchanges, indicating that simple cost performance indicators improve with the size of FMI.

<Insert Figure 1 & Figure 2 here>

Comparison across regions reveals that the average *TC/NT*, *TC/VT*, *TR/NT*, and *TR/VT* in North America are the lowest compared to other regions, consistent with the view of Lannoo and Levin (2002), Giovannini Group (2002, 2003), Hasan et al. (2003), and Schmiedel et al. (2006) that FMI providers in North America are highly efficient and operate in a highly competitive environment. The average *VT/NT* in North America is $267.2 million, which is higher compared to other regions. A potential explanation is that FMI providers from North America offer services to larger and more international firms with a higher average value of transaction.

We also check whether performance indicators vary with horizontal and vertical integration, and with a focus on a broad versus narrow range of asset classes. Horizontally integrated FMI providers have lower *TC/NT*, *TR/NT*, and *TR/VT* than non-horizontally integrated FMI providers. Vertically integrated FMI providers have higher *TC/NT* and *TR/NT* and lower *TR/NT* and *TR/VT* than non-vertically integrated FMI providers. The FMI that provide services for a broad range of asset classes also have significantly higher *TC/NT* and *TR/NT* and lower *TR/NT* and *TR/VT* than FMI that focus on a narrow range of asset classes.

4.2 Economies of Scale

We now estimate whether economies of scale exist in FMI. We apply the single-input and single-output model in (5) and multiple-inputs and multiple-outputs model in (4) for our total sample and for various subsamples.[11] Following Hughes and Mester (2013), we compute the mean of cost scale elasticities for the total sample and various subsamples (see Panel A and Panel B in Table 4, respectively). The results in each panel are reported based on size, horizontal and vertical integration, type of FMI, geographical location, and specialization. In the case of a single input and a single output model, the mean cost scale elasticity of the total sample with respect to the number of transactions is 0.0889. This indicates that the operating cost increases by 8.89% if the number of transactions is doubled.

The mean cost scale elasticity based on the multiple-inputs and multiple-outputs model with respect to the number of transactions is 0.155 (Panel B in Table 4). This indicates that the operating cost would increase by 15.5% if the number of transactions were doubled. The mean cost scale elasticity with respect to the value of transactions is 0.0604, meaning that the operating cost would increase by 6.04% if the value of transactions were doubled. The

[11] We derive the value of economies of scale (see (4) and (5)) from the coefficients estimated in column (6) of Panel A and Panel B in Table A2, respectively.

operating cost increases by 21.54% if both outputs are doubled.[12] These findings confirm the existence of economies of scale in the FMI.

<Insert Table 4 here>

In order to test the impact of institution size on the economies of scale of the FMI, we divide our sample into four subsamples based on the total assets, and estimate the cost scale elasticities of four different subsamples. The results indicate that the economies of scale are higher for large institutions than for small ones. If the number (value) of transactions is doubled, the operating cost increases by 25.06% (10.76%) for the smallest institutions in the first quantile, but only by 8.79% (6.07%) for the largest ones in the fourth quantile.

Table 4 shows that the economies of scale are higher if FMI providers are vertically or horizontally integrated. Results of the single-input and single-output model (see Panel A of Table 4) show that operating costs of vertically integrated FMI providers increase by 7.6% if the number of transactions is doubled, compared to 9.27% for FMI providers that are not vertically integrated. Results of the multiple-inputs and multiple-outputs model (see Panel B of Table 4) show that operating costs of vertically integrated FMI providers increase by 16.30% if both outputs are doubled, compared to 23.84% for FMI providers that are not vertically integrated. The results of horizontal integration are similar. This confirms that vertical and horizontal integration within FMI is associated with higher economies of scale and corroborates previous evidence in Tapking and Yang (2006).

We confirm that economies of scale exist within different types of FMI (i.e., clearing houses, CSDs, and stock exchanges). Doubling the number of transactions increases the operating cost by 8.35% (16.95%) for clearing houses, 7.46% (19.13%) for CSDs, and 10.39% (23.83%) for stock exchanges, as predicted by the single-input and single-output model

[12] Instead of the translog model in (1), we also use the loglinear model with qualitatively similar results (see Appendix, Table A1).

(multiple-inputs and multiple-outputs model). Our results indicate that economies of scale are the highest for clearing houses, lower for CSDs, and the lowest for stock exchanges.

Larger FMI providers (the top 50% in total assets) realize higher economies of scale than smaller ones (the bottom 50% in total assets). This is confirmed across the total sample and within the subsamples of clearing houses, CSDs, and stock exchanges.

Our findings confirm the existence of economies of scale in each regional subsample. A substantial variation in the degree of economies of scale exists across regions. The economies of scale are the highest in North America and the lowest in South America and Africa. The doubling of the outputs increases costs by 6.07% and 14.35%, as predicted by the single-input and single-output model for North America and for South America and Africa, respectively (and by 13.47% and 43.73% as predicted by the multiple-inputs and multiple-outputs model).

We also separate FMI based on their specialization. Doubling the outputs results in a lower cost increase for FMI providers that offer services for a broad range of asset classes compared to FMI providers that offer services for a narrow range of asset classes.

4.3 Efficiency Scores

We perform DEA estimation on the total sample that includes stock exchanges, CSDs, and clearing houses, and we estimate average technical efficiency (TE_{it}), pure technical efficiency (PTE_{it}), cost efficiency (CE_{it}), cost efficiency purged of scale efficiency ($CEScope_{it}$), cost efficiency based on variable returns to scale technology (VCE_{it}), revenue efficiency (RE_{it}), revenue efficiency purged of scale efficiency ($REScope_{it}$), revenue efficiency based on variable returns to scale technology (VRE_{it}), input-oriented scale efficiency (SE_{it}), input-oriented allocative efficiency (AE_{it}), and profit efficiency (PE_{it}); see Table 5.

Clearing houses on average have higher technical, cost, revenue, scale, and profit efficiency than stock exchanges and CSDs. Cost efficiency under constant returns to scale (variable returns to scale) averages 34.18% (46.72%) for clearing houses, 5.92% (16.66%) for stock exchanges, and 4.13% (12.91%) for CSDs. Revenue efficiency under constant returns to scale (variable returns to scale) averages 17.95% (24.13%) for clearing houses, 2.43% (9.23%) for stock exchanges, and 3.97% (4.03%) for CSDs.

<Insert Table 5 here>

Revenue, scale, and profit efficiency are significantly higher, whereas technical and cost efficiency are significantly lower for large FMI providers (the top 50% in total assets) than for small FMI providers (the bottom 50% in total assets). This indicates that economies of scale in FMI stem from revenue, scale, and profit efficiency rather than from technical and cost efficiency.

We also analyze how horizontal and vertical integration affect the efficiency of FMI providers. Horizontal integration is associated with significantly decreased technical efficiency, cost, revenue, scale, and profit efficiency, whereas vertical integration is associated with significantly increased pure technical, revenue, and profit efficiency. A negative relationship between horizontal integration and efficiency indicators and a positive relationship between vertical integration and efficiency indicators also persists across subsamples of stock exchanges, CSDs, and clearing houses.

FMI providers that focus on a broad range of asset classes operate less efficiently than FMI providers that focus on a narrow range of asset classes.

The results of returns to scale are presented in Panel B in Table 5. None of the stock exchanges, and only 2.1% of CSDs and 7.7% of clearing houses, operate under constant returns to scale. All three types of institutions are more likely to operate under increasing returns to scale than under decreasing returns to scale, supporting the presence of economies of scale in FMI.

5. Multiple Regression Analysis

5.1 Factors Affecting Economies of Scale

We now analyze the factors that affect the economies of scale in FMI using the single-input and single-output model in (5) and the multiple-inputs and multiple-outputs model in (4) to estimate cost scale elasticities; see Table 6.

<Insert Table 6 here>

Dummy clearing house$_i$ and *Dummy CSD*$_i$ are negatively and significantly related to cost scale elasticity. The absolute value of the regression coefficient of *Dummy CSD*$_i$ is smaller than the regression coefficient of *Dummy clearing house*$_i$. This provides some evidence that the economies of scale for clearing houses (and to a smaller level also for CSDs) are significantly higher than the economies of scale for stock exchanges.

We find that the size of FMI providers is negatively associated with cost scale elasticity, indicating that economies of scale increase with the institution size. The dummy variable *Horizontally integrated*$_{it}$ is negatively related to cost scale elasticity, showing that the economies of scale are positively related to horizontal integration. The dummy variable *Vertically integrated*$_{it}$ is negatively related to cost scale elasticity, indicating that the economies of scale are positively related to vertical integration.

The negative sign of the regression coefficient of *Broad range of asset classes*$_i$ confirms that the FMI providers that offer services for a broad range of asset classes have higher economies of scale than the ones that only focus on a narrow range of asset classes.

We also find that the dummy variables *Dummy Europe*$_i$ and *Dummy Asia-Pacific*$_i$ are positively related to cost scale elasticity, and *Dummy North America*$_i$ is negatively related to cost scale elasticity. This indicates that economies of scale are lower in Europe and the Asia-Pacific region and higher in North America compared to other regions.

Variable ICT_{it} is negatively and statistically significantly related to cost scale elasticity. This is consistent with the view that with the technological development is positively associated with economies of scale in financial institutions (see Boot, 2014; Hasan et al., 2003; Knieps, 2006; Marinč, 2013).

To conclude, economies of scale increase with size and with horizontal and vertical integration. Clearing houses (and CSDs) have higher economies of scale than stock exchanges. Economies of scale are significantly higher in North America than in other regions. The FMI providers that provide services for a broad range of asset classes can exploit higher economies of scales. Technological development is positively related to the economies of scale in FMI.

5.2 Factors Affecting Efficiency Scores

We now analyze factors that affect efficiency scores using the regression analysis in (6). We find that large FMI providers have significantly higher revenue efficiency but lower cost, scale, and allocative efficiency than smaller FMI providers. See Table 7.

<Insert Table 7 here>

Vertical integration is positively associated with pure technical and cost efficiency, whereas horizontal integration is negatively associated with pure technical and cost efficiency.

Technical, cost, revenue, and profit efficiency are significantly higher for clearing houses than for stock exchanges and CSDs. FMI providers in North America have higher allocative efficiency but lower technical, revenue, and scale, and profit efficiency than FMI providers in other regions. One explanation is that FMI from North America provide transaction services with high volume and values, but with lower cost and revenue, and they are largely engaged in cross-border trading.

FMI providers that focus on a broad range of asset classes have significantly lower technical and cost efficiency than FMI providers that focus on a narrow range of asset classes.

Focusing on cost and revenue efficiency purged of scale efficiency effects ($CEScope_{it}$ and $REScope_{it}$), we can confirm that large FMI providers have significantly lower $CEScope_{it}$ but higher $REScope_{it}$ than smaller FMI providers. $CEScope_{it}$ is positively associated with vertical integration and negatively with horizontal integration. Clearing houses have significantly higher $CEScope_{it}$ and $REScope_{it}$ than stock exchanges. FMI in Europe have significantly lower $REScope_{it}$ and $CEScope_{it}$ compared to other regions.

5.3 Integration and the Efficiency of FMI Providers

Now we analyze whether vertical and horizontal integration affect efficiency of stock exchanges, CSDs and clearing houses in the same way.

<Insert Table 8 here>

The results in Panel A of Table 8 show that horizontal integration of stock exchanges is negatively whereas horizontal integration of CSDs is positively related to several measures of efficiency (except for scale efficiency). Our results indicate that especially horizontal integration of stock exchanges requires further scrutiny by the shareholders and regulators whereas horizontal integration of CSDs may even be beneficial for efficiency.

Panel B of Table 8 indicates that vertical integration of a stock exchange is positively associated with cost and allocative efficiency. Vertical integration of a clearing house is positively associated with pure technical and cost efficiency, but negatively associated with allocative efficiency. Vertical integration of a CSD is negatively related to scale efficiency.

Panel C of Table 8 confirms that a stock exchange that provides services for a broad range of asset classes has lower technical, pure technical, and cost efficiency. A clearing house that provides services for a broad range of asset classes has lower technical, pure technical, cost, revenue, and profit efficiency, but higher scale and allocative efficiency. A CSD that provides services for a broad range of asset classes has higher revenue and allocative efficiency.

5.4 Efficiency of FMI providers and Systemic Risk

Now we analyze whether the efficiency of the FMI providers is associated with the systemic risk in the financial system. We use different measures of systemic risk. As a measure of the financial distress of the banking sectors, we use the variable *NPL*, which is defined as the bank non-performing loans to total gross loans in a financial system. As a measure of systemic risk of the stock market, we use the variable *Stock Market Index Volatility*, which is defined as the volatility of the stock market index return for each country at each year and calculated based on the monthly returns of the stock market index. To measure the systemic risk in the EU countries, we employ the variable *Country-Level Index of Financial Stress (CLIFS)*, which is defined as a measure of financial stress in Duprey et al. (2015) and Duprey and Klaus (2017).

Following Levine et al. (2000), Laeven (2003), Carlin and Mayer (2003), and Cecchetti and Kharroubi (2012), we include *GDP growth* and *Inflation* in each country at each year as control variables to account for economic cycle. *Interest rate* and *Number of FMIs* control for the changes of monetary policy and the industry structure of the FMIs in a given country. *ICT* controls for the changes of technology development. We also include variable *Private credit by banks to GDP* to control for the financial sector size. We employ the feasible generalized least squares (FGLS) estimator to cope with potential heteroskedasticity problems and include the yearly dummies to control the time fixed effects. See Table 9.

<Insert Table 9 here>

The results in Table 9 indicate that revenue efficiency is negatively and significantly associated with the non-performing loan ratio (*NPL*) whereas cost efficiency is positively related to *NPL*. Increasing revenue efficiency and decreasing cost efficiency of the FMI providers may be associated with higher stability of the banking system.

Table 9 shows that efficiency measures of FMI providers are not statistically significantly related to *Stock Market Index Volatility*, which is used as a measure of the stock market financial distress.

Table 9 also shows that pure technical efficiency and revenue efficiency are negatively associated with *Country-Level Index of Financial Stress* (*CLIFS*), which is used as a measure of a systemic risk in the financial systems.[13]

In sum, we find some support for the relationship between the efficiency measures of FMI providers and systemic risk. However, the relationships are only weakly significant and no causality is established. Further analysis is needed to support our results.

5.5 Integrations of FMI Providers, Systemic Risk, and Financial Development

We are also interested whether the form of integration between FMI providers is related to the systemic risk within the financial system. We employ the variables, including *NPL*, *Stock Market Index Volatility*, and *Country-Level Index of Financial Stress (CLIFS)*, as measures of financial distress of financial system. We follow Cecchetti and Kharroubi (2012) and use two different measures: *Stock Market Capitalization Ratio*, which is defined as the ratio of market capitalization of listed companies to GDP, and *Banking System Asset to GDP Ratio,* which is defined as the banking system asset to GDP ratio, as the measures of stock market and banking system development.

We include the variables *Size*, *Broad range of asset classes*, *Dummy clearing house*, *Dummy CSD*, *Dummy Europe*, *Dummy North America*, and *Dummy Asia-Pacific* to control for the

[13] As the data of *Country-Level Index of Financial Stress (CLIFS)* is only available for EU countries, we only perform our analysis on the subsample of EU countries.

firm-level characteristics. We also include a set of control variables including *GDP growth*, *Inflation rate*, *Interest rate*, *ICT*, and *ln EOA*, and employ the feasible generalized least squares (FGLS) estimator to cope with potential heteroskedasticity problems. Year dummies are also included to control the time fixed effects. See Table 10.

<Insert Table 10 here>

Columns (1)–(3) in Table 10 show that vertical and horizontal integration are negatively and significantly associated with non-performing loan ratio (*NPL*).[14] Columns (4)-(5) show that vertical integration is positively and significantly related to *Banking System Asset to GDP ratio*, and horizontal integration is positively and significantly associated with both *Stock Market Capitalization Ratio* and *Banking System Asset to GDP ratio*. *Broad range of asset classes* is positively and significantly related to the measures of systemic risk (*NPL*, *Stock Market Index Volatility,* and *CLIFS)* and to the measures of financial system development (*Banking System Asset to GDP ratio* and *Banking System Asset to GDP ratio*).

Hence, horizontal and vertical integration as well as broad orientation of FMI providers (that offer services for broad range of asset classes) is associated with several measures of systemic risk and financial system development.

6. Conclusion

In this article we analyze economies of scale and scope within FMI, based on the panel data of thirty stock exchanges, twenty-nine clearing houses, and twenty-three CSDs from thirty-six countries. We investigate the impact of size, horizontal and vertical integration, type, focus on a narrow versus broad range of asset classes, and geographic location on economies of scale and scope.

We confirm the existence of economies of scale in FMI. Economies of scale are positively

[14] Dummy variables *Dummy Europe*, *Dummy North America*, and *Dummy Asia-Pacific* are dropped out of the regression in column (3) in Table 10 because of the data of *CLIFS* is only available for EU countries.

associated with size, horizontal and vertical integration of an FMI provider, and its focus on a broad range of asset classes, and are the highest in North America and Europe. This indicates that the best strategy for large, horizontally and vertically integrated FMI providers is to focus further on high growth and reap the benefits of economies of scale.

Our findings also suggest that economies of scale mostly derive from the improvements in revenue efficiency and profit efficiency rather than cost efficiency. A potential explanation is that larger FMI providers offer higher quality products and services that raise costs but also raise revenues by more than the cost increases; this is consistent with evidence in the banking industry (see Berger and Mester, 2003).

We find that the efficiency of FMI providers is positively related to vertical integration but negatively to horizontal integration and to the focus on a broad range of asset classes. Therefore, economies of scope seem to be present in vertical integration of clearing houses and CSDs with stock exchanges but not in horizontal integration across the FMI providers of equal types, nor in the combination of services provided for a broad range of asset classes.

References

Acharya, V., and Bisin, A. (2014). Counterparty risk externality: Centralized versus over-the-counter markets. *Journal of Economic Theory*, *149*, 153-182.

Acharya, V. V., Hasan, I., and Saunders, A. (2006). Should Banks Be Diversified? Evidence from Individual Bank Loan Portfolios. *Journal of Business*, *79*(3), 1355–1412.

Banker, R. D., Charnes, A., and Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, *30*(9), 1078–1092.

Beccalli, E., Anolli, M., and Borello, G. (2015). Are European banks too big? Evidence on economies of scale. *Journal of Banking & Finance, 58*, 232-246. doi: http://dx.doi.org/10.1016/j.jbankfin.2015.04.014.

Beijnen, C., and Bolt, W. (2009). Size matters: Economies of scale in European payments processing. *Journal of Banking & Finance, 33*(2), 203-210.

Berger, A. N., Hasan, I., Zhou, M. (2010). The Effects of Focus Versus Diversification on Bank Performance: Evidence from Chinese Banks. *Journal of Banking & Finance*, 34(7), 1417–1435.

Berger, A. N., and Mester, L. J. (2003). Explaining the Dramatic Changes in Performance of US Banks: Technological Change, Deregulation, and Dynamic Changes in Competition. *Journal of Financial Intermediation*, *12*(1), 57–95.

Bernanke, B. S. (1990). Clearing and Settlement during the Crash. *Review of Financial Studies, 3*(1), 133–151.

Berndt, E. (1991). *The Practice of Econometrics: Classic and Contemporary*. Cambridge, MA: Massachusetts Institute of Technology and the National Bureau of Economic Research; Reading, MA: Addison-Wesley Publishing Company, Inc.

Boot, A. W. A. (2014). Financial Sector in Flux. *Journal of Money, Credit and Banking, 46*(1), 129–135.

Boot, A. W. A. (2016). Understanding the Future of Banking: Scale & Scope Economies, and Fintech, in *The Future of Large Internationally Active Banks* (A. Demirgüç-Kunt, D.D. Evanoff, and G. Kaufmann, eds.). World Scientific Studies in International Economics, 55, pp. 429–448.

Carlin, W., and Mayer, C. (2003). Finance, investment, and growth. *Journal of Financial Economics, 69*(1), 191-226.

Cecchetti, S. G., and Kharroubi, E. (2012). Reassessing the Impact of Finance on Growth.

BIS Working Papers.

Charles, A., Darné, O., Kim, J. H., and Redor, E. (2016). Stock Exchange Mergers and Market Efficiency. *Applied Economics, 48*(7), 576–589. doi: 10.1080/00036846.2015.1083090.

Charnes, A., Cooper, W. W., and Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, *2*(6), 429–444.

Cherbonnier, F., and Rochet, J.-C. (2010). *Vertical Integration and Regulation in the Securities Settlement Industry*. TSE Working Paper.

Choi, S., Francis, B. B., and Hasan, I. (2010). Cross-Border Bank M&As and Risk: Evidence from the Bond Market. *Journal of Money, Credit and Banking*, *42*, 615–645.

Cooper, W. W., Seiford, L. M., and Zhu, J. (2004). *Data Envelopment Analysis*. Boston: Kluwer Academic.

Committee on Payment and Settlement Systems, Board of the International Organization of Securities Commissions. (2012). *Principles For Financial Market Infrastructure*. Bank for International Settlements, April 2012. http://www.bis.org/cpmi/publ/d101a.pdf

Cummins, J. D., Weiss, M. A., Xie, X., and Zi, H. (2010). Economies of Scope in Financial Services: A DEA Efficiency Analysis of the US Insurance Industry. *Journal of Banking & Finance*, *34*(7), 1525–1539.

Davies, R., and Tracey, B. (2014). Too Big to Be Efficient? The Impact of Implicit Subsidies on Estimates of Scale Economies for Banks. *Journal of Money, Credit and Banking, 46*(s1), 219–253. doi: 10.1111/jmcb.12088

De Carvalho, C. (2004). *Cross-Border Securities Clearing and Settlement Infrastructure in the European Union as a Prerequisite to Financial Markets Integration: Challenges and Perspectives*. HWWA Discussion Paper no. 287.

Dicle, M. F., and Levendis, J. (2013). The Impact of Technological Improvements on Developing Financial Markets: The Case of the Johannesburg Stock Exchange. *Review of Development Finance, 3*(4), 204–213. doi: http://dx.doi.org/10.1016/j.rdf.2013.09.001

Droll, T., Podlich, N., and Wedow, M. (2016). Out of Sight, Out of Mind? On the Risk of Sub-Custodian Structures. *Journal of Banking & Finance*, *68*, 47–56.

Duprey, T., and Klaus, B. (2017). *How to Predict Financial Stress? An Assessment of Markov Switching Models*. ECB Working Paper No. 2057.

Duprey, T., Klaus, B., and Peltonen, T. (2015). *Dating Systemic Financial Stress Episodes in the EU Countries*. ECB Working Paper No. 1873.

European Commission. (2015). *Action Plan on Building a Capital Markets Union*, COM(2015) 468 final. http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0468&from=EN

Fang, Y., Hasan, I., and Marton, K. (2011). Bank Efficiency in South-Eastern Europe. *Economics of Transition*, *19*, 495–520. doi:10.1111/j.1468-0351.2011.00420.x

Ferrarini, G., and Saguato, P. (2015). Regulating Financial Market Infrastructures. In E. Ferran, N. Moloney, & J. Payne (eds.), *The Oxford Handbook of Financial Regulation*, pp. 568–595. Oxford: Oxford University Press.

Francis, B. B., Hasan, I., and Sun, X. (2008). Financial Market Integration and the Value of Global Diversification: Evidence for US Acquirers in Cross-Border Mergers and Acquisitions. *Journal of Banking & Finance*, *32*(8), 1522–1540.

Fu, X. M., Lin, Y. R., and Molyneux, P. (2014). Bank Competition and Financial Stability in Asia Pacific. *Journal of Banking & Finance, 38*, 64–77.

Gehrig, T., and Stenbacka, R. (2007). Information Sharing and Lending Market Competition with Switching Costs and Poaching. *European Economic Review, 51*(1), 77–99.

Giddy, I., Saunders, A., and Walter, I. (1996). Alternative Models for Clearance and Settlement: The Case of the Single European Capital Market. *Journal of Money, Credit and Banking*, *28*(4), 986–1000.

Giovannini Group. (2002). *Cross-Border Clearing and Settlement Arrangements in the European Union*. Brussels: Directorate-General for Economic and Financial Affairs, European Commission.

Giovannini Group. (2003). *Second Report on EU Clearing and Settlement Arrangements*. Brussels: Directorate-General for Economic and Financial Affairs, European Commission.

Hasan, I., and Malkamäki, M. (2001). Are Expansions Cost Effective for Stock Exchanges? A Global Perspective. *Journal of Banking & Finance, 25*(12), 2339–2366.

Hasan, I., Malkamäki, M., and Schmiedel, H. (2003). Technology, Automation, and Productivity of Stock Exchanges: International Evidence. *Journal of Banking & Finance, 27*(9), 1743–1773.

Hasan, I., and Schmiedel, H. (2004). Networks and Equity Market Integration: European

Evidence. *International Review of Financial Analysis, 13*(5), 601–619.

Hasan, I., Schmiedel, H., and Song, L. (2012a). Growth Strategies and Value Creation: What Works Best for Stock Exchanges? *Financial Review, 47*(3), 469–499.

Hasan, I., Schmiedel, H., and Song, L. (2012b). How Stock Exchange Mergers and Acquisitions Affect Competitors' Shareholder Value: Global Evidence. In G. Poitras (ed.), *Handbook of Research on Stock Market Globalization*, vol. 1, pp. 181–194. Cheltenham, UK: Edward Elgar Publishing.

Heath, A., Kelly, G., Manning, M., Markose, S., and Shaghaghi, A. R. (2016). CCPs and network stability in OTC derivatives markets. *Journal of Financial Stability, 27*, 217-233.

Holthausen, C., and Tapking, J. (2007). Raising Rival's Costs in the Securities Settlement Industry. *Journal of Financial Intermediation, 16*(1), 91–116.

Hou, X., Wang, Q., and Li, C. (2015). Role of Off-Balance Sheet Operations on Bank Scale Economies: Evidence from China's Banking Sector. *Emerging Markets Review, 22*, 140–153. doi: http://dx.doi.org/10.1016/j.ememar.2014.10.001

Hughes, J. P., and Mester, L. J. (1993). A Quality and Risk-Adjusted Cost Function for Banks: Evidence on the "Too-Big-to-Fail" Doctrine. [journal article]. *Journal of Productivity Analysis, 4*(3), 293–315. doi: 10.1007/bf01073414

Hughes, J. P., and Mester, L. J. (2013). Who Said Large Banks Don't Experience Scale Economies? Evidence from a Risk-Return-Driven Cost Function. *Journal of Financial Intermediation*, *22*(4), 559–585.

International Monetary Fund. (2009). Global Financial Stability Report, October 2009: Navigating the Financial Challenges Ahead. 250.

Juranek, S., and Walz, U. (2010). Vertical Integration, Competition, and Financial Exchanges: Is There Grain in the Silo? CFS Working Paper.

Köppl, T. V., and Monnet, C. (2007). Guess What: It's the Settlements! Vertical Integration as a Barrier to Efficient Exchange Consolidation. *Journal of Banking & Finance, 31*(10), 3013–3033.

Kauko, K. (2007). Interlinking Securities Settlement Systems: A Strategic Commitment? *Journal of Banking & Finance, 31*(10), 2962–2977.

Knieps, G. (2006). Competition in the Post-Trade Markets: A Network Economic Analysis of the Securities Business. *Journal of Industry, Competition and Trade, 6*(1), 45–60.

Koetter, M., Kolari, J. W., and Spierdijk, L. (2012). Enjoying the Quiet Life under

Deregulation? Evidence from Adjusted Lerner Indices for US Banks. *Review of Economics and Statistics, 94*(2), 462–480.

Laeven, L. (2003). Does financial liberalization reduce financing constraints? *Financial Management*, 5-34.

Lannoo, K., and Levin, M. (2002). *The Securities Settlement Industry in the EU: Structure, Costs and the Way Forward*. CEPS Reports in Finance and Banking No. 26. CEPS.

Levine, R., Loayza, N., and Beck, T. (2000). Financial intermediation and growth: causality and causes. *Journal of Monetary Economics, 46*, 31-77.

Li, S., and Marinč, M. (2016a). *Mandatory Clearing of Derivatives and Systemic Risk of Bank Holding Companies*. Available at SSRN: https://ssrn.com/abstract=2734134.

Li, S., and Marinč, M. (2016b). Competition in the Clearing and Settlement Industry. *Journal of International Financial Markets, Institutions and Money, 40*, 134–162.

Lee, R. (2010). *The Governance of Financial Market Infrastructure*. Indianapolis, IN: Oxford Finance Group.

Lepetit, L., Nys, E., Rous, P., and Tarazi, A, (2008). Bank Income Structure and Risk: An Empirical Analysis of European Banks. *Journal of Banking & Finance*, *32*(8), 1452–1467.

Lozano-Vivas, A., Pastor, J. T., and Hasan, I. (2001). European Bank Performance Beyond Country Borders: What Really Matters? *European Finance Review*, *5*(1–2), 141–165.

Malkamäki, M. (1999). *Are there economies of scale in stock exchange activities?* Bank of Finland Discussion Papers, 21/99.

Marinč, M. (2013). Banks and Information Technology: Marketability vs. Relationships. *Electronic Commerce Research, 13*(1), 71–101.

Meslier, C., Morgan, D. P., Samolyk, K., and Tarazi, A. (2016). The Benefits and Costs of Geographic Diversification in Banking. *Journal of International Money and Finance*, *69*, 287–317.

Meslier, C., Tacneng, R., and Tarazi, A. (2014). Is Bank Income Diversification Beneficial? Evidence from an Emerging Economy. *Journal of International Financial Markets, Institutions and Money*, *31*, 97–126.

Milne, A. (2007). Competition and the Rationalization of European Securities Clearing and Settlement. In D. Mayes & G. E. Wood (eds.), *The Structure of Financial Regulation*, pp. 370–409. London: Routledge.

Milne, A. (2016). Central Securities Depositories and Securities Clearing and Settlement:

Business Practice and Public Policy Concerns. In M. Diehl, B. Alexandrova-Kabadjova, R. Heuver & S. Martínez-Jaramillo (eds.), *Analyzing the Economics of Financial Market Infrastructures*, pp. 334–358. Hershey, PA: IGI Global.

Nielsson, U. (2009). Stock Exchange Merger and Liquidity: The Case of Euronext. *Journal of Financial Markets, 12*(2), 229–267.

Pirrong, C. (2007). *The Industrial Organization of Execution, Clearing and Settlement in Financial Markets*. CFS Working Paper no. 2008/43.

Pownall, G., Vulcheva, M., and Wang, X. (2014). The Ability of Global Stock Exchange Mechanisms to Mitigate Home Bias: Evidence from Euronext. *Management Science, 60*(7), 1655–1676.

Ray, A., and Jaswal, A. (2015). *Challenging Times for the Post-Trade Industry: Improving Efficiency and Achieving Stability amidst Growing Complexity.* New York: Oliver Wyman.

Rochet, J.-C. (2006). *The Welfare Effects of Vertical Integration in the Securities Clearing and Settlement Industry*. IDEI, Toulouse University, mimeo.

Roe, M. J. (2013). Clearinghouse Overconfidence. *California Law Review, 101*(6), 1641–1703.

Schaper, T. (2008). Trends in European Cross-Border Securities Settlement–TARGET2-Securities and the Code of Conduct. In D. Veit, D. Kundisch, T. Weitzel, & F. Rajola (eds.), *Enterprise Applications and Services in the Finance Industry*, vol. 4, pp. 50–65. Berlin: Springer.

Schaper, T., and Chlistalla, M. (2010). The Impact of Information Technology on European Post-Trading. In M. L. Nelson, M. Shaw, & T. J. Strader (eds.), *Sustainable e-Business Management*, pp. 48–62. Berlin: Springer.

Schmiedel, H. (2001). Technological development and concentration of stock exchanges in Europe. *Bank of Finland Discussion Paper Series, 21/2001*.

Schmiedel, H. (2002). Total factor productivity growth in European stock exchanges: A non-parametric frontier approach. *Bank of Finland Discussion Paper Series, 11 /2002*.

Schmiedel, H., Malkamäki, M., and Tarkka, J. (2006). Economies of Scale and Technological Development in Securities Depository and Settlement Systems. *Journal of Banking & Finance, 30*(6), 1783–1806.

Schmiedel, H., and Schönenberger, A. (2005). *Integration of Securities Market*

Infrastructures in the Euro Area. European Central Bank Working Paper Series No. 33. Frankfurt: European Central Bank.

Serifsoy, B. (2007). Stock Exchange Business Models and Their Operative Performance. *Journal of Banking & Finance, 31*(10), 2978–3012.

Serifsoy, B., and Weiß, M. (2007). Settling for Efficiency—A Framework for the European Securities Transaction Industry. *Journal of Banking & Finance, 31*(10), 3034–3057.

Tapking, J., and Yang, J. (2006). Horizontal and Vertical Integration and Securities Trading and Settlement. *Journal of Money, Credit and Banking, 38*(7), 1–16.

Van Cayseele, P. (2004). *Competition and the Organisation of the Clearing and Settlement Industry*. CES, KU Leuven Discussion Paper.

Van Cayseele, P., and Wuyts, C. (2007). Cost Efficiency in the European Securities Settlement and Depository Industry. *Journal of Banking & Finance, 31*(10), 3058–3079.

Wendt, F. (2006). *Intraday Margining of Central Counterparties: EU Practice and a Theoretical Evaluation of Benefits and Costs*. De Nederlandsche Bank Working Paper.

Appendix A: Estimation of the Translog Cost Function

We now perform an analysis based on the simple loglinear models by using the number and value of transactions as proxies for output. The output variables (NT_{it}, denoted as Q_{it}^{1}, and VT_{it}, denoted as Q_{it}^{2}) as well as the proxy variables for technological development (t and ICT_{it}, denoted as P_{it}^{2}) are individually and jointly regressed on total operating cost variable (TC_{it}) (see Table A1). The model was estimated in loglinear form and the t-statistics are reported in parenthesis.

<Insert Table A1 here>

The results in Table A1 show that the output variables NT_{it} (Q_{it}^{1}) and VT_{it} (Q_{it}^{2}) are significantly and positively related to the operating cost. This result confirms that the variables NT_{it} and VT_{it} can serve as proxies for output. Hence, the variables NT_{it} and VT_{it} are selected for future analysis.

We now estimate the translog model using alternative input, output, and other specifications as shown in (1), following the studies by Hasan and Malkamäki (2001) and Schmiedel et al. (2006). In Panel A of Table A2, we present the results of the translog estimation, including single input $GDPPC_{it}$ (P_{it}^{1}), single output NT_{it} (Q_{it}^{1}), year dummy variables, and time trend variable t. In Panel B of Table A2, we present the results of the translog estimation, including multiple inputs ($GDPPC_{it}$ (P_{it}^{1}) and ICT_{it} (P_{it}^{2})), multiple outputs (NT_{it} (Q_{it}^{1}) and VT_{it} (Q_{it}^{2})), year dummy variables, and time trend variable t.

The translog specifications are performed using different estimations. In columns (1)–(3), we control the fixed effects of the FMI and cluster the standard errors at each institution; similarly to Fu et al. (2014) and Koetter et al. (2012), and in columns (4)–(6) we employ the stochastic frontiers analysis (*SFA*). We use column (6) in panel A and B of Table A2 for our main estimation of economies of scale. Note that the estimates of cost scale elasticities do not change substantially under different estimations; see the last line in Table A2.

The translog specifications in Table A2 have significant second-order terms confirming that the use of translog form is appropriate. With technological development, the sign of the coefficients of time trend variable t or year dummy variables should be negative, indicating that the cost function is shifting downward over time. Based on this observation, stochastic frontiers analysis (*SFA*) might be a preferred estimation method because the coefficients of year dummy variables are negative and the significance level of the second-order terms is higher compared to other model specifications.

<Insert Table A2 here>

For a robustness check, we also perform an analysis on the subsample for which the institutions report the direct personnel cost in their financial statements; see Table A3. In Panel A of Table A3, we report the results of the subsamples by using GDP *per capita* ($GDPPC_{it}$ (P^1_{it})) as a measure of labor cost and number of transactions (NT_{it} (Q^1_{it})) as output, and, in Panel B of Table A3, we report the results of the subsample by using the personnel cost ($STAFF_{it}$ (P^3_{it})) as a measure of labor cost and the number of transactions (NT_{it} (Q^1_{it})) as output. We notice that the results of the subsample yield similar results by using GDP *per capita* (P^1_{it}) and personnel expense (P^3_{it}) as a different measure of labor cost; this provides empirical support that GDP *per capita* ($GDPPC_{it}$) is a reliable measure of labor cost for the total sample.

<Insert Table A3 here>

Appendix B: Analysis Based on Two-inputs and Four-outputs Model

Now we expand our previous analysis and allow for four outputs to distinguish among different businesses that stock exchanges, clearing houses, and CDSs perform.

We first use variables *Number of transactions* (*NT_{it}*, denoted as Q_{it}^{1}) and *Value of transactions* (*VT_{it}*, denoted as Q_{it}^{2}) as two measures of the similar operations of FMIs. Considering the different content and value of the services provided by stock exchanges, CSDs, and clearing houses, we introduce the third output variable *Number of listed companies / Number of issuers (*$NLCS_{it}$, denoted as Q_{it}^{3}) that equals to the number of listed companies for stock exchanges and the number of issuers for CSDs and clearing houses. For stock exchanges, the number of listed companies is used as a proxy for the stock exchange's effort to monitor how company-specific information is released and whether companies observe the regulations set by the marketplace. For CSDs and clearing houses, the number of issuers is used as proxy for number of issuers using the CSD notary service. The fourth output variable *Market capitalization / Securities held on accounts* (*$MCSA_{it}$*, denoted as Q_{it}^{4}) indicates the market capitalization of the stock exchanges and the value of securities held on accounts for CSDs and clearing houses. For stock exchanges, the variable market capitalization is defined as the total number of issued shares of companies multiplied by their respective prices at a given time. For CSDs and clearing houses, the securities held on accounts is defined as *the* Value of securities held on accounts.[15,16,17]

The definition of input variables is the same as before: variable GDP *per capita* (*$GDPPC_{it}$*, denoted as P_{it}^{1}) measures the labor cost for different countries at different years, and the ratio of the country-specific share of information and communication technology expenditure to

[15] For the selection of outputs variables, see also Malkamäki (1999), Hasan and Malkamäki (2001), Schmiedel (2001, 2002), Schmiedel et al. (2006), and Serifsoy (2007).

[16] The detail information for the variables of stock exchanges can be found on the webpage of World Federation of Exchange (WFE). See https://www.world-exchanges.org/home/index.php/statistics/statistics-definitions.

[17] The detail information for the variables of CSDs and clearing houses can be found on the webpage of European Central Securities Depositories Association (ECSDA). See http://ecsda.eu/wp-content/uploads/ECSDA_DB_Methodology.pdf.

GDP (ICT_{it}, denoted as P_{it}^{2}) measures the technology investments. The information of number of issuers and securities held on accounts for CSDs and clearing houses is only available from 2010 onwards. Therefore, we focus on the period between 2010 and 2015.[18]

<Insert Table B1 & Table B2 here>

Table B1 indicates that, based on the two-inputs and four-outputs model, economies of scale are higher for large institutions than for smaller ones and if FMI providers are vertically or horizontally integrated. FMI providers that offer services for a broad range of asset classes have higher economies of scale compared to the FMI providers that offer services for a narrow range of asset classes. Economies of scale are the highest for clearing houses, lower for CSDs, and the lowest for stock exchanges.

Table B2 indicates that larger institutions have lower cost, revenue, scale, and allocative efficiency, but higher profit efficiency. Horizontal integration is associated with lower cost, allocative, and profit efficiency, but higher revenue and scale efficiency whereas vertical integration is associated with higher revenue and scale efficiency. FMI providers that focus on a broad range of asset classes operate less efficiently than FMI providers that focus on a narrow range of asset classes. Clearing houses on average have higher scale efficiency and profit efficiency, while stock exchanges on average have higher technical efficiency.

In sum, the results from two-inputs and four-outputs model are consistent with our conclusion based on the two-inputs and two-outputs model.

[18] For some outputs variables which equals to zero (because certain FMI providers do not engage in all businesses) or missing, we follow the study of Beijnen and Bolt (2009) and set the missing outputs to a small value (0.0001).

Tables and Figures

Table 1: Variable Definitions and Data Sources

This table reports definitions and data sources of the variables in our analysis.

Variables	Definitions and Measurement Units	Data Sources
TR	Total operating income in US$ '000	Annual Reports 2000–2015; Bankscope (2016)
TC	Total operating cost in US$ '000	Annual Reports 2000–2015; Bankscope (2016)
TP	Total profit in US$ '000	Annual Reports 2000–2015; Bankscope (2016)
Input Variable		
GDPPC	Gross domestic product per capita in US$ '000	IMF IFS Yearbooks 2000–2015
ICT	Total information and communication technology expenditure to GDP	IMF IFS Yearbooks 2000–2015; OECD factbooks
STAFF	Price of labor, total personnel expenses divided by total assets	Annual Reports 2000–2015; Bankscope (2016)
Output Variables		
NT	Number of transactions in thousands	Annual Reports 2000–2015; World Federation of Exchanges; BIS Statistics on Payment and Settlement Systems
VT	Value of transactions in US$ '000	Annual Reports 2000–2015; World Federation of Exchanges; BIS Statistics on Payment and Settlement Systems
NLCS	The number of listed companies for stock exchanges and number of issuers for CSDs and clearing houses	Annual Reports 2010–2015; World Federation of Exchanges; BIS Statistics on Payment and Settlement Systems
MCSA	The market capitalization of the stock exchanges and the value of securities held on accounts for CSDs and clearing houses in US$ '000	Annual Reports 2010–2015; World Federation of Exchanges; BIS Statistics on Payment and Settlement Systems
Factor Variables		
Size	The logarithm of total assets representing a proxy for the size	Annual Reports 2000–2015; Bankscope (2016)
Vertically integrated	A binary variable that equals 1 since the year that the institution *i* (a stock exchange, CSD, or clearing house) was vertically integrated with different types of institutions (e.g., a merger between a stock exchange and a CSD, a merger between a stock exchange and a clearing house, or a merger between a CSD and a clearing house) or if a clearing house or a CSD is owned by a stock exchange or if a clearing house is owned by a CSD; and 0 otherwise	Zephyr (2016); Annual Reports 2000–2015
Horizontally integrated	A binary variable that equals 1 since the year that a merger was announced between the same type of institution (a merger between stock exchanges, CSDs, or clearing houses), and 0 otherwise	Zephyr (2016)
Dummy CSD	A binary variable that equals 1 if the institution is a CSD, and 0 otherwise	BIS Statistics on Payment and Settlement Systems
Dummy clearing house	A binary variable that equals 1 if the institution is a clearing house, and 0 otherwise	BIS Statistics on Payment and Settlement Systems
Dummy stock exchange	A binary variable that equals 1 if the institution is a stock exchange, and 0 otherwise	BIS Statistics on Payment and Settlement Systems
Dummy Europe	A binary variable that equals 1 if the institution is from Europe, and 0 otherwise	
Dummy North America	A binary variable that equals 1 if the institution is from the US or Canada, and 0 otherwise	
Dummy Asia-Pacific	A binary variable that equals 1 if the institution is from the Asia-Pacific region, and 0 otherwise	
Broad range of asset classes	A binary variable that equals 1 if the institution also provides services for a broad range of financial instruments such as derivatives and commodities, and equals 0 if the institution only provides services that focus on bonds and equities securities.	Annual Reports 2000–2015
t	Linear time trend variable	
Year	Dummy variables for the years between 2000 and 2015	
Control Variables		
GDP growth	Annual growth rate of GDP at market prices based on constant local currency	World Bank Database
Inflation	Inflation rate	World Bank Database
Interest rate	The interest rate charged by banks on loans to prime customers	World Bank Database
Stocks traded ratio	The value of stocks traded in the security market divided by GDP	World Bank Database
EOA	Equity to total assets ratio	Annual Reports 2000–2015
Systemic Risk Variables		
NPL	is defined as the bank nonperforming loans to total gross loans in a financial system	World Bank Database

Table 1: Variable Definitions and Data Sources

This table reports definitions and data sources of the variables in our analysis.

Variables	Definitions and Measurement Units	Data Sources
Stock Market Index Volatility	The volatility of the stock market index return for each country at each year and calculated based on the monthly return of the stock market index	World Bank Database
CLIFS	The country-level index of financial stress	European Central Bank
Stock Market Efficiency Variables		
Stock Market Capitalization Ratio	The market capitalization of listed domestic companies to GDP ratio	World Bank Database
Banking System Asset to GDP Ratio	The banking system asset to GDP ratio.	World Bank Database

Table 2: Data Statistics for Total Sample and Subsamples

This table reports summary statistics of the variables for the full sample, and different subsamples according to type, specialization, and horizontal and vertical integration of FMI. Our sample period is 2000–2015. All data are inflation-adjusted.

	Total Sample			Different Types			Specialization		Horizontally Integrated		Vertically Integrated	
				Stock Exchanges	Clearing Houses	CSDs	Broad Range of Asset Classes = 1	Broad Range of Asset Classes = 0	Horizontally Integrated = 1	Horizontally Integrated = 0	Vertically Integrated = 1	Vertically Integrated = 0
Variable	Mean (Standard Deviation)	Min	Max	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)	Mean (Standard Deviation)
TC (US$ million)	256.85	0.05	6481	364.82	113.74	268.31	343.54	78.11	1397.57	154.38	449.15	200.87
	(590.85)			(864)	(131.10)	(375.20)	(698)	(129.86)	(1312.3)	(317.59)	(754.42)	(521.67)
TR (US$ million)	348.90	0.1	6861	525.74	198.58	330.08	471.9	95.24	1858.8	213.27	602.96	274.93
	(735)			(1072.50)	(191.50)	(432)	(863.8)	(146.1)	(1540.4)	(394.76)	(1016.46)	(611.73)
GDPPC (US$ ’000)	32.21	0.46	116.6	21.55	35.60	42.48	32.5	31.56	42.65	31.33	39.96	29.92
	(23.01)			(15.80)	(17.10)	(29.86)	(25.7)	(23.7)	(10.1)	(23.57)	(23.93)	(22.25)
ICT (%)	1.66	0.08	3.47	1.33	1.97	1.71	1.73	1.51	2.2	1.60	2.03	1.54
	(0.80)			(0.88)	(0.64)	(0.76)	(0.81)	(0.78)	(0.52)	(0.81)	(0.84)	(0.76)
Personnel expense (US$ million)	78.81	0.07	949	85.84	44.27	107.45	102	32	293.9	58.60	100.53	72.38
	(140)			(166)	(51.02)	(156.80)	(161.3)	(59.20)	(282.5)	(96.56)	(154.41)	(134.99)
NT (million)	1305.89	0.02	23254	803.57	2128.74	1079.54	1005.5	1925.22	1107.5	1323.71	2278.12	1022.81
	(3125)			(1353)	(4259)	(3203)	(2535.1)	(4018)	(1133.6)	(3244.75)	(4553.49)	(2500.56)
VT (US$ billion)	66620	0.08	23252000	4477	403300	63980	37840	139200	25230	72410	205100	15790
	(233900)			(30060)	(552700)	(110600)	(90800)	(407000)	(69660)	(247900)	(415400)	(47520)
EOA (%)	31.51	0.05	99.4	52.58	7.93	27.37	32.39	29.61	36.37	31.08	24.69	33.60
	(31.66)			(29.24)	(21.20)	(29.10)	(31.85)	(31.24)	(25.8)	(32.12)	(32.00)	(31.30)
Total assets (US$ billion)	1104	0	679900	65.33	3367	6.56	1640	3.53	184.4	1184	130.15	1418
	(26850)			(616.80)	(47480)	(8.70)	(32750)	(6.83)	(981)	(27990)	(89.10)	(30530)
Size	13.81	4.4	27.25	12.75	14.57	14.40	14.44	12.53	13.68	15.38	13.49	14.9
	(2.89)			(3)	(2.92)	(2.23)	(2.67)	(2.9)	(2.8)	(3.47)	(2.88)	(2.68)
Vertically integrated	0.23	0	1	0.15	0.26	0.30	0.23	0.005	0.434	0.21	1	0
	(0.42)			(0.36)	(0.44)	(0.46)	(0.42)	(0.069)	(0.50)	(0.41)	(0)	(0)
Horizontally integrated	0.08	0	1	0.18	0	0.04	0.11	0.03	1	0	0.159	0.06
	(0.28)			(0.39)	(0)	(0.19)	(0.31)	(0.17)	(0)	(0)	(0.37)	(0.24)
GDP growth (%)	2.35	−9.13	27.5	2.97	1.93	1.99	2.45	2.14	1.68	2.41	1.92	2.48
	(3.30)			(3.73)	(2.82)	(3.10)	(3.43)	(3.01)	(2.95)	(3.32)	(2.97)	(3.38)
Inflation	3.40	−6	103.8	4.33	3.03	2.57	2.94	4.36	1.60	3.56	2.63	3.63
	(5.72)			(7.94)	(4.20)	(2.69)	(3.57)	(8.55)	(0.97)	(5.94)	(3.2)	(6.26)
Interest rate	2.92	−42.3	44.6	3.63	1.93	3.14	3.10	2.52	2.40	2.97	3.63	2.73
	(5.18)			(6.60)	(3.40)	(3.27)	(4.71)	(6.18)	(2.33)	(5.38)	(6.8)	(4.66)
Stock traded ratio (%)	80.58	0.02	952.7	77.83	106.71	55.03	92.19	55.90	116.8	77.28)	93.97	76.59
	(102.29)			(127.70)	(92.80)	(60.20)	(111.6)	(73.2)	(89.6)	(102.81)	(94.61)	(104.24)

Table 3: Average Key Performance Ratios

This table presents the mean of performance ratios for the total sample, and various subsamples according to institution size, horizontal and vertical integration, type, specialization, and geographical location. Our sample period is 2000–2015. All currency and price-related data are inflation-adjusted and expressed in US$. *TC* is operating cost in US$ '000; *TR* is operating income in US$ '000; *NT* is the number of transactions in thousands; *VT* is the value of transactions in US$ '000. ***TC/NT*** indicates cost per trade; ***TC/VT*** indicates cost per value of transactions; ***TR/NT*** indicates operating income per trade; ***TR/VT*** indicates operating income per value of transactions; ***VT/NT*** indicates value per transactions. Significance of group mean differences: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Sample	*N*	*TC/NT*	*TC/VT*	*TR/NT*	*TR/VT*	*VT/NT (US$ million)*
All	403	158.20	0.002263	272.96	0.002281	146.59
Institution Size						
Quantile 4 (Largest)	99	917.16	0.000263	1584.49	0.000342	604.59
Quantile 3	98	47.83	0.000688	148.14	0.000986	0.96
Quantile 2	98	1.61	0.001040	3.63	0.002456	0.39
Quantile 1 (Smallest)	98	12.58	0.005514	14.51	0.005680	0.04
Top 50%	196	308.40	0.000402	543.21	0.000572	333.57
Bottom 50%	197	10.81	0.003164	13.38	0.003766	0.34
Group Mean Difference		**297.59*****	**−0.00276*****	**529.83*****	**−0.00319*****	**333.23*****
Type of Integration						
Horizontally integrated	57	45.51	0.003171	39.90	0.000722	3.50
Non-horizontally integrated	346	170.02	0.002113	297.41	0.002539	170.30
Group Mean Difference		**−124.51*****	**0.001058**	**−257.51*****	**−0.00182*****	**−166.8*****
Vertically integrated	105	498.75	0.000262	740.39	0.000333	553.67
Non-vertically integrated	298	61.00	0.002973	139.54	0.002972	2.19
Group Mean Difference		**437.75*****	**−0.00271*****	**600.85*****	**−0.00264*****	**551.48*****
Specialization						
Broad range of asset classes	292	225.11	0.001426	391.36	0.001534	201.24
Narrow range of asset classes	111	17.06	0.004451	23.18	0.004233	3.81
Group Mean Difference		**208.05*****	**−0.003025*****	**368.18*****	**−0.0027*****	**197.43*****
Regions						
Europe	219	200.51	0.002046	284.17	0.002732	7.89
North America	47	1.56	0.000066	1.71	0.000076	267.16
Asia-Pacific	109	122.13	0.001423	430.04	0.002653	1.56
South America & Africa	28	1.66	0.005544	2.33	0.006369	0.050
Type of FMI						
CSDs	**100**	**423.77**	**0.000700**	**616.38**	**0.000773**	**580.08**
Group Mean Difference between Different Subsamples						
Top 50% − Bottom 50%		781.4***	−0.00052	1164.1***	−0.000051	1347.2***
Broad range of asset classes − Narrow range of asset classes		629.42***	0.00081**	934.17***	0.0009**	772.68***
Horizontally integrated − Non-horizontally integrated		−221.92	−0.0007**	−341.17	−0.00078**	−491.01**
Vertically integrated − Non-vertically integrated		1159.93***	−0.00098**	1762.6***	−0.00105**	1515.9***
Stock Exchanges	**257**	**63.16**	**0.003281**	**202.95**	**0.003283**	**0.51**
Group Mean Difference between Different Subsamples						
Top 50% − Bottom 50%		118.2***	−0.00399***	416.34***	−0.00453***	1.08***
Broad range of asset classes − Narrow range of asset classes		77.1***	−0.00672***	255.03***	−0.00616***	0.65***
Horizontally integrated − Non-horizontally integrated		−48.86*	0.000004	−246.34***	−0.00323***	−0.61***
Vertically integrated − Non-vertically integrated		−71.98***	−0.0031***	−234.24***	−0.00289***	−0.57***
Clearing Houses	**46**	**38.71**	**0.000009**	**50.84**	**0.000012**	**14.00**
Group Mean Difference between Different Subsamples						
Top 50% − Bottom 50%		76.79**	0.000009	90.66**	0.00	11.59***
Broad range of asset classes − Narrow range of asset classes		60.7**	0.00002	69.06**	0.000019	−1.46
Vertically integrated − Non-vertically integrated		50.34	0.000002	61.51	0.00	−4.11

Table 4: Cost Scale Elasticities Based on Single-Input and Single-Output Model and Multiple-Inputs and Multiple-Outputs Model According to Size, Type, Integration, Specialization, and Geographical Location

This table presents the mean of cost scale elasticities for the total sample, and various subsamples according to institution size, horizontal and vertical integration, type, specialization, and geographical location. Our sample period is 2000–2015. We report the cost scale elasticities with respect to the number of transactions (based on a single-input, single-output model as presented in the equation in (5)) in Panel A, and the cost scale elasticities with respect to the number of transactions and the value of transactions (based on a multiple-inputs, multiple-outputs model as presented in the equation in (4)) in Panel B. Significance of group mean differences: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

	Panel A: Cost scale elasticities based on single-input and single-output model including time trend variable *t*	**Panel B: Cost scale elasticities based on multiple-inputs and multiple-outputs model including time trend variable *t***		
Category	$\frac{\partial \ln TC}{\partial \ln Q_1}$	$\frac{\partial \ln TC}{\partial \ln Q_1}$	$\frac{\partial \ln TC}{\partial \ln Q_2}$	$\sum \frac{\partial \ln TC}{\partial \ln Q_i}$
Total Sample	0.0889	0.1550	0.0604	0.2154
Institution Size				
Quantile 4 (Largest)	0.0625	0.0879	0.0607	0.1486
Quantile 3	0.0788	0.1366	0.0539	0.1905
Quantile 2	0.1065	0.1436	0.0697	0.2133
Quantile 1 (Smallest)	0.1086	0.2506	0.1076	0.3582
Top 50%	0.0706	0.1121	0.0573	0.1694
Bottom 50%	0.1076	0.1974	0.0868	0.2608
Group Mean Difference (Top 50% − Bottom 50%)	**−0.037*****	**−0.0853*****	**−0.0285**	**−0.0914*****
Type of Integration				
Horizontally integrated	0.0655	0.0653	0.0600	0.1277
Non-horizontally integrated	0.0912	0.1709	0.0623	0.2310
Group Mean Difference	**−0.0257*****	**−0.1056*****	**−0.0023**	**−0.1033*****
Vertically integrated	0.0760	0.1318	0.0312	0.1630
Non-vertically integrated	0.0927	0.1652	0.0731	0.2384
Group Mean Difference	**−0.0167*****	**−0.0334****	**−0.0419*****	**−0.0754*****
Specialization				
Broad range of asset classes	0.0880	0.1519	0.0466	0.1985
Narrow range of asset classes	0.0910	0.1641	0.1004	0.2645
Group Mean Difference	**−0.003**	**−0.0122**	**−0.0538*****	**−0.066*****
Regions				
Europe	0.0817	0.1431	0.0674	0.2105
North America	0.0607	0.0692	0.0654	0.1347
Asia-Pacific	0.1139	0.2160	0.0562	0.2722
South America & Africa	0.1435	0.3495	0.0878	0.4373
Type of FMI				
CSDs	**0.0746**	**0.1600**	**0.0314**	**0.1913**
Group Mean Difference between Different Subsamples				
Top 50% − Bottom 50%	−0.0188***	−0.0608***	0.0087	−0.0521***
Broad range of asset classes − Narrow range of asset classes	−0.0086**	−0.1043***	−0.0108	−0.115***
Horizontally integrated − Non-horizontally integrated	−0.01	−0.0795	0.0761**	−0.0034
Vertically integrated − Non-vertically integrated	0.0014	0.0129	−0.0379***	−0.025
Stock Exchanges	**0.1039**	**0.1494**	**0.0890**	**0.2383**
Group Mean Difference between Different Subsamples				
Top 50% − Bottom 50%	−0.0222***	−0.0062	−0.0618***	−0.068***
Broad range of asset classes − Narrow range of asset classes	−0.0088	0.0845***	−0.1832***	−0.0988***
Horizontally integrated − Non-horizontally integrated	−0.0476***	−0.1134***	−0.0382	−0.1517***
Vertically integrated − Non-vertically integrated	−0.0192***	−0.0254	−0.0672**	−0.0925***
Clearing Houses	**0.0835**	**0.1690**	**0.0005**	**0.1695**
Group Mean Difference between Different Subsamples				
Top 50% − Bottom 50%	−0.0344***	−0.1443***	−0.1671***	−0.3114***
Broad range of asset classes − Narrow range of asset classes	−0.0059	−0.0932	−0.0909**	−0.1841***
Vertically integrated − Non-vertically integrated	−0.0206***	−0.2573***	−0.0602***	−0.3175***

Table 5: Summary Statistics of Efficiency Scores

This table presents the means of efficiency scores for the total sample, and various subsamples according to institution size, horizontal and vertical integration, type, specialization, and geographical location. Our sample period is 2000–2015. ***TE*** indicates technical efficiency, ***PTE*** indicates pure technical efficiency, ***CE*** indicates cost efficiency based on constant returns to scale technology, ***CEScope*** indicates *CE* purged of scale efficiency, ***VCE*** indicates cost efficiency based on variable returns to scale technology, ***RE*** indicates revenue efficiency based on constant returns to scale technology, ***REScope*** indicates *RE* purged of scale efficiency, ***VRE*** indicates revenue efficiency based on variable returns to scale technology, ***SE*** indicates input-oriented scale efficiency, ***AE*** indicates input-oriented allocative efficiency, ***PE*** indicates profit efficiency estimated based on Cooper et al. (2004, Eq. (8.1)), ***CRS*** indicates constant returns to scale, ***VRS*** indicates variable returns to scale, ***IRS*** indicates increasing returns to scale, ***DRS*** indicates decreasing returns to scale. Significance of group mean differences: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Panel A: Mean of Efficiency

	N	TE	PTE	CE	CEScope	VCE	RE	REScope	VRE	SE	AE	PE
All	319	0.1921	0.2568	0.0947	0.1318	0.1301	0.0571	0.0809	0.0756	0.8193	0.4562	0.0679
Institution Size												
Quantile 4 (Largest)	79	0.2058	0.3333	0.0860	0.1528	0.0998	0.1633	0.2174	0.2022	0.6263	0.4420	0.1634
Quantile 3	80	0.0917	0.1863	0.0422	0.0984	0.1022	0.0142	0.0392	0.0273	0.7613	0.4851	0.0143
Quantile 2	80	0.2584	0.2857	0.1160	0.1358	0.1488	0.0474	0.0634	0.0697	0.9287	0.4688	0.0645
Quantile 1 (Smallest)	80	0.2411	0.2464	0.1515	0.1542	0.1896	0.0055	0.0055	0.0056	0.9793	0.4391	0.0347
Top 50%	159	0.1484	0.2593	0.0640	0.1255	0.1010	0.0882	0.1277	0.1142	0.9538	0.4637	0.0884
Bottom 50%	160	0.2498	0.2662	0.1336	0.1450	0.1690	0.0266	0.0347	0.0379	0.6942	0.4541	0.0497
Group Mean Difference		**−0.1014***	**−0.0069**	**−0.0696***	**−0.0195**	**−0.068***	**0.0616***	**0.093***	**0.0763***	**0.2596***	**0.0096**	**0.0387***
Type of Integration												
Horizontally integrated	52	0.0537	0.1613	0.0282	0.1066	0.0337	0.0050	0.0120	0.0145	0.5273	0.5396	0.0050
Non-horizontally integrated	267	0.2177	0.2745	0.1070	0.1364	0.1479	0.0668	0.0937	0.0869	0.8733	0.4408	0.0795
Group Mean Difference		**−0.164***	**−0.1132***	**−0.0788***	**−0.0298**	**−0.1142***	**−0.0618**	**−0.0817**	**−0.0724**	**−0.346***	**0.0988**	**−0.0745**
Vertically integrated	95	0.2038	0.3749	0.0873	0.1823	0.1606	0.1411	0.2058	0.1771	0.6344	0.4747	0.1412
Non-vertically integrated	224	0.1875	0.2111	0.0976	0.1122	0.1183	0.0247	0.0326	0.0363	0.8908	0.4491	0.0395
Group Mean Difference		**0.0163**	**0.1638***	**−0.0103**	**0.0701***	**0.0423**	**0.1164***	**0.1732***	**0.1408***	**−0.2564***	**0.0256**	**0.1017***
Specialization												
Broad range of asset classes	238	0.1559	0.2081	0.0575	0.0851	0.0672	0.0466	0.0665	0.0617	0.7976	0.4402	0.0513
Narrow range of asset classes	81	0.2937	0.3938	0.1993	0.2628	0.3070	0.0868	0.1215	0.1146	0.8802	0.5012	0.1144
Group Mean Difference		**−0.1378***	**−0.1857***	**−0.1418***	**−0.1777***	**−0.2398***	**−0.0402***	**−0.055**	**−0.0529***	**−0.0826**	**−0.061**	**−0.0631**
Region												
Europe	208	0.1657	0.2078	0.0705	0.0910	0.084	0.0514	0.0727	0.0659	0.8647	0.4257	0.0517
North America	38	0.175	0.4225	0.1362	0.2944	0.2818	0.1308	0.1784	0.1603	0.4242	0.7341	0.1309
Asia-Pacific	64	0.3138	0.3458	0.1672	0.1884	0.2138	0.0365	0.0570	0.0651	0.911	0.4143	0.0952
South America & Africa	9	0.1204	0.1379	0.0299	0.0341	0.0337	0.0060	0.0069	0.0060	0.8794	0.2467	0.0066
Type of FMI												
Stock Exchanges	**185**	**0.0640**	**0.1580**	**0.0592**	**0.1471**	**0.1666**	**0.0243**	**0.149**	**0.0923**	**0.3013**	**0.9320**	**0.0700**
Group Mean Difference between Different												
Top 50% − Bottom 50%		−0.0146	−0.057*	−0.0078	−0.0509	−0.0651***	0.0205***	0.1473***	−0.0742	0.136***	−0.0243	−0.0105
Broad range of asset classes − Narrow range of asset classes		−0.09***	−0.0465	−0.0722***	−0.0274	−0.0095	0.0163**	0.1135**	0.0871	−0.1697***	0.0203	0.0084**
Horizontally integrated − Non-horizontally integrated		−0.0096	−0.1053***	−0.004***	−0.0923***	−0.1062***	0.0386***	−0.0698	−0.0496	−0.2784***	−0.0607***	−0.0401
Vertically integrated − Non-vertically integrated		0.0143	0.052	0.0192	0.041	−0.0378	0.0496***	−0.0474	0.0297	0.4157***	0.0575***	0.0143
CSDs	**95**	**0.0452**	**0.1029**	**0.0413**	**0.0969**	**0.1291**	**0.0397**	**0.0784**	**0.0403**	**0.3549**	**0.9519**	**0.0398**
Group Mean Difference between Different												
Top 50% − Bottom 50%		0.0489***	0.007	−0.042***	0.0009	−0.017	0.0446***	0.0218*	0.0449***	0.2311***	−0.0309*	0.0447***
Broad range of asset classes − Narrow range of asset classes		−0.0571***	−0.0117	−0.0517***	−0.0091	0.0108	−0.051***	−0.0112	−0.0513***	−0.4257***	−0.0011	−0.0511***
Horizontally integrated − Non-horizontally integrated		0.0509	0.0183	0.0231	−0.016	−0.033	0.0565	0.0433	0.058	−0.4414*	−0.2848***	0.0565
Vertically integrated − Non-vertically integrated		0.0236*	0.0354***	0.0166	0.0255**	0.0342**	0.0315**	0.0495***	0.0316***	−0.106	0.0507***	0.0314***
Clearing Houses	**39**	**0.3488**	**0.4701**	**0.3418**	**0.4228**	**0.4672**	**0.1795**	**0.2917**	**0.2413**	**0.7422**	**0.9097**	**0.2980**
Group Mean Difference between Different												
Top 50% − Bottom 50%		0.3121***	−0.3502***	−0.3181***	−0.0902	−0.3205***	0.1436	0.5215***	0.2532**	0.6447***	−0.2574***	0.278
Broad range of asset classes − Narrow range of asset classes		−0.3192***	−0.4935***	−0.3169***	−0.4204***	−0.4723***	−0.1608**	−0.3426***	−0.2743***	−0.0378	0.011	−0.356***
Vertically integrated − Non-vertically integrated		0.4468***	0.1184	0.4558***	0.247***	0.1214	0.204***	−0.1142	0.0204	0.5849***	0.2098***	0.3816***

Panel B: Return to Scales

	N	CRS		IRS		DRS	
		N	%	*N*	%	*N*	%
Stock Exchanges	185	0	0	164	88.7	21	11.3
CSDs	95	2	2.1	54	56.8	39	41.1
Clearing Houses	39	3	7.7	24	61.5	12	30.8

Table 6: Factors Affecting Economies of Scale

This table presents the regressions of various factors on economies of scale. Our sample period is 2000–2015. The dependent variable $\frac{1}{ES1_{it}}$ indicates cost scale elasticities estimated by using the single-input (***GDPPC$_{it}$*** $(\boldsymbol{P^1_{it}})$), single-output (***Number of transactions*** $(\boldsymbol{Q^1_{it}})$) and time trend variable ***t*** as in column (6) of Panel A in Table A2; $\frac{1}{ES2_{it}}$ indicates cost scale elasticities estimated by using the multiple-inputs (***GDPPC$_{it}$*** $(\boldsymbol{P^1_{it}})$ and ***ICT$_{it}$*** $(\boldsymbol{P^2_{it}})$), multiple-outputs (***Number of transactions*** $(\boldsymbol{Q^1_{it}})$ and ***Value of transactions*** $(\boldsymbol{Q^2_{it}})$) and time trend variable ***t*** as in column (6) of Panel B in Table A2. In the regressions, we include: ***Size*** measured by the natural logarithm of financial market infrastructures assets, a dummy variable ***Vertically integrated*** that equals one since the year that the institution *i* (a stock exchange, CSD, or clearing house) was vertically integrated with an institution of a different type (e.g., a merger between a stock exchange and a CSD, a merger between a stock exchange and a clearing house, or a merger between a CSD and a clearing house) or if a clearing house or a CSD is owned by a stock exchange or if a clearing house is owned by a CSD, a dummy variable ***Horizontally integrated*** that equals one since the year that a merger was announced between the same type of institutions (a merger between stock exchanges, between CSDs, or between clearing houses), a dummy variable ***Broad range of asset classes*** that equals one if the institution provides services for a broad range of financial instruments (including derivatives and commodities) and equals zero if it provides services only for debt and equities securities, a dummy variable ***Dummy clearing house*** that equals one if the institution is a clearing house, a dummy variable ***Dummy CSD*** that equals one if the institution is a CSD, a dummy variable ***Dummy Europe*** that equals one if the institution is from Europe, a dummy variable ***Dummy North America*** that equals one if the institution is from the US or Canada, a dummy variable ***Dummy Asia-Pacific*** that equals one if the institution is from the Asia-Pacific region, the variable ***ICT*** defined as the % of total information and communication technology expenditure to GDP, ***GDP growth*** and ***Inflation*** as proxies for macroeconomics factors, ***Interest rate*** as a proxy for monetary policy, ***Stocks traded ratio*** (based on the value of stocks traded in as % of GDP) as a proxy for the security market size in a given country, and ***ln EOA*** as a proxy for the risk-taking of the institutions. All regressions are feasible generalized least square (FGLS) estimation and control for the yearly fixed effects. Heteroskedasticity-robust *t*-values are reported in parentheses. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

	$\frac{1}{ES1_{it}}$	$\frac{1}{ES2_{it}}$	$\frac{1}{ES1_{it}}$	$\frac{1}{ES2_{it}}$
Variables	(1)	(2)	(3)	(4)
Size	-0.00551***	-0.0134***	-0.00450***	-0.0105***
	(-15.88)	(-6.16)	(-13.03)	(-5.25)
Vertically integrated	0.00122	-0.0613***	-0.00372***	-0.0599***
	(0.78)	(-6.18)	(-2.67)	(-6.38)
Horizontally integrated	-0.0113***	-0.0125	-0.00563**	-0.00322
	(-3.85)	(-1.20)	(-2.29)	(-0.36)
Broad range of asset classes	-0.00512**	-0.0423***	-0.00948***	-0.0302***
	(-2.20)	(-4.45)	(-4.02)	(-3.03)
Dummy clearing house	-0.0187***	-0.0988***	-0.0107***	-0.0925***
	(-7.59)	(-4.17)	(-4.67)	(-4.12)
Dummy CSD	-0.00611**	-0.0240**	0.00378	-0.0176
	(-2.35)	(-2.13)	(1.53)	(-1.54)
Dummy Europe	0.0240***	0.0424***	0.0141***	0.0723***
	(8.41)	(3.43)	(3.32)	(7.28)
Dummy North America	0.00267	-0.0874***	0.00215	-0.0523***
	(0.85)	(-5.35)	(0.50)	(-4.05)
Dummy Asia-Pacific	0.0256***	0.0499***	0.0163***	0.0630***
	(9.23)	(3.48)	(3.39)	(6.36)
ln ICT			-0.0121***	-0.0341***
			(-6.38)	(-7.84)
GDP growth	0.00252***	0.000335	0.00153***	-0.000401
	(6.06)	(0.21)	(3.26)	(-0.35)
Inflation	0.00233***	0.00916***	0.00251***	0.00687***
	(11.96)	(8.10)	(9.82)	(6.35)
Interest rate	0.00188***	0.00584***	0.00151***	0.00512***
	(8.92)	(4.56)	(7.17)	(4.49)
Stocks traded ratio	0.0000274***	0.000104***	0.0000286***	0.0000825***
	(2.76)	(2.71)	(2.68)	(2.59)
ln EOA	0.0000626	0.0106**	0.000718	0.00877*
	(0.11)	(2.06)	(1.52)	(1.85)
Intercept	0.143***	0.359***	0.147***	0.289***
	(17.67)	(6.65)	(16.56)	(5.36)
Year Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**
N	486	182	383	182
Wald Chi-square	8274.1	2621.8	2839.3	9086.8

Table 7: Factors Affecting Efficiency

This table presents the regressions of various factors on efficiency. Our sample period is 2000–2015. The dependent variable ***TE*** indicates technical efficiency, ***PTE*** indicates pure technical efficiency, ***CE*** indicates cost efficiency based on constant returns to scale technology, ***CEScope*** indicates *CE* purged of scale efficiency, ***VCE*** indicates cost efficiency based on variable returns to scale technology, ***RE*** indicates revenue efficiency based on constant returns to scale technology, ***REScope*** indicates *RE* purged of scale efficiency, ***VRE*** indicates revenue efficiency based on variable returns to scale technology, ***SE*** indicates input-oriented scale efficiency, ***AE*** indicates input-oriented allocative efficiency, and ***PE*** indicates profit efficiency estimated based on Cooper et al. (2004, Eq. (8.1)). In the regressions, we include: ***Size*** measured by the natural logarithm of FMI assets, a dummy variable ***Vertically integrated*** that equals one since the year that the FMI provider *i* was vertically integrated with a FMI provider of a different type (e.g., a merger between a stock exchange and a CSD, a merger between a stock exchange and a clearing house, or a merger between a CSD and a clearing house) or if a clearing house or a CSD is owned by a stock exchange or if a clearing house is owned by a CSD, a dummy variable ***Horizontally integrated*** that equals one since the year of a merger between the same type of institutions (a merger between stock exchanges, CSDs, or clearing houses), a dummy variable ***Broad range of asset classes*** that equals one if the institution provides services for a broad range of financial instruments (including derivatives and commodities) and equals zero if it provides services only for debt and equities securities, a dummy variable ***Dummy clearing house*** that equals one if the institution is a clearing house, dummy variable ***Dummy CSD*** that equals one if the institution is a CSD, a dummy variable ***Dummy Europe*** that equals one if the institution is from Europe, a dummy variable ***Dummy North America*** that equals one if the institution is from the US or Canada, a dummy variable ***Dummy Asia-Pacific*** that equals one if the institution is from the Asia-Pacific region, ***GDP growth*** and ***Inflation*** as proxies for macroeconomics factors, ***Interest rate*** as a proxy for monetary policy, ***Stocks traded ratio*** (based on the value of stocks traded as % of GDP) as a proxy for the security market size in a given country, and ***ln EOA*** as a proxy for the risk-taking of the institutions. All regressions are feasible generalized least square (FGLS) estimation and control for the yearly fixed effects. Heteroskedasticity-robust *t*-values are reported in parentheses. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Variables	TE	PTE	CE	CEScope	VCE	RE	REScope	VRE	SE	AE	PE
Size	-0.00462	0.00384	-0.0103***	-0.00678*	-0.0186***	0.00259	0.0107*	0.00822	-0.0403***	-0.0428***	0.00124
	(-1.14)	(0.70)	(-3.23)	(-1.69)	(-4.21)	(0.78)	(1.70)	(1.35)	(-5.29)	(-4.76)	(0.33)
Vertically integrated	0.00442	0.0929***	0.0210**	0.0573***	0.0518**	-0.00410	0.00852	-0.00643	-0.0568*	0.0190	0.00211
	(0.24)	(3.15)	(2.00)	(3.88)	(2.49)	(-0.22)	(0.31)	(-0.23)	(-1.89)	(0.66)	(0.12)
Horizontally integrated	-0.0211	-0.0980***	-0.0393**	-0.0496**	-0.0545**	0.0135	-0.0167	0.00115	-0.0157	-0.0474	0.00636
	(-1.20)	(-3.12)	(-2.53)	(-2.36)	(-2.18)	(0.86)	(-0.82)	(0.05)	(-0.42)	(-1.21)	(0.38)
Broad range of asset classes	-0.116***	-0.128***	-0.0770***	-0.132***	-0.0932***	-0.0107	-0.0221	0.000480	0.0187	0.0662	-0.0162
	(-5.88)	(-4.37)	(-4.54)	(-7.22)	(-3.92)	(-0.61)	(-0.84)	(0.02)	(0.58)	(1.58)	(-0.82)
Dummy clearing house	0.119***	0.598***	0.0700**	0.184***	0.272***	0.180***	0.263***	0.245***	-0.196***	0.0796	0.191***
	(2.85)	(8.89)	(2.56)	(4.46)	(4.50)	(4.02)	(4.14)	(3.62)	(-2.99)	(0.97)	(3.82)
Dummy CSD	0.00786	0.0231	-0.0253	-0.0629***	-0.0221	0.0291	0.0486	0.0786**	0.0765**	-0.0967**	0.0262
	(0.41)	(0.70)	(-1.58)	(-2.69)	(-0.76)	(1.39)	(1.51)	(2.47)	(2.23)	(-2.41)	(1.07)
Dummy Europe	-0.207***	-0.519***	-0.0524	-0.122***	-0.0840*	-0.00935	-0.0863*	-0.106*	0.199***	0.0662	-0.0889
	(-3.75)	(-7.99)	(-1.36)	(-2.77)	(-1.91)	(-0.42)	(-1.71)	(-1.90)	(5.04)	(1.14)	(-1.56)
Dummy North America	-0.197***	-0.339***	0.0155	0.0577	0.0479	-0.0250	-0.0844	-0.105*	-0.331***	0.683***	-0.0867
	(-3.53)	(-4.61)	(0.38)	(1.19)	(0.98)	(-0.83)	(-1.44)	(-1.70)	(-7.09)	(10.24)	(-1.47)
Dummy Asia-Pacific	-0.118**	-0.325***	-0.0150	-0.0726	-0.0218	0.00683	0.0196	0.0209	0.0505	0.0370	-0.0593
	(-2.12)	(-4.84)	(-0.39)	(-1.63)	(-0.54)	(0.29)	(0.39)	(0.38)	(1.33)	(0.63)	(-1.06)
GDP growth	-0.000317	-0.0141**	0.000380	-0.00229	-0.00141	-0.000226	-0.00776**	-0.00899**	0.0158***	0.00250	0.000243
	(-0.09)	(-2.39)	(0.15)	(-0.77)	(-0.38)	(-0.11)	(-2.02)	(-2.38)	(3.16)	(0.36)	(0.07)
Inflation	0.000598	-0.0130***	-0.000800	-0.00133	-0.000575	-0.000617	-0.00659**	-0.00686**	0.00974***	0.00794*	-0.00154
	(0.25)	(-3.64)	(-0.48)	(-0.60)	(-0.28)	(-0.42)	(-2.45)	(-2.37)	(2.90)	(1.75)	(-0.65)
Interest rate	-0.00504***	-0.0143***	-0.00259**	-0.00447***	-0.00341**	-0.000352	-0.00241	-0.00367*	0.00802***	-0.00184	-0.00169
	(-3.15)	(-7.20)	(-1.98)	(-3.63)	(-2.31)	(-0.28)	(-1.47)	(-1.80)	(3.42)	(-0.89)	(-0.89)
Stocks traded ratio	-0.0000621	-0.0000897	-0.000101***	-0.0000567	-0.0000237	-0.0000215	-0.000159**	-0.000198***	0.000252**	-0.000365***	-0.0000213
	(-1.44)	(-1.20)	(-2.97)	(-1.46)	(-0.51)	(-0.56)	(-2.24)	(-2.84)	(2.13)	(-4.10)	(-0.46)
ln EOA	0.0105	0.0893***	0.000452	0.0203**	0.0227**	-0.00380	0.0118	0.00869	-0.0906***	-0.00806	-0.00132
	(0.97)	(6.02)	(0.07)	(2.39)	(2.05)	(-0.43)	(0.82)	(0.60)	(-6.01)	(-0.49)	(-0.13)
Intercept	0.470***	0.503***	0.331***	0.334***	0.384***	-0.00959	-0.0913	-0.0511	1.632***	0.692***	0.0747
	(3.44)	(2.80)	(4.30)	(3.45)	(3.79)	(-0.13)	(-0.60)	(-0.32)	(8.55)	(3.35)	(0.70)
Year Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
N	200	200	200	195	200	200	195	200	195	195	200
Wald Chi-square	181.8	426.0	151.8	663.0	231.5	42.58	100.6	95.98	1191.3	800.8	38.83

Table 8: Impact of Integration on the Efficiency of FMI Providers

This table presents the regressions of the impact of financial integration on the efficiency of FMI providers. Our sample period is 2000–2015. The dependent variable ***TE*** indicates technical efficiency, ***PTE*** indicates pure technical efficiency, ***CE*** indicates cost efficiency based on constant returns to scale technology, ***CEScope*** indicates *CE* purged of scale efficiency, ***VCE*** indicates cost efficiency based on variable returns to scale technology, ***RE*** indicates revenue efficiency based on constant returns to scale technology, ***REScope*** indicates *RE* purged of scale efficiency, ***VRE*** indicates revenue efficiency based on variable returns to scale technology, ***SE*** indicates input-oriented scale efficiency, ***AE*** indicates input-oriented allocative efficiency, and ***PE*** indicates profit efficiency estimated based on Cooper et al. (2004, Eq. (8.1)). Dummy variable ***Vertically integrated*** equals one since the year that the FMI provider *i* was vertically integrated with a FMI provider of a different type (e.g., a merger between a stock exchange and a CSD, a merger between a stock exchange and a clearing house, or a merger between a CSD and a clearing house) or if a clearing house or a CSD is owned by a stock exchange or if a clearing house is owned by a CSD, dummy variable ***Horizontally integrated*** equals one since the year of a merger between the same type of institutions (a merger between stock exchanges, CSDs, or clearing houses), dummy variable ***Broad range of asset classes*** equals one if the institution provides services for a broad range of financial instruments (including derivatives and commodities) and equals zero if it provides services only for debt and equities securities, a dummy variable ***Dummy clearing house*** equals one if the institution is a clearing house, a dummy variable ***Dummy CSD*** equals one if the institution is a CSD, and a dummy variable ***Dummy stock exchange*** equals one if the institution is a stock exchange. All regressions are feasible generalized least square (FGLS) estimation and control for the yearly fixed effects. Heteroskedasticity-robust *t*-values are reported in parentheses. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

Panel A **Variables**	**(1)** **TE**	**(2)** **PTE**	**(3)** **CE**	**(4)** **CEScope**	**(5)** **VCE**	**(6)** **RE**	**(7)** **REScope**	**(8)** **VRE**	**(9)** **SE**	**(10)** **AE**	**(11)** **PE**
Horizontally integrated * Dummy stock exchange	-0.0656***	-0.131***	-0.0653***	-0.0699***	-0.0743***	0.00251	-0.0269	-0.0148	0.0340	-0.0686	0.000308
	(-2.70)	(-3.97)	(-3.62)	(-3.22)	(-2.85)	(0.14)	(-1.29)	(-0.63)	(1.03)	(-1.42)	(0.02)
Horizontally integrated * Dummy CSD	0.0493	0.141***	0.0572**	0.140***	0.108***	0.0827**	0.181***	0.158***	-0.578***	0.0112	0.0767
	(1.56)	(3.08)	(2.51)	(5.00)	(2.72)	(2.54)	(3.59)	(2.96)	(-13.05)	(0.19)	(1.32)
Vertically integrated	0.0194	0.0961***	0.0205*	0.0571***	0.0520**	-0.000614	0.00992	-0.00245	-0.0615**	0.0242	0.00553
	(1.00)	(3.26)	(1.96)	(3.97)	(2.50)	(-0.03)	(0.37)	(-0.09)	(-2.09)	(0.85)	(0.30)
Broad range of asset classes	-0.127***	-0.141***	-0.0897***	-0.135***	-0.0966***	-0.0174	-0.0324	-0.0140	0.0404	0.0585	-0.0194
	(-6.32)	(-4.92)	(-5.29)	(-7.86)	(-4.07)	(-0.97)	(-1.24)	(-0.50)	(1.34)	(1.35)	(-0.99)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	200	200	200	195	200	200	195	200	195	195	200
Wald Chi-square	190.4	458.9	212.2	777.2	234.9	96.81	170.5	152.3	3081.4	988.7	40.47

Panel B **Variables**	**(1)** **TE**	**(2)** **PTE**	**(3)** **CE**	**(4)** **CEScope**	**(5)** **VCE**	**(6)** **RE**	**(7)** **REScope**	**(8)** **VRE**	**(9)** **SE**	**(10)** **AE**	**(11)** **PE**
Horizontally integrated	-0.0323*	-0.0705**	-0.0467***	-0.0407*	-0.0436*	0.00553	-0.0111	-0.00737	0.000947	-0.116**	0.00310
	(-1.77)	(-2.09)	(-2.82)	(-1.88)	(-1.76)	(0.35)	(-0.53)	(-0.30)	(0.03)	(-2.25)	(0.20)
Vertically integrated * Dummy stock exchange	-0.00940	0.0383	0.0385***	0.0544***	0.0295	-0.00512	-0.0234	-0.0199	-0.0484	0.346***	-0.00286
	(-0.77)	(1.22)	(2.94)	(3.18)	(1.27)	(-0.37)	(-0.98)	(-0.72)	(-1.44)	(6.24)	(-0.19)
Vertically integrated * Dummy clearing house	-0.0403	0.292***	-0.0615	0.157***	0.321***	0.00387	0.0938	0.0133	0.127	-0.438***	-0.0277
	(-0.46)	(3.48)	(-1.14)	(3.20)	(4.10)	(0.04)	(1.13)	(0.13)	(1.32)	(-6.14)	(-0.31)
Vertically integrated * Dummy CSD	0.0144	0.155	-0.0523	-0.0274	-0.0118	0.0928	0.108	0.0870	-0.137**	-0.0205	0.107
	(0.14)	(1.42)	(-1.21)	(-0.58)	(-0.23)	(1.01)	(1.08)	(0.87)	(-2.47)	(-0.41)	(1.03)
Broad range of asset classes	-0.112***	-0.0966***	-0.103***	-0.131***	-0.0723***	-0.00529	-0.00521	0.000790	0.0258	-0.0103	-0.0101
	(-5.56)	(-3.01)	(-5.80)	(-6.53)	(-2.74)	(-0.31)	(-0.20)	(0.03)	(0.81)	(-0.28)	(-0.58)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	200	200	200	195	200	200	195	200	195	195	200
Wald Chi-square	270.9	501.7	284.8	531.3	253.0	38.39	106.3	93.75	1244.6	888.8	39.41

Panel C **Variables**	**(1)** **TE**	**(2)** **PTE**	**(3)** **CE**	**(4)** **CEScope**	**(5)** **VCE**	**(6)** **RE**	**(7)** **REScope**	**(8)** **VRE**	**(9)** **SE**	**(10)** **AE**	**(11)** **PE**
Horizontally integrated	-0.0410*	-0.0389	-0.0159	-0.00438	-0.0178	0.00776	0.000964	0.0138	-0.0220	-0.0628	0.0115
	(-1.75)	(-1.38)	(-1.25)	(-0.27)	(-0.94)	(0.51)	(0.04)	(0.57)	(-0.58)	(-1.38)	(0.53)
Vertically integrated	0.00666	0.0378	0.0426***	0.0544***	0.0311*	-0.0104	-0.0349	-0.0286	-0.0394	0.0585	-0.0202
	(0.28)	(1.16)	(3.42)	(3.82)	(1.80)	(-0.51)	(-1.17)	(-0.98)	(-1.26)	(1.55)	(-0.87)
Broad range of asset classes * Dummy stock exchange	-0.150***	-0.122***	-0.142***	-0.159***	-0.0799***	-0.00531	0.00561	0.0168	-0.0479	-0.110	-0.00566
	(-5.74)	(-3.67)	(-6.07)	(-7.26)	(-2.58)	(-0.30)	(0.18)	(0.51)	(-1.05)	(-1.47)	(-0.21)
Broad range of asset classes * Dummy clearing house	-0.237***	-0.583***	-0.126**	-0.313***	-0.486***	-0.350***	-0.504***	-0.474***	0.177**	0.274***	-0.339***
	(-3.64)	(-6.54)	(-2.23)	(-6.41)	(-6.63)	(-6.49)	(-6.34)	(-5.28)	(2.04)	(2.95)	(-4.88)
Broad range of asset classes * Dummy CSD	-0.0208	-0.0118	0.0292	0.00964	0.0257	0.0242	0.0693*	0.0889**	0.0512	0.116**	0.00896
	(-0.48)	(-0.28)	(1.34)	(0.39)	(1.08)	(0.68)	(1.66)	(2.01)	(0.97)	(2.05)	(0.21)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	200	200	200	195	200	200	195	200	195	195	200
Wald Chi-square	249.4	469.5	286.2	583.2	221.4	70.80	120.0	119.8	972.1	680.6	54.27

Note: In the regressions, we also include the following control variables: ***Size*** which is measured by the natural logarithm of FMI assets, a dummy variable ***Dummy clearing house*** equals one if the institution is a clearing house, a dummy variable ***Dummy CSD*** equals one if the institution is a CSD, a dummy variable ***Dummy Europe*** that equals one if the institution is from Europe, a dummy variable ***Dummy North America*** that equals one if the institution is from the US or Canada, a dummy variable ***Dummy Asia-Pacific*** that equals one if the institution is from the Asia-Pacific region, ***GDP growth*** and ***Inflation*** as proxies for macroeconomics factors, ***Interest rate*** as a proxy for monetary policy, ***Stocks traded ratio*** (based on the value of stocks traded as % of GDP) as a proxy for the security market size in a given country, and ***ln EOA*** as a proxy for the risk-taking of the institutions. For brevity, the result of ***Intercept*** for each regression and ***Control Variables*** are not reported in the table.

Table 9: Impact of An efficient FMIs on Systemic Risk of Financial System

This table presents the results that examine the impact of an efficient of FMIs on the systemic risk of financial system. Our sample period is 2000–2015. The dependent variable ***NPL*** is defined as the bank nonperforming loans to total gross loans in a financial system, ***Stock Market Index Volatility*** is defined as the volatility of the stock market index return for each country at each year and calculated based on the monthly return of the stock market index, ***CLIFS*** is defined as the country-level index of financial stress, which is obtained from the European Central Bank. ***TE*** indicates technical efficiency, ***PTE*** indicates pure technical efficiency, ***CE*** indicates cost efficiency based on constant returns to scale technology, ***CEScope*** indicates *CE* purged of scale efficiency, ***VCE*** indicates cost efficiency based on variable returns to scale technology, ***RE*** indicates revenue efficiency based on constant returns to scale technology, ***REScope*** indicates *RE* purged of scale efficiency, ***VRE*** indicates revenue efficiency based on variable returns to scale technology, ***SE*** indicates input-oriented scale efficiency, ***AE*** indicates input-oriented allocative efficiency, and ***PE*** indicates profit efficiency estimated based on Cooper et al. (2004, Eq. (8.1)). In the regressions, we also include the following control variables: ***GDP growth*** and ***Inflation*** as proxies for macroeconomics factors, ***Interest rate*** and ***Number of FMIs*** to control for the changes of monetary policy and the industry structure of the FMIs in a given country, ***ICT*** is included to control for the changes of technology development during our sample period, *Private credit by banks to GDP* to control for the financial sector size. All regressions are feasible generalized least square (FGLS) estimation and control for the yearly fixed effects. Heteroskedasticity-robust *t*-values are reported in parentheses. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

	NPL				Stock Market Index Volatility				CLIFS			
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(11)
GDP growth	-0.518***	-0.474***	-0.519***	-0.512***	0.00221	0.00248	0.00220	0.00220	-0.0116**	-0.0109**	-0.0116**	-0.0116**
	(-6.26)	(-5.54)	(-6.65)	(-6.51)	(0.73)	(0.79)	(0.71)	(0.72)	(-2.54)	(-2.23)	(-2.51)	(-2.52)
Inflation	0.111**	0.108**	0.108**	0.107**	0.00560***	0.00590***	0.00639***	0.00672***	0.00217	0.00172	0.00144	0.00143
	(2.25)	(2.14)	(2.28)	(2.25)	(2.88)	(3.03)	(3.35)	(3.58)	(0.43)	(0.31)	(0.28)	(0.28)
Interest rate	-0.0902***	-0.0837***	-0.0888***	-0.0890***	-0.000606	-0.000646	-0.000573	-0.000590	-0.00346	-0.00369	-0.00400	-0.00402
	(-3.62)	(-3.36)	(-3.75)	(-3.77)	(-0.58)	(-0.56)	(-0.52)	(-0.53)	(-0.88)	(-0.85)	(-1.02)	(-1.02)
Number of FMIs	0.0756	-0.0584	0.101	0.0962	-0.00114	-0.0000850	-0.000974	-0.00101	-0.00341	0.000348	-0.00328	-0.00329
	(0.77)	(-0.60)	(1.09)	(1.03)	(-0.36)	(-0.02)	(-0.26)	(-0.27)	(-0.73)	(0.10)	(-0.67)	(-0.67)
ICT	-0.733***	-0.743***	-0.663***	-0.657**	0.00191	0.000489	0.00273	0.00283	-0.00787	-0.00739	-0.00299	-0.00293
	(-2.76)	(-2.78)	(-2.58)	(-2.56)	(0.23)	(0.06)	(0.31)	(0.32)	(-0.72)	(-0.55)	(-0.26)	(-0.25)
Private credit by banks to GDP	-0.00903**	-0.0125***	-0.00990***	-0.0103***	-0.000133	-0.000118	-0.000147	-0.000151	0.0000328	-0.0000705	-0.0000106	-0.0000105
	(-2.32)	(-3.20)	(-2.62)	(-2.72)	(-1.12)	(-1.02)	(-1.23)	(-1.25)	(0.26)	(-0.41)	(-0.09)	(-0.09)
PTE	-0.279				-0.0203				-0.0311*			
	(-0.50)				(-1.33)				(-1.65)			
VCE		1.110**				-0.0127				0.0384		
		(2.16)				(-0.70)				(0.50)		
REScope			-1.933**				-0.0227				-0.0327*	
			(-2.55)				(-0.94)				(-1.78)	
VRE				-1.984***				-0.0259				-0.0328*
				(-2.65)				(-1.07)				(-1.79)
Intercept	7.954***	7.978***	9.857***	7.995***		0	0.0392	0	0.120	0.112	0.121	0.121
	(6.97)	(7.40)	(7.73)	(7.08)		.	(1.28)	.	(1.29)	(1.17)	(1.30)	(1.30)
Year Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
N	96	96	96	96	128	128	128	128	65	65	65	65
Wald Chi-square	179.9	197.8	207.1	205.3	317.8	304.2	78.60	328.2	756.2	714.7	742.8	742.4

Table 10: Financial Integration of FMI Providers and Systemic Risk

This table presents the regressions of financial integration of FMI providers and systemic risk. Our sample period is 2000–2015. The dependent variable ***NPL*** is defined as the bank nonperforming loans to total gross loans in a financial system, ***Stock Market Index Volatility*** is defined as the volatility of the stock market index return for each country at each year and calculated based on the monthly return of the stock market index, ***CLIFS*** is defined as the country-level index of financial stress, ***Stock Market Capitalization Ratio*** is defined as the market capitalization of listed domestic companies to GDP ratio, ***Banking System Asset to GDP Ratio*** is defined as the banking system asset to GDP ratio. All dependent variables are country-level data and obtained from the Word Bank database. In the regressions, we include: ***Size*** measured by the natural logarithm of financial market infrastructures assets, a dummy variable ***Vertically integrated*** that equals one since the year that the institution *i* (a stock exchange, CSD, or clearing house) was vertically integrated with an institution of a different type (e.g., a merger between a stock exchange and a CSD, a merger between a stock exchange and a clearing house, or a merger between a CSD and a clearing house) or if a clearing house or a CSD is owned by a stock exchange or if a clearing house is owned by a CSD, a dummy variable ***Horizontally integrated*** that equals one since the year that a merger was announced between the same type of institutions (a merger between stock exchanges, between CSDs, or between clearing houses), a dummy variable ***Broad range of asset classes*** that equals one if the institution provides services for a broad range of financial instruments (including derivatives and commodities) and equals zero if it provides services only for debt and equities securities, a dummy variable ***Dummy clearing house*** that equals one if the institution is a clearing house, a dummy variable ***Dummy CSD*** that equals one if the institution is a CSD, a dummy variable ***Dummy Europe*** that equals one if the institution is from Europe, a dummy variable ***Dummy North America*** that equals one if the institution is from the US or Canada, a dummy variable ***Dummy Asia-Pacific*** that equals one if the institution is from the Asia-Pacific region, the variable ***ICT*** defined as the % of total information and communication technology expenditure to GDP, ***GDP growth*** and ***Inflation*** as proxies for macroeconomics factors, ***Interest rate*** as a proxy for monetary policy, and ***ln EOA*** as a proxy for the risk-taking of the institutions. All regressions are feasible generalized least square (FGLS) estimation and control for the yearly fixed effects. Heteroskedasticity-robust *t*-values are reported in parentheses. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

	NPL	Stock Market Index Volatility	CLIFS	Stock Market Capitalization Ratio	Banking System Asset to GDP Ratio
Variables	(1)	(2)	(3)	(4)	(5)
Size	-0.214***	-0.000274	-0.00240**	1.813***	2.558***
	(-4.58)	(-0.34)	(-2.29)	(4.07)	(7.46)
Vertically integrated	-0.639***	0.00468	-0.0119	-1.260	3.689**
	(-2.76)	(1.01)	(-1.46)	(-0.57)	(2.15)
Horizontally integrated	-1.813***	-0.00545	0.00269	15.03***	14.81***
	(-5.00)	(-0.87)	(0.28)	(3.40)	(5.70)
Broad range of asset classes	0.704***	0.0111*	0.0117**	5.973***	11.45***
	(2.80)	(1.92)	(1.98)	(2.98)	(7.87)
Dummy clearing house	-2.462***	-0.00469	-0.0259**	8.544***	7.392***
	(-6.63)	(-0.73)	(-2.40)	(2.64)	(3.48)
Dummy CSD	-1.063***	-0.00557	-0.00995	-7.368**	-3.538
	(-2.95)	(-0.92)	(-1.25)	(-2.42)	(-1.55)
Dummy Europe	4.697***	0.0421***		-65.36***	2.965
	(8.90)	(4.51)		(-9.73)	(1.02)
Dummy North America	6.725***	0.0541***		-44.18***	-73.73***
	(11.29)	(5.67)		(-6.11)	(-22.83)
Dummy Asia-Pacific	2.743***	0.0698***		-58.83***	18.46***
	(4.99)	(7.91)		(-7.92)	(6.25)
GDP growth	-0.346***	0.000109	-0.0173***	2.058***	-3.172***
	(-5.47)	(0.07)	(-7.41)	(2.92)	(-9.05)
Inflation	0.258***	0.00701***	0.00197	-0.120	-3.749***
	(7.10)	(8.19)	(0.86)	(-0.24)	(-14.09)
Interest rate	0.164***	0.000412	-0.00136	-2.136***	-1.757***
	(5.23)	(0.80)	(-0.98)	(-10.56)	(-6.53)
ICT	-1.485***	-0.0106***	-0.0167**	12.20***	7.994***
	(-8.40)	(-2.91)	(-2.18)	(5.94)	(6.99)
ln EOA	-0.178**	0.000176	-0.00450**	-2.660***	-3.051***
	(-2.48)	(0.14)	(-2.48)	(-3.87)	(-5.74)
Intercept	4.400**	-0.00643	0.266***	119.8***	88.59***
	(2.13)	(-0.28)	(8.36)	(9.10)	(11.11)
Year Fixed Effects	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
N	245	324	230	457	528
Wald Chi-square	635.1	511.2	2139.9	4770.7	5490.6

Note: Dummy variables ***Dummy Europe***, ***Dummy North-America***, and ***Dummy Asia-Pacific*** are dropped out of the regression in column (3) because of the data of ***CLIFS*** is only available for EU countries.

Figure 1: Cost and Number of Transactions

Figure 1 illustrates the relation between the number of transactions and the cost per trade. Our sample period is 2000–2015. The x axis is defined as the logarithm of the number of transactions in thousands and the y axis is defined as the logarithm of ***TC/NT*** (cost / number of transactions). The fitted regression lines of CSDs, stock exchanges, and clearing houses are represented by a solid line, long-dash line, and long-dash-dot-dot line, respectively.

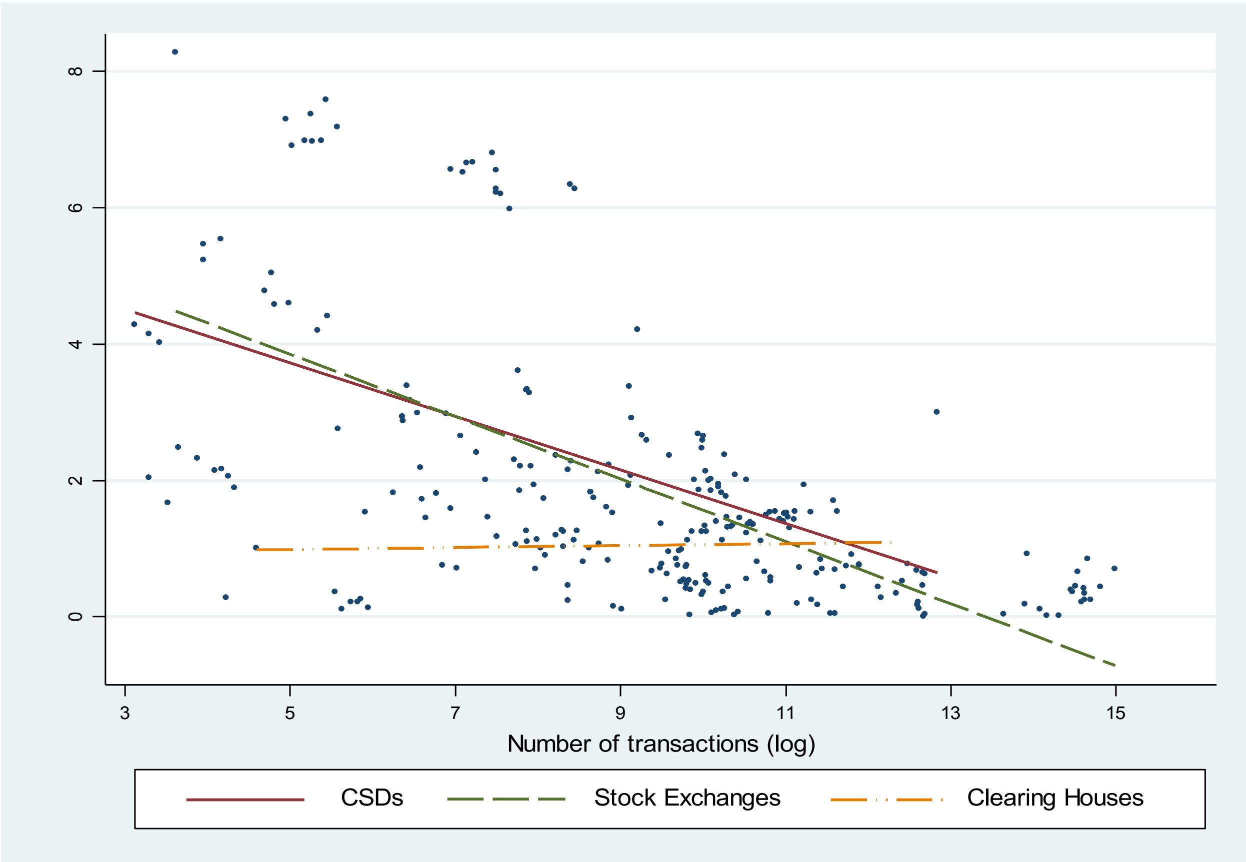

Figure 2: Cost and Value of Transactions

Figure 2 illustrates the relation between the value of transactions and the cost per value of transactions. Our sample period is 2000–2015. The *x* axis is defined as the logarithm of value of transactions in US$ '000 and the *y* axis is defined as the logarithm of ***TC/VT*** (cost / value of transactions). The fitted regression lines of CSDs, stock exchanges, and clearing houses are represented by a solid line, long-dash line, and long-dash-dot-dot line, respectively.

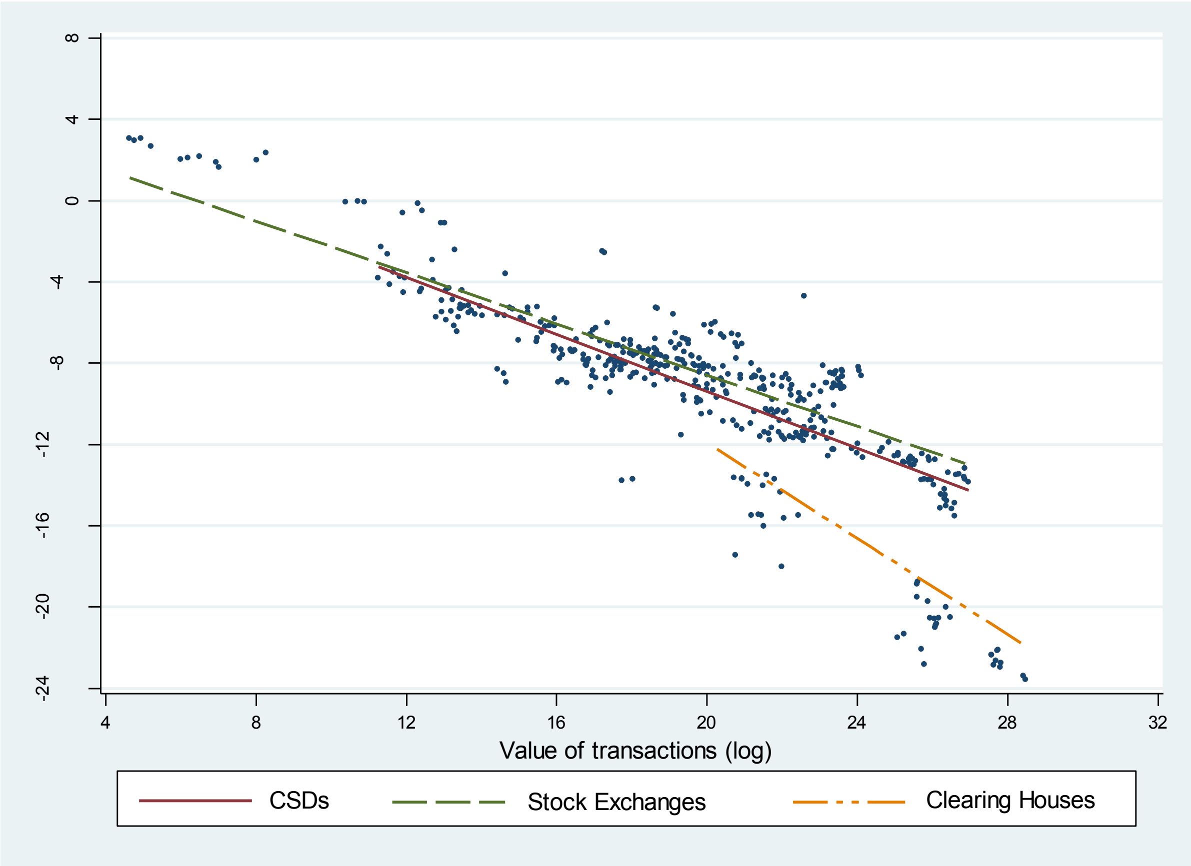

Table A1: Cost Regressed on Output Proxies

This table presents the regressions of the simple loglinear model by using the *number of transactions*, NT_{it} (denoted as $\boldsymbol{Q_{it}^{1}}$), and the *value of transactions*, VT_{it} (denoted as $\boldsymbol{Q_{it}^{2}}$)) as proxies for output. We also include time trend variable $\boldsymbol{t}$ and $\boldsymbol{ICT_{it}}$ (denoted as $\boldsymbol{P_{it}^{2}}$) as proxies for technological development. Our sample period is 2000–2015. The dependent variable represents the logarithm of total operating costs ($\boldsymbol{TC_{it}}$). All regressions are OLS estimations. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
ln Q_1	0.175***		0.115***	0.113***	0.139***
	(7.64)		(3.90)	(3.83)	(4.08)
ln Q_2		0.286***	0.331***	0.330***	0.221***
		(18.72)	(20.89)	(20.45)	(7.12)
t				−0.00386	−0.0280
				(−0.18)	(−1.24)
ln P_2					−0.741***
					(−4.81)
Intercept	8.825***	5.365***	3.080***	3.202***	5.637***
	(30.37)	(17.43)	(7.47)	(5.51)	(7.79)
N	653	445	401	399	318
R^2-adjusted	0.0801	0.404	0.469	0.464	0.489
F-statistic	58.36***	350.3***	248.3***	162.7***	92.31***

Table A2: Full Sample Translog Cost Regression Estimation, including the Single-Input Single-Output Model and Multiple-Inputs, Multiple-Outputs Model

This table presents the regressions results of the translog specification as presented in the equation in (1). Our sample period is 2000–2015. Panel A shows the results of translog specifications, including single-input ($\boldsymbol{GDPPC_{it}}$ (denoted as $\boldsymbol{P^1_{it}}$)), single-output (number of transactions, NT_{it} (denoted as $\boldsymbol{Q^1_{it}}$)), year dummy variables, and time trend variable $\boldsymbol{t}$. Panel B shows the results of translog specifications, including multiple-inputs ($\boldsymbol{GDPPC_{it}}$ (denoted as $\boldsymbol{P^1_{it}}$) and $\boldsymbol{ICT_{it}}$ (denoted as $\boldsymbol{P^2_{it}}$)), multiple-outputs (number of transactions, NT_{it} (denoted as $\boldsymbol{Q^1_{it}}$) and value of transactions VT_{it} (denoted as $\boldsymbol{Q^2_{it}}$)), year dummy variables, and time trend variable $\boldsymbol{t}$. Regressions in Columns (1)–(3) in Panel A and Panel B are fixed effect estimations that control for the fixed effects of the FMI and cluster the standard errors at each institution; regressions in Columns (4)–(6) in Panel A and Panel B are stochastic frontiers analysis (SFA) estimations. Heteroskedasticity-robust t-values are reported in parentheses. The cost scale elasticities (mean) in the last row are the mean of cost scale elasticities for the total sample based on different specifications. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

	Panel A: Single-input, single-output model						**Panel B: Multiple-inputs, multiple-outputs model**					
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$\ln P_1$	1.228***	1.243**	0.953**	1.040***	1.288***	1.157***	−2.915*	−1.600	−3.355**	−2.053*	−1.170	−2.018*
	(2.92)	(2.53)	(2.29)	(3.25)	(3.77)	(3.44)	(−1.75)	(−1.17)	(−2.30)	(−1.78)	(−0.98)	(−1.71)
$\ln Q_1$	0.140	0.0948	0.158	0.152	0.153	0.201*	0.365	0.146	0.344	0.521*	0.413	0.520*
	(0.82)	(0.55)	(0.89)	(1.40)	(1.42)	(1.84)	(0.85)	(0.30)	(0.79)	(1.82)	(1.49)	(1.82)
$\ln P_1 * \ln P_1$	−0.00325	0.00434	−0.0842	0.0284	0.0164	−0.00166	0.838**	0.524	0.830**	0.319	0.219	0.317
	(−0.02)	(0.03)	(−0.64)	(0.29)	(0.17)	(−0.02)	(2.32)	(1.44)	(2.52)	(1.14)	(0.76)	(1.13)
$\ln Q1 * \ln Q1$	0.00413	0.00635	0.00309	0.00282	0.00295	0.000420	0.00735	0.0135	0.00226	−0.00207	0.00995	−0.00185
	(0.23)	(0.37)	(0.17)	(0.32)	(0.34)	(0.05)	(0.30)	(0.46)	(0.09)	(−0.13)	(0.63)	(−0.11)
$\ln P_1 * \ln Q_1$	−0.0256	−0.0206	−0.0257	−0.0258	−0.0331*	−0.0375**	−0.239**	−0.210**	−0.227**	−0.165***	−0.155***	−0.165***
	(−0.87)	(−0.73)	(−0.89)	(−1.40)	(−1.80)	(−2.00)	(−2.31)	(−2.18)	(−2.16)	(−3.81)	(−3.73)	(−3.82)
t			0.0382**			0.0598*			0.0395			−0.00591
			(2.11)			(1.92)			(1.17)			(−0.17)
$\ln P_2$							7.412***	6.672***	7.362***	4.567***	4.967***	4.581***
							(3.25)	(3.60)	(3.44)	(3.01)	(3.33)	(3.01)
$\ln Q_2$							−1.531**	−1.242**	−1.412**	−0.478	−0.467	−0.488
							(−2.44)	(−2.21)	(−2.27)	(−1.15)	(−1.14)	(−1.16)
$\ln P_2 * \ln P_2$							0.257	−0.0602	0.128	0.248	0.273	0.252
							(0.77)	(−0.16)	(0.39)	(1.21)	(1.40)	(1.22)
$\ln Q_2 * \ln Q_2$							0.0352	0.0262	0.0282	−0.00194	0.00395	−0.00140
							(1.37)	(1.04)	(1.10)	(−0.10)	(0.20)	(−0.07)
$\ln Q_2 * \ln Q_1$							0.0250	0.0255	0.0264	0.00724	0.00447	0.00730
							(1.48)	(1.55)	(1.61)	(0.64)	(0.42)	(0.65)
$\ln Q_2 * \ln P_1$							0.186*	0.147*	0.187*	0.179***	0.153***	0.178***
							(1.77)	(1.71)	(1.83)	(3.49)	(3.00)	(3.45)
$\ln P_2 * \ln P_1$							−0.940**	−0.905**	−1.080**	−0.134	−0.176	−0.136
							(−2.03)	(−2.31)	(−2.53)	(−0.56)	(−0.76)	(−0.57)
$\ln P_2 * \ln Q_1$							0.0150	−0.00583	0.0125	0.0280	0.0504	0.0281
							(0.20)	(−0.08)	(0.17)	(0.49)	(0.92)	(0.49)
$\ln P_2 * \ln Q_2$							−0.238**	−0.217**	−0.239**	−0.202***	−0.237***	−0.202***
							(−2.53)	(−2.23)	(−2.66)	(−3.03)	(−3.53)	(−3.02)
Intercept	6.198***	6.730***	6.462***	2.768***	2.469**	0.928	26.66***	24.34***	26.19***	10.99**	−259.5	11.16**
	(4.61)	(4.67)	(4.94)	(2.83)	(2.35)	(0.53)	(3.29)	(3.46)	(3.37)	(2.29)	(.)	(2.27)
N	642	642	641	642	642	641	312	312	312	312	312	312
R^2-adjusted	0.119	0.144	0.131				0.166	0.171	0.169			
F-statistic	7.155***	4.113***	7.047***				16.35***	70.93***	17.39***			
Wald Chi-squared				82.46***	109.2***	78.16***				135.3***	154.6***	134.7***
Year Dummy Variables	**No**	**Yes**	**No**	**No**	**Yes**	**No**	**No**	**Yes**	**No**	**No**	**Yes**	**No**
Estimation Method	**FE**	**FE**	**FE**	**SFA**	**SFA**	**SFA**	**FE**	**FE**	**FE**	**SFA**	**SFA**	**SFA**
Cost Scale Elasticities (Mean)	**0.1077**	**0.1033**	**0.1129**	**0.1042**	**0.0835**	**0.0889**	**0.2153**	**0.1502**	**0.1985**	**0.2154**	**0.2262**	**0.2154**

Table A3: Subsample Loglinear and Translog Cost Regression Estimation

This table presents the regressions of loglinear and translog cost specifications on the subsample that reports the direct personnel cost in financial statements. Our sample period is 2000–2015. Panel A shows the results of loglinear and translog specifications by using GDP *per capita* ($\boldsymbol{GDPPC_{it}}$ (denoted as $\boldsymbol{P^1_{it}}$)) as a measure of labor costs and the number of transactions ($\boldsymbol{GDPPC_{it}}$ (denoted as $\boldsymbol{Q^1_{it}}$)) as output. Panel B shows the results of loglinear and translog specifications by using personnel cost ($\boldsymbol{STAFF_{it}}$ (denoted as $\boldsymbol{P^3_{it}}$)) as a measure of labor costs and the number of transactions ($\boldsymbol{GDPPC_{it}}$ (denoted as $\boldsymbol{Q^1_{it}}$)) as output. All regressions are stochastic frontiers analysis (SFA) estimation. Heteroskedasticity-robust t-values are reported in parentheses. The cost scale elasticities (mean) in the last row are the mean of cost scale elasticities for the total sample based on different specifications. The superscripts ***, **, * indicate significance levels of 0.01, 0.05, and 0.10, respectively.

Panel A			Panel B		
Variables	**(1)**	**(2)**	**Variables**	**(1)**	**(2)**
ln P_1	0.800***	0.983**	ln P_3	0.0898**	0.155
	(5.05)	(2.41)		(2.49)	(0.94)
ln Q_1	0.102***	0.291**	ln Q_1	0.113***	0.251***
	(4.51)	(2.57)		(5.14)	(2.70)
ln P_1 * ln P_1		0.123	ln P_3 * ln P_3		0.0365*
		(1.03)			(1.72)
ln Q_1 * ln Q_1		−0.00701	ln Q_1 * ln Q_1		−0.0128
		(−0.76)			(−1.38)
ln P_1 * ln Q_1		−0.0401**	ln P_3 * ln Q_1		0.00715
		(−2.09)			(0.59)
Intercept	3.145***	1.901	Intercept	−2594.9***	−1818.7***
	(3.06)	(1.47)		(−7643.26)	(−3344.71)
N	500	500	N	500	500
Wald Chi-squared	50.95***	63.32***	Wald Chi−squared	31.14***	36.48***
Cost Scale Elasticities (Mean)	0.102	0.0796		0.113	0.0909

Table A4: Summary of Institutions in the Sample, 2000–2015

ID	Country / Region	Name	Broad Range of Asset Classes	Institution Type	Vertical Integration	Horizontal Integration
1	France	EBA Clearing	0	Clearing House	0	0
2	Netherlands	ABN AMRO Clearing Bank NV	1	Clearing House	0	0
3	Hong Kong	ABN AMRO Clearing Hong Kong Limited	1	Clearing House	0	0
4	Singapore	ABN AMRO Clearing Singapore Pte Ltd	1	Clearing House	0	0
5	Australia	ABN AMRO Clearing Sydney Pte Ltd	1	Clearing House	0	0
6	Argentina	Argentina Clearing SA	0	Clearing House	0	0
7	Netherlands	CITCO Bank Nederland NV	0	Clearing House	0	0
8	Switzerland	CLS Group Holdings AG	1	Clearing House	0	0
9	Russia	Central Clearing House	0	Clearing House	1	0
10	Luxembourg	CETREL SC	0	Clearing House	0	0
11	India	Clearing Corporation of India Ltd	0	Clearing House	1	0
12	Luxembourg	Clearstream Services SA	0	Clearing House	1	0
13	Germany	Eurex Clearing AG	1	Clearing House	1	0
14	Netherlands	European Central Counterparty NV	0	Clearing House	0	0
15	Germany	European Commodity Clearing AG	1	Clearing House	0	0
16	United States	Fixed Income Clearing Corporation [#]	0	Clearing House	1 from 2003	0
17	Netherlands	Fortis Clearing International BV	0	Clearing House	0	0
18	Hong Kong	Hong Kong Exchanges And Clearing Limited	1	Clearing House	0	0
19	United Kingdom	LCH. Clearnet Group Limited	1	Clearing House	1	0
20	United Kingdom	LCH. Clearnet Limited	1	Clearing House	1	0
21	Russia	Moscow Clearing Centre	1	Clearing House	1	0
22	Russia	National Clearing Centre CJSC JSCB	1	Clearing House	0	0
23	United States	National Securities Clearing Corporation	0	Clearing House	1	0
24	France	Natixis Paiements SA	0	Clearing House	0	0
25	United States	Options Clearing Corporation	1	Clearing House	1	0
26	Germany	Swiss Euro Clearing Bank GmbH (SECB)	0	Clearing House	0	0
27	United Kingdom	Tradition London Clearing Limited	1	Clearing House	0	0
28	United Kingdom	UBS Clearing and Execution Services Limited	1	Clearing House	0	0
29	Russia	United Settlement System	0	Clearing House	0	0
30	Greece	Athens Exchange Group	1	Stock Exchange	0	0
31	India	BSE India Ltd	1	Stock Exchange	1 from 2011	0
32	Brazil	BM&F Bovespa	1	Stock Exchange	0	0
33	Hungary	Budapest Stock Exchange	1	Stock Exchange	0	0
34	Malaysia	Bursa Malaysia	1	Stock Exchange	1 from 2009	0
35	Cyprus	Cyprus Stock Exchange	0	Stock Exchange	0	0
36	Germany	Deutsche Börse AG	1	Stock Exchange	1 from 2002	1 from 2003
37	France	Euronext	1	Stock Exchange	0	1 from 2002
38	Belgium	Euronext Brussels	1	Stock Exchange	0	0
38	France	Euronext Paris SA	1	Stock Exchange	1	1 from 2007
40	Hong Kong	Hong Kong Stock Exchange	1	Stock Exchange	0	0
41	Indonesia	Indonesia Stock Exchange	1	Stock Exchange	0	0
42	Turkey	Istanbul Stock Exchange	1	Stock Exchange	0	0
43	Jamaica	Jamaica Stock Exchange	0	Stock Exchange	0	0
44	South Africa	Johannesburg Stock Exchange	1	Stock Exchange	0	0

Table A4: Summary of Institutions in the Sample, 2000–2015

ID	Country / Region	Name	Broad Range of Asset Classes	Institution Type	Vertical Integration	Horizontal Integration
45	United Kingdom	London Stock Exchange	1	Stock Exchange	1 from 2006	1 from 2003
46	Malta	Malta Stock Exchange	0	Stock Exchange	0	0
47	Russia	Moscow Exchange	1	Stock Exchange	0	0
48	Oman	Muscat Securities Market	0	Stock Exchange	0	0
49	United States	NASDAQ	1	Stock Exchange	1 from 2008	1 from 2007
50	United States	NYSE	1	Stock Exchange	0	1 from 2007
51	Nigeria	Nigerian Stock Exchange	0	Stock Exchange	0	0
52	Czech Republic	Praha Stock Exchange	0	Stock Exchange	0	1 from 2008
53	Switzerland	SIX Swiss Exchange	1	Stock Exchange	1 from 2014	0
54	Singapore	Singapore Exchange	1	Stock Exchange	0	1 from 2010
55	Thailand	Stock Exchange of Thailand	1	Stock Exchange	0	0
56	Iran	Tehran Stock Exchange	1	Stock Exchange	0	0
57	Israel	Tel-Aviv Stock Exchange (TASE)	1	Stock Exchange	0	0
58	Japan	Tokyo Stock Exchange (TSE)	0	Stock Exchange	0	1 from 2012
59	Austria	Wiener Börse AG – Vienna Stock Exchange	1	Stock Exchange	0	1 from 2008
60	United Kingdom	BNP Paribas Securities Services Custody Bank Limited	0	CSD	0	0
61	Brazil	BM&F Bovespa	0	CSD	1	0
62	France	CACEIS Bank France SA	0	CSD	0	0
63	Luxembourg	Cedel International	0	CSD	1	0
64	Bosnia and Herzegovina	Central Registry of Securities JSC Banja Luka	0	CSD	0	0
65	Turkey	Central Securities Depository of Turkey	1	CSD	1	0
66	Slovakia	Central Securities Depository of the Slovak Republic	0	CSD	1	0
67	Germany	Clearstream Banking AG Frankfurt	1	CSD	1	0
68	Luxembourg	Clearstream International	1	CSD	1	0
69	Belgium	Euroclear Bank SA	1	CSD	1	1 from 2001
70	France	Euroclear France SA	1	CSD	1	0
71	United Kingdom	Euroclear Plc	1	CSD	1	0
72	Belgium	Euroclear SA/NV	1	CSD	1	0
73	France	IXIS Investor Services SA	0	CSD	0	0
74	Japan	Japan Securities Clearing Corporation	1.	CSD	1	0
75	Poland	KDPW	0	CSD	0	0
76	Russia	National Settlement Depository	0	CSD	1	0
77	Austria	Oesterreichische Clearingbank AG	0	CSD	0	0
78	Netherlands	RBC Dexia Investor Services Netherlands NV	0	CSD	0	0
79	Luxembourg	RBC Investor Services Bank SA	0	CSD	0	0
80	Spain	RBC Investor Services España SA	0	CSD	0	0
81	Turkey	Takasbank	1	CSD	0	0
82	United States	The Depository Trust Company	1	CSD	0	1 from 2010

Table B1: Cost Scale Elasticities Based on Two-inputs and Four-outputs Model According to Size, Type, Integration, Specialization, and Geographical Location

This table presents the mean of cost scale elasticities estimated by using the two-inputs (***GDPPC***$_{it}$ (***P_{it}^1***) and ***ICT***$_{it}$ (***P_{it}^2***)), four-outputs (***Number of transactions*** (***Q_{it}^1***), ***Value of transactions*** (***Q_{it}^2***), ***Number of listed companies / Number of Issuers*** (***Q_{it}^3***)), and ***Market capitalization / Securities held on accounts*** (***Q_{it}^4***)) and time trend variable ***t***, for the total sample, and various subsamples according to institution size, horizontal and vertical integration, type, specialization, and geographical location. Our sample period is 2010–2015. We report the cost scale elasticities with respect to the number of transactions (based on a single-input, single-output model as presented in the equation in (5)) in Panel A, and the cost scale elasticities with respect to the number of transactions and the value of transactions (based on a multiple-inputs, multiple-outputs model as presented in the equation in (4)) in Panel B. Significance of group mean differences: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

	Cost scale elasticities based on two-inputs and four-outputs model including time trend variable *t*				
Category	$\frac{\partial \ln TC}{\partial \ln Q_1}$	$\frac{\partial \ln TC}{\partial \ln Q_2}$	$\frac{\partial \ln TC}{\partial \ln Q_3}$	$\frac{\partial \ln TC}{\partial \ln Q_4}$	$\sum \frac{\partial \ln TC}{\partial \ln Q_i}$
Total Sample	0.0522	0.1704	0.1109	0.3536	0.6871
Institution Size					
Quantile 4 (Largest)	0.0419	0.1431	0.0834	0.3306	0.5990
Quantile 3	0.0623	0.1731	0.0988	0.3765	0.7107
Quantile 2	0.0574	0.1888	0.1228	0.3491	0.7181
Quantile 1 (Smallest)	0.0505	0.1749	0.1273	0.3605	0.7131
Top 50%	0.0507	0.1560	0.0901	0.3504	0.6471
Bottom 50%	0.0533	0.1804	0.1255	0.3559	0.7151
Group Mean Difference (Top 50% − Bottom 50%)	**0.0026**	**−0.0244*****	**−0.0354*****	**-0.0056**	**−0.0680*****
Type of Integration					
Horizontally integrated	0.0484	0.1654	0.1072	0.3431	0.6641
Non-horizontally integrated	0.0782	0.2043	0.1356	0.4260	0.8441
Group Mean Difference	**−0.0298*****	**−0.0389*****	**−0.0294*****	**-0.0829*****	**−0.1800*****
Vertically integrated	0.0487	0.1577	0.1091	0.3433	0.6588
Non-vertically integrated	0.0640	0.2124	0.1166	0.3879	0.7809
Group Mean Difference	**−0.0153****	**−0.0548****	**−0.0075**	**-0.0446******	**−0.1221*****
Specialization					
Broad range of asset classes	0.0423	0.1534	0.1079	0.3177	0.6213
Narrow range of asset classes	0.0556	0.1762	0.1119	0.3662	0.7100
Group Mean Difference	**−0.0134*****	**−0.0228*****	**−0.0040**	**-0.0484*****	**−0.0886*****
Regions					
Europe	0.0788	0.2000	0.1090	0.4016	0.7894
North America	0.0454	0.1589	0.1064	0.3420	0.6527
Asia-Pacific	0.1091	0.2065	0.0374	0.4508	0.8037
South America & Africa	0.0659	0.2217	0.1691	0.3697	0.8265
Type of FMI					
CSDs	**0.0465**	**0.1748**	**0.1030**	**0.3636**	**0.6880**
Group Mean Difference between Different Subsamples					
Top 50% − Bottom 50%	−0.0060	−0.0188	-0.0085	-0.0261*	-0.0072
Broad range of asset classes − Narrow range of asset classes	0.0052	−0.0153	0.0030	-0.0268**	−0.0340
Horizontally integrated − Non-horizontally integrated	−0.00384**	−0.0225***	-0.0109**	-0.0556***	−0.01263***
Vertically integrated − Non-vertically integrated	-0.0262***	-0.0565***	0.0121	-0.0529***	-0.0989***
Stock Exchanges	**0.0664**	**0.1880**	**0.1034**	**0.3865**	**0.7443**
Group Mean Difference between Different Subsamples					
Top 50% − Bottom 50%	−0.0271***	−0.0651***	−0.0620***	-0.0797***	−0.2339***
Broad range of asset classes − Narrow range of asset classes	−0.0433***	-0.0619***	−0.0451***	-0.0863***	−0.2365***
Horizontally integrated − Non-horizontally integrated	−0.0166*	−0.0311**	−0.0547***	-0.0564***	−0.1587***
Vertically integrated − Non-vertically integrated	−0.0370**	−0.0373*	−0.0125**	-0.1069***	−0.1937***
Clearing Houses	**0.0430**	**0.1437**	**0.1301**	**0.3017**	**0.6185**
Group Mean Difference between Different Subsamples					
Top 50% − Bottom 50%	0.0090	-0.0456***	−0.0220***	-0.0309***	−0.0896***
Broad range of asset classes − Narrow range of asset classes	-0.0036	0.0131	0.0080	-0.0161**	0.0014
Vertically integrated − Non-vertically integrated	0.0104*	-0.0795***	-0.0227**	0.0038	-0.0880***

Table B2: Summary Statistics of Efficiency Scores Based on Two-inputs and Four-outputs Model

This table presents the means of efficiency scores estimated by using the two-inputs (***GDPPC***$_{it}$ (P^1_{it}) and ***ICT***$_{it}$ (P^2_{it})), four-outputs (***Number of transactions*** (Q^1_{it}), ***Value of transactions*** (Q^2_{it}), ***Number of listed companies / Number of Issuers*** (Q^3_{it})), and ***Market capitalization / Securities held on accounts*** (Q^4_{it})), for the total sample, and various subsamples according to institution size, horizontal and vertical integration, type, specialization, and geographical location. Our sample period is 2010–2015. ***TE*** indicates technical efficiency, ***PTE*** indicates pure technical efficiency, ***CE*** indicates cost efficiency based on constant returns to scale technology, ***CEScope*** indicates *CE* purged of scale efficiency, ***VCE*** indicates cost efficiency based on variable returns to scale technology, ***RE*** indicates revenue efficiency based on constant returns to scale technology, ***REScope*** indicates *RE* purged of scale efficiency, ***VRE*** indicates revenue efficiency based on variable returns to scale technology, ***SE*** indicates input-oriented scale efficiency, ***AE*** indicates input-oriented allocative efficiency, ***PE*** indicates profit efficiency estimated based on Cooper et al. (2004, Eq. (8.1)), ***CRS*** indicates constant returns to scale, ***VRS*** indicates variable returns to scale, ***IRS*** indicates increasing returns to scale, ***DRS*** indicates decreasing returns to scale. Significance of group mean differences: * Significant at the 10% level. ** Significant at the 5% level. *** Significant at the 1% level.

Panel A: Mean of Efficiency	***N***	**TE**	**PTE**	**CE**	**CEScope**	**VCE**	**RE**	**REScope**	**VRE**	**SE**	**AE**	**PE**
All	388	0.3972	0.2859	0.3622	0.1817	0.2024	0.2949	0.2624	0.3390	0.2736	0.5482	0.6404
Institution Size												
Quantile 4 (Largest)	104	0.3836	0.3146	0.4457	0.0386	0.0639	0.2412	0.0439	0.1431	0.1068	0.3762	0.7008
Quantile 3	70	0.3180	0.3301	0.3515	0.2464	0.3086	0.3130	0.1562	0.4038	0.3167	0.5018	0.6809
Quantile 2	94	0.6074	0.3050	0.4354	0.3316	0.2792	0.3996	0.4832	0.5514	0.3568	0.6279	0.5627
Quantile 1 (Smallest)	120	0.2905	0.2203	0.2387	0.1505	0.2004	0.2487	0.3409	0.3045	0.3279	0.6620	0.6251
Top 50%	174	0.3572	0.3208	0.3251	0.1222	0.1624	0.2701	0.0890	0.2480	0.1912	0.4267	0.6928
Bottom 50%	214	0.4297	0.2575	0.4078	0.2301	0.2350	0.3150	0.4034	0.4129	0.3406	0.6470	0.5977
Group Mean Difference		**−0.0725**	**0.0633**	**-0.0827***	**−0.1079*****	**−0.0726*****	**-0.0449**	**-0.3144**	**-0.1650*****	**-0.1494*****	**-0.2203*****	**0.0951****
Type of Integration												
Horizontally integrated	50	0.4591	0.2983	0.2912	0.0109	0.1444	0.3017	0.4315	0.4329	0.1849	0.7385	0.5369
Non-horizontally integrated	338	0.3880	0.2841	0.3727	0.2070	0.2110	0.2939	0.2374	0.3251	0.2867	0.5201	0.6557
Group Mean Difference		**0.0711**	**−0.0413**	**-0.0815**	**-0.1961*****	**-0.0667**	**0.0078**	**0.1941*****	**0.1078**	**0.1018***	**−0.2184*****	**-0.1187***
Vertically integrated	84	0.5602	0.3411	0.3818	0.1584	0.2422	0.4075	0.4822	0.4146	0.2572	0.7394	0.5374
Non-vertically integrated	304	0.3522	0.2707	0.3568	0.1881	0.1914	0.2638	0.2017	0.3181	0.2781	0.4954	0.6688
Group Mean Difference		**0.0280**	**0.0704**	**0.0250**	**-0.0297**	**0.0508**	**0.1437*****	**0.2805*****	**0.0964***	**−0.0209**	**0.0440*****	**-0.1315*****
Specialization												
Broad range of asset classes	287	0.3902	0.2851	0.3609	0.1653	0.1811	0. 2362	0.2069	0.3415	0.2771	0.5850	0.6510
Narrow range of asset classes	101	0.4172	0.2883	0.3658	0.2283	0.2630	0. 3155	0. 2820	0.3317	0.2637	0.4438	0.6103
Group Mean Difference		**-0.0270**	**−0.0032**	**−0.0049**	**-0.0629**	**-0.0818***	**-0.0792***	**-0.0750***	**0.0098**	**0.0134**	**−0.1412****	**−0.0407**
Region												
Europe	253	0.1409	0.1303	0.3626	0.2294	0.2105	0.1814	0.2116	0.2936	0.2927	0.4012	0.7667
North America	39	0.9413	0.5633	0.3193	0.1294	0.3005	0.5023	0.5898	0.4614	0.4091	0.8992	0.4372
Asia-Pacific	76	0.7303	0.5261	0.3919	0.0893	0.1561	0.5043	0.2592	0.4521	0.1890	0.7517	0.4486
South America & Africa	29	0.7684	0.7934	0.5466	0.0216	0.1227	0.5122	0.2034	0.2399	0.0614	0.9002	0.1839
Type of FMI												
Stock Exchanges	**163**	**0.6632**	**0.4023**	**0.4247**	**0.0455**	**0.1156**	**0.3726**	**0.2640**	**0.3752**	**0.1366**	**0.6223**	**0.5353**
Group Mean Difference between Different Subsamples												
Top 50% − Bottom 50%		0.2903	−0.0033	−0.0782	−0.0139	-0.0192	0.0647	0.3886***	0.3335***	-0.0271	−0.3009***	−0.2114***
Broad range of asset classes − Narrow range of asset classes		−0.1356	−0.0438	−0.0215	0.0552***	0.1037***	0.0793	0.3175***	0.3531	0.1612***	0.1442	0.1282
Horizontally integrated − Non-horizontally integrated		−0.2169	−0.1323*	−0.1439	-0.0462*	0.0461	-0.1217*	0.2104***	0.0848	0.0851	0.01205	−0.0356
Vertically integrated − Non-vertically integrated		0.1339	0.0142	-0.0275	-0.0444	0.1128	0.0594	0.3380***	0.3051***	0.0320	0.3309***	-0.1581*
CSDs	**118**	**0.0810**	**0.1686**	**0.3959**	**0.1358**	**0.1620**	**0.2649**	**0.2992**	**0.2463**	**0.1970**	**0.4872**	**0.6733**
Group Mean Difference between Different Subsamples												
Top 50% − Bottom 50%		-0.0752	0.0197	−0.2744***	0.0453	0.2012***	0.0943	0.2600***	0.1813**	-0.0838	−0.1891**	-0.1306*
Broad range of asset classes − Narrow range of asset classes		0.1068***	0.2268***	0.0211	−0.0784	-0.0432	0.2842***	−0.1362*	-0.1384	−0.0020	−0.2299**	−0.1026
Horizontally integrated − Non-horizontally integrated		-0.0475	-0.0589*	-0.3853***	−0.1415***	−0.0615	0.2000	0.2816	0.1603	−0.1377*	−0.5355***	-0.3683***
Vertically integrated − Non-vertically integrated		-0.0392	0.0211***	0.0601	0.1020	0.0130	0.0348	0.1796*	0.0746	0.0458	0.1972*	-0.0558
Clearing Houses	**107**	**0.3407**	**0.2380**	**0.2298**	**0.4398**	**0.3793**	**0.2095**	**0.2195**	**0.3860**	**0.5669**	**0.5028**	**0.7642**
Group Mean Difference between Different Subsamples												
Top 50% − Bottom 50%		0.4278**	0.0355	0.0428	−0.2203**	−0.3464***	0.2344***	0.2076***	-0.0512	-0.0706	0.3408***	-0.1935***
Broad range of asset classes − Narrow range of asset classes		−0.2227	−0.2612***	−0.1151	0.0389	−0.1629*	−0.1835**	−0.2235**	−0.1746*	0.1139	0.0098	0.2126**
Vertically integrated − Non-vertically integrated		0.5696**	0.2162**	0.1321	-0.2832***	-0.0872	0.3842***	0.3428***	-0.1113	0.3087***	0.2438**	-0.2565***