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Guess what: It's the Settlements!

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Abstract

Exchanges and other trading platforms are often vertically integrated to carry out trading and settlement as one operation. We show that these vertical silos can prevent the full realization of efficincy gains from horizontal consolidation of trading and settlement platforms. Independent of the gains from such consolidation, when costs of settlement are private information, a merger of vertical silos cannot be designed to always ensure efficient trading and settlement after the merger. Furthermore, we show that efficiency can nevertheless be guaranteed either by delegating the operation of settlement platforms to agents or by forcing competition across vertical silos through cross-listings.

Keywords: Clearing and Settlement; Cross-listing; Horizontal and Vertical Integration; Mechanism Design

JEL Classifications: C73, G20, G34, L22

1 Introduction

Lately, clearing and settlement systems have received a lot of attention in the context of financial integration of the Euro-area. These systems lie at the core of financial markets infrastructure and typically show a complex organization especially for enabling trades across borders and different systems. The Giovannini Reports (2001) and (2003) discovered sizeable transaction costs and risks in the current infrastructure for clearing and settlement that prevent efficient cross-border trading within Europe.

Using data on fees and price schedules, Malkamäki, Schmiedel and Tarkka (2002) report that settlement of domestic securities transactions in Europe is 33% more costly than in the US. The average fee per transaction settled is \$3.9 in Europe compared to only \$2.9 in the US. This difference is partly explained by the segmentation of the European market, where each country uses a domestic Central Security Depository. For cross-border transactions within Europe, settlement is carried out either by intermediaries or international Central Security Depositories with charges averaging approximately \$40 per transaction. Furthermore, looking at economies of scale in Europe and the US, Malkamäki, Schmiedel and Tarkka (2002) present compelling evidence that clearing and settlement in the latter area takes place at a much more efficient level. This leads to the conclusion that Europe can gain immensely from further consolidation of this infrastructure.

Based on the two Giovannini reports, a policy debate developed emphasizing that "the process of consolidation of ... [the] clearing infrastructure should be driven by the private sector, unless there are clear signs of market failures" (European Central Bank (2001), p.4). In particular, the strategy for achieving efficiency gains is mainly based on mediating horizontal consolidation among national, private providers of clearing and settlement. While competitive pressures are deemed important, co-operation is seen as essential for attaining efficient solutions through horizontal consolidation.

In this paper, we point out that there are limits for providers of financial infrastructure in Europe to co-operate in order to achieve efficiency. In particular, we find that it is impossible to reap the full gains of horizontal consolidation whenever trading, clearing and settlement take place in segmented, vertically integrated exchanges and costs for trading, clearing and settlement are private information.

Our model departs from the situation in Europe when financial markets were characterized by a high degree of segmentation. Each country had its own clearing and settlement infrastructure, and most national corporations had little choice but to list on their national exchange. Consequently, national exchanges could capture national markets with all trades carried out at the exchange and channeled through a national clearing and settlement system. Technology for clearing and settlement was not homogeneous across countries, and systems often applied specialized solutions which lead to costs being non-transparent and difficult to compare.

More formally, we consider two players each operating a vertically integrated exchange. These exchanges offer trading as well as clearing and settlement of trades in two completely separated markets. They contemplate a consolidation of their trading and settlement activities, according to which they would pool their technology. We call such consolidation a merger. A merger between the firms is beneficial, since it increases overall profits due to two reasons. First, we allow for the merger to increase the joint demand for trading of the two firms and, hence, to generate higher joint revenue. Second, the costs for settling trades can be different across firms. Hence, a merged firm can settle trades at the lower cost of the two firms. The costs for settling trades are, however, private information of the players. Furthermore, we assume that the captive nature of the market by exchanges leads to prices not completely revealing cost structures. These assumptions capture the nature of specialized settlement solutions with non-transparent cost structures as well as high segmentation of markets.

Using a result of Myerson and Satterthwaite (1983), we show that there is no mechanism that allows the players to merge the vertically integrated firms such as to guarantee that trading and settlement are produced efficiently after the merger. Interestingly, this is independent of the overall gains in revenue that are obtained from increasing overall demand for the merged firms. It is important to stress here that this result is not about the possibility of a merger per se, but about achieving an efficient merger, i.e. a merger that realizes *all* possible benefits associated with the merger.

The reason for this result is as follows. A merger has to specify how the overall joint revenue is shared between the players and which of the two firms provides the settlement of trades after the merger. For the merger to be efficient, the players have to ensure that the lowest cost firm will carry out settlement. Since the costs for settlement are private information, truthful revelation of the costs implies that the share of revenue a player obtains varies with the costs announced by a player. However the total post-merger revenue net of production cost is constant. Therefore, it is infeasible to give proper incentive to both players simultaneously, since what is granted to one cannot be granted to the other and vice versa.

We offer three ways to overcome the problems of asymmetric information about costs together with a vertically integrated structure. First, if a subsidy is available to vary the overall gains from merging, the incentives to reveal the costs can be restored. Second, we prove that each player has an incentive to merge the trading platforms, if each player can delegate the operation of his settlement platform to an agent which we assume to be an insider (i.e., we assume that the agent can observe the true cost of settlement). By paying the agents a (small) share of the profits, competition for settling trades reveals costs. This results in the efficient solution where trading platforms are merged, while all trades get settled at the lowest cost.[1] The third alternative requires the two players to offer trading and settlement to the whole market and not only to their own market segment. This proxies for cross-listing between the two vertically integrated exchanges. Again, competition leads to prices that fully reveal costs. Hence, efficiency results as all trading and settlement takes place at the lowest cost.[2]

Our contribution is, hence, twofold. We show that segmented market structures and specialized settlement systems with non-transparent costs are important enough barriers for preventing national exchanges and settlement providers to achieve efficient consolidation. Moreover, we emphasize that competition is a powerful tool to overcome the problems associated with such barriers. We recognize, however, that weakening the degree of market segmentation

[1]Tapking and Yang (2004) look at other potential solutions to achieve efficiency such as establishing links between settlement systems rather than merging two systems. On this aspect of integration, see also Kauko (2003) for a related paper.

[2]On cross-listing and competition between exchanges, see also the recent papers by Shy and Tarkka (2001) and Santos and Scheinkman (2004).

by itself will lead to more competition as exchanges can compete directly through strategic variables such as the choice of settlement technology or attracting more corporations to list on the exchange.

The recent experience of consolidation among European stock exchanges (which we review in detail below) seem to support our findings. The case of Euronext, a merger between the Paris, Bruxelles and Amsterdam stock exchanges, was accompanied with the vertical disintegration of these exchanges which originally were set up as vertical structures. A similar project, the iX trading platform between London Stock Exchange and the Deutsche Börse in Frankfurt, failed however. Interestingly, Deutsche Börse pursued the creation of a vertical silo in parallel to the planned merger. Below we describe these recent experiences in more detail and provide evidence that vertical structures such as Deutsche Börse formed until recently an impediment to efficient market consolidation.[3]

The remainder of the paper is organized as follows. We start our analysis in Section 2 with a detailed case study of the Euronext and the planned iX merger. Section 3 outlines our model. We derive the impossibility result of achieving an ex-post efficient merger in Section 4. We then describe how a subsidy (or a tax) can restore efficiency. Section 5 demonstrates how market solutions can solve the problem of achieving full efficiency. The last section concludes.

[3]Quite interestingly, the policy debate has shifted towards establishing a framework that induces more competitive pressure while this paper was written. The European Commission has announced its plans to issue a formal Directive that aims at ensuring unrestricted access to financial infrastructures across Europe where market participant are free to choose the location of settlement independent of trading (see European Commission (2004)). Our work shows that such a policy *can* create the competition necessary to achieve an efficient financial market system across the Euro-area.

2 Securities Settlement Systems and the Consolidation of Securities Markets

2.1 Securities Market Organization - A Brief Overview

Transacting securities involves other actions than simply trading, i.e., buying and selling a security. For completeness and to demonstrate their importance, we briefly review so-called back office services that are necessary to effect a trade in securities markets.

There are two different main operations that complete the trade of a security. The first one, clearing the trade, confirms the legal obligations from the trade. Clearing involves (among possible other services) transmitting and reconciling the terms of a securities' trade between the buyer and seller. In some cases this is taken on by a special entity, a clearing house, that can also function as what is called a Central Counterparty or CCP. This entity interposes itself as the buyer to every seller and the seller to every buyer of a security.

Following the clearing stage the second operation is settling a trade. This involves the actual transfer of ownership from the seller to the buyer as well as the payment for the security by the buyer thereby discharging the legal obligations from the trade. This operation is often handled by a so-called Central Security Depository (or CSD) that holds the security and transfers the title of the security from the seller to the buyer after the transaction has been cleared.

Stock exchanges and other trading platforms often operate in vertical silos offering a one-stop service to traders. This service ranges from executing a trade over clearing the transaction to settling it by transferring the title of the security and the payment between the parties of the trade. In these vertical silos, the stock exchange either directly owns or controls the clearing house and/or the CSD that are responsible for clearing and settling the trades.

In the context of cross-border transactions the complexity of clearing trades rises considerably. In such transactions, buyers and sellers (or their brokers) transact on an exchange often without having direct access to the clearing infrastructure. This necessitates some form of intermediation where the intermediary takes on indirectly all the responsibilities arising from the trade within the clearing process. One possibility is that International CSDs guarantee the clearing and settlement of such transactions by functioning as specialized intermediaries between several national CSDs. Alternatively, CSDs can be linked and coordinate among themselves the clearing of such transactions. Finally, banks and other financial institutions often use their direct access to function as a local intermediary for the foreign party transacting the security.

2.2 Securities Market Consolidation in Europe - A Case Study

The introduction of a single currency for the Euro-area from 1998 onwards prompted a process of consolidation within the infrastructure of European securities markets. We give here a brief overview over this process. Our goal is to demonstrate that questions regarding the ownership and structure of clearing and settlement arrangements decisively shaped this process.

There are two recent examples from the European experience that indicate why some consolidation was successful, while other developments are still unresolved. The first one is the successful merger between the Amsterdam, Bruxelles and Paris stock exchanges labelled Euronext. The second one is the failed creation of iX, a merger of Deutsche Börse (DB) and the London Stock Exchange (LSE). In both cases it is striking that settlement arrangements played seemingly an important - if not decisive - role for the outcome of the merger.

As early as 1998, the LSE and DB expressed their intention to form a joint trading platform called iX to consolidate the nationally orientated exchanges. Spurred by the promise of huge cost savings[4] the move gathered momentum quickly with six other European exchanges (Amsterdam, Bruxelles, Madrid, Milan, Paris, Swiss) joining the plan until May, 1999. During the merger talks between the exchanges, a parallel process was initiated in the area of back office operations. CEDEL, an internationally operating settlement agent merged with DB Clearing in July 1999 to form Clearstream. Shortly after, DB bought a controlling stake

[4]The LSE for example estimates the total cost savings from consolidation of clearing and settlement in Europe to be around 1.6bn Euro per year (LSE, 2002).

(50%) in Clearstream to set up a vertically integrated exchange in Germany.

This move coincides with a reorientation of some other stock exchanges. First, Euronext was launched in March 2000, when Sicovam, the CSD of the Paris stock exchange, broke off merger talks with Clearstream. Shortly afterwards, the iX merger failed seemingly over problems with finding the right arrangement on the settlement layer. The Financial Times reported in their July, 20th 2000 edition that

> "Clearstream and Crest [the settlement agent for London's securities markets] would make an announcement at the end of August on what clearing and settlement service they intended to offer to users of ... iX. Shareholders of the two exchanges are already agitating for answers to that essential question. It seems likely that the solution to be offered will be interim. Such a step would be unlikely to offer the cost savings that iX is promising,..."

While the iX merger failed, the Euronext merger was completed by September 2000. The key step was to consolidate clearing and settlement in an independent entity. This was achieved through incorporating the French, Dutch and Belgian CSDs into Euroclear, the second major international settlement agent. Euronext has expanded recently to include the Lisbon exchange as well as the LIFFE, a London based future and derivatives exchange. Both these acquisitions were accompanied by the merger of the settlement agents, Interbolsa and Crest, with Euroclear. Finally, in June 2003, the clearing arrangements for Euronext were consolidated by merging Clearnet, the former French CPP, with its London counterpart, the London Clearing House (LCH).

Looking back at this experience one is struck by the evidence that the success for consolidation rested upon finding a solution for merging not only trading, but also settlement and clearing arrangements.[5] DB's strategy of erecting a vertical silo seemed to be the main reason that

[5] As the Financial Times noted on July, 14th 2000, "...[The] integration of Euronext for trading, settlement and clearing will probably be faster and easier to achieve than for the proposed iX merger...[which] still has to decide whether it will rely on Crest ... or Clearstream to settle equities. . experts question whether this is feasible in practice." On October 25th, 1999 it was stated that "At the heart of the problem has been

prevented a potential merger to realize efficiency gains between LSE and DB. This is backed best by a recent statement issued by the LSE (LSE, 2002).

> "...[The] optimal solution is to create a single system ... that is run as a 'utility' and is independent of exchanges and other trading platforms. (p.8) ... Action is required to impose the separation of trading platforms and clearing and settlement activities. Vertical silos, especially if run as for-profit businesses, have perverse incentives ... to prevent interoperability and further consolidation at the clearing and settlement level. Breaking up these silos and separating trading platforms from clearing and settlement systems is a vital preliminary step towards establishing an efficient market structure. (p.21)"

Why was the Euronext merger then successful? The answer seems again to be buried in the back office structures. Euroclear was an independent entity from the start. After the acquisition of Clearstream by DB, it was the natural catalyst for moving from vertical to horizontal integration for the Euronext project. The vertical silo structure of DB to the contrary was a clear disadvantage in leading a consolidation process. As Pierre Francotte, CEO of Euroclear, expressed it when defending the company's approach,

> "Euroclear believes that horizontal integration, with users rather than stock exchanges owning and governing the settlement service providers, is the best way of achieving the market's objectives of lower transaction costs and higher efficiency. However, until such time that a pan-European settlement solution is in place, it is essential for users to have a choice of settlement location for their trade. ... The vertical silo approach - where stock exchanges own and govern their clearing and settlement houses - makes settlement location more difficult to achieve. Which stock exchange or CCP will want to feed business and revenues to a settlement house that is owned and controlled by one of its competitors?" (The Banker, June 1st, 2002)

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disagreement between London and Frankfurt over which electronic trading platform and which clearing and settlement system to choose."

Even though these statements obviously reflect particular interests, we feel that they highlight three important factors. First, major gains from horizontal consolidation of security markets arise in form of cost savings in the area of back office operations. Second, ownership of settlement and clearing operations by exchanges can be an impediment to realize these gains. Third, breaking up vertically integrated exchanges can be a way to capture the gains from horizontal consolidation.

3 Environment

We confirm our assessment now by analyzing a simple model that investigates whether vertically integrated firms can capture all gains from horizontal consolidation. We consider an economy with two firms, $i = 1, 2$, owned by player i. Each firm produces a service, which encompasses production of a final product (here carrying out a trade on a stock exchange) and distributing the product (here clearing and settling a trade). The cost for a firm of running the trading platform is normalized to 0 while the cost of running the settlement platform is θ_i, distributed according to a common density function f with support $[0, 1]$. We assume that θ_i is private information of player i.

Each firm is assumed to be initially vertically integrated. If a trade takes place on platform i, it has to be settled on platform i. For simplicity, we assume that each firm faces a demand D_i taking the following form: $D_i = 1$ if $p_i \leq \bar{p}$ and zero otherwise.[6] Hence, there is no substitution between the products of the two firms and the demand is inelastic up to price $\bar{p}$. The profit of player i from operating the firm is $\tilde{\Pi}_i(\theta_i) = \bar{p} - \theta_i$. Note that the price does not reveal the cost of settlement. Hence, player j cannot observe the cost θ_i from the price firm j quotes for trading plus settlement. We assume that $\bar{p} > 1$.[7]

If the two firms merge, they can realize an additional demand equal to $d \geq 0$. Total demand

[6] We do not model here any benefits from vertical integration, since these are neither driving nor preventing our results.

[7] This assumption can be interpreted as the firms operating in segmented markets offering a single, indivisible good. We discuss this assumption in more detail in the last section of the paper.

for the merged firms is then given by $2 + d$ if $p \leq \bar{p}$ and 0 otherwise. Hence, there are two potential gains from merging. First, the players could merge the firms and realize the extra demand if $d > 0$. Second, if θ_1 and θ_2 are different the merged firm could offer settlement for all the demand at lower cost. Thus, if the costs were common knowledge, then firm 1 and 2 would merge, satisfy the joint demand of $2 + d$ at a price $p = \bar{p}$, produce settlement at $\min\{\theta_i, \theta_j\}$ and realize in all cases a joint profit that is larger than the sum of individual profits. Costs θ_i are private information, however, and can not be discovered by merging the two firms. This means that the costs do not become common knowledge for the players after a merger between the firms is completed.[8]

4 Impossibility of Ex-Post Efficient Mergers

The benefits from merging can only be exploited if settlement costs are known. In this section we show that private information on the costs of settlement renders an efficient merger impossible independent of d. For an efficient merger the additional benefits arise in part from the use of the most efficient settlement system. These benefits have to be shared among the two firms with the size of the benefits depending on the difference of settlement costs between the two firms. With θ_i being private information, how these profits are shared can, however, only depend on the costs the firms announce. Hence, a firm can influence its share of the profit through its announcement of costs. Unless the sharing rule can elicit truthful revelation of costs, an efficient merger is then not possible.

Using ideas from mechanism design we ask whether there exists a mechanism that can implement the use of the most efficient settlement platform after the merger between the firms has taken place. Invoking the revelation principle, we restrict ourselves to studying direct mechanisms where firms only make a cost announcement. A direct mechanism is a function $M = (t, y)$ that specifies for each announcement $\theta = (\theta_1, \theta_2)$ a transfer rule $t(\theta) = (t_1(\theta), t_2(\theta))$ and an allocation rule $y(\theta) = (y_1(\theta), y_2(\theta))$ of settlement operations. Given θ, the payoff for

[8]The often intricate nature of settlement and clearing procedures make it difficult to identify the true costs of any particular arrangement (see for example Giovannini, 2001 and 2003).

each player is then given by $\Pi_i(t, y|\theta) = t_i(\theta) - (2 + d)y_i(\theta)\theta_i$. We define further that a mechanism is *Bayesian incentive-compatible* if for each i, j such that θ_i is the true type of i and θ_j is the true type of j,

$$\int t_i(\theta_i, \theta_j) - (2+d)y_i(\theta_i, \theta_j)\theta_i dF(\theta_j) \geq \int t_i(\theta_i', \theta_j) - (2+d)y_i(\theta_i', \theta_j)\theta_i dF(\theta_j) \quad \text{for all } \theta_i'. \tag{1}$$

Next, a mechanism is *feasible* if, first, it is individually rational, i.e., the expected profit for each player from merging is at least as high as the profit from not merging,

$$\int \Pi_i(t, y|\theta_i, \theta_j) f(\theta_j) d\theta_j \geq \tilde{\Pi}_i(\theta_i), \tag{2}$$

second, the whole return from the merged firms are distributed between the players

$$t_1(\theta) + t_2(\theta) = (2 + d)\bar{p}, \tag{3}$$

third, transfers are feasible, i.e., positive,

$$t_i(\theta) \geq 0 \text{ for all } \theta, \tag{4}$$

since we assume that the players do not have initial wealth[9] and

$$\sum_{i=1}^{2} y_i(\theta) = 1 \text{ for all } \theta, \tag{5}$$

where $y_i(\theta) \geq 0$ for all i.

Finally, an allocation is *ex-post efficient* if the settlement platform with the lowest cost carries out settlement, i.e.,

$$y_i(\theta) = 1 \text{ if } \theta_i \leq \theta_j \text{ and } 0 \text{ otherwise.} \tag{6}$$

In the sequel we will abuse language slightly by using 'ex-post efficient merger' instead of 'ex-post efficient allocation' of settlement activities. We then have the following impossibility result which is an application of a result due to Myerson and Satterthwaite (1983).

Proposition 1. *There is no incentive-compatible and feasible mechanism that implements an ex-post efficient merger between the two firms.*

[9]Note, however, from the definition of Π_i that the players' payoffs can be negative.

Proof. Suppose that there exists an incentive compatible and feasible mechanism (t, y), where y is ex-post efficient. Define the expected payoff of type θ_i from taking part in the mechanism given type j reveals his type truthfully as $\bar{\Pi}_i(t, y|\theta_i) = \int \Pi_i(t, y|\theta_i, \theta_j) f(\theta_j) d\theta_j$. Also define the expected probability to produce of a type θ_i given j reveals his type truthfully as $\bar{y}_i(\theta_i) = \int y_i(\theta_i, \theta_j) f(\theta_j) d\theta_j$. Similarly, define the expected transfer to a type θ_i as $\bar{t}_i(\theta_i) = \int t_i(\theta_i, \theta_j) f(\theta_j) d\theta_j$. From the incentive compatibility constraint (1) we have for all θ_i and θ_i'

$$\begin{aligned}
\bar{\Pi}_i(t, y|\theta_i) = \bar{t}_i(\theta_i) - (2+d)\bar{y}_i(\theta_i)\theta_i &\geq \bar{t}_i(\theta_i') - (2+d)\bar{y}_i(\theta_i')\theta_i \\
\bar{\Pi}_i(t, y|\theta_i') = \bar{t}_i(\theta_i') - (2+d)\bar{y}_i(\theta_i')\theta_i' &\geq \bar{t}_i(\theta_i) - (2+d)\bar{y}_i(\theta_i)\theta_i'.
\end{aligned}$$

Therefore,

$$(2+d)\bar{y}_i(\theta_i)(\theta_i' - \theta_i) \geq \bar{\Pi}_i(t, y|\theta_i) - \bar{\Pi}_i(t, y|\theta_i') \geq (2+d)\bar{y}_i(\theta_i')(\theta_i' - \theta_i)$$

which shows that $\bar{y}_i(\theta_i)$ is non-increasing. Setting $\theta_i' = \theta_i + \varepsilon$ and letting ε converge to zero, we obtain

$$\frac{\partial \bar{\Pi}_i(t, y|\theta_i)}{\partial \theta_i} = -(2+d)\bar{y}_i(\theta_i).$$

Hence we have that $\bar{\Pi}_i(t, y|\theta_i) = \bar{\Pi}_i(t, y|s_i) - \int_{s_i}^{\theta_i} (2+d)\bar{y}(v_i) dv_i$.

From the definition of expected transfer we obtain

$$\begin{aligned}
\int_0^1 \bar{t}_i(\theta_i) f(\theta_i) d\theta_i &= \int_0^1 \left(\bar{\Pi}_i(t, y|\theta_i) + (2+d)\bar{y}_i(\theta_i)\theta_i\right) f(\theta_i) d\theta_i \\
&= \int_0^1 \left(\bar{\Pi}_i(t, y|s_i) - (2+d)\left[\int_{s_i}^{\theta_i} \bar{y}_i(v_i) dv_i\right] + (2+d)\bar{y}_i(\theta_i)\theta_i\right) f(\theta_i) d\theta_i \\
&= \bar{\Pi}_i(t, y|s_i) + (2+d)\int_0^1 \left(\bar{y}_i(\theta_i)\theta_i - \int_{s_i}^{\theta_i} \bar{y}_i(v_i) dv_i\right) f(\theta_i) d\theta_i \\
&= \bar{\Pi}_i(t, y|s_i) + (2+d)\int_0^1 \bar{y}_i(\theta_i)\Psi(\theta_i, s_i) f(\theta_i) d\theta_i
\end{aligned}$$

where $\Psi(\theta_i, s_i) = \theta_i - \frac{1-F(\theta_i)}{f(\theta_i)}$ if $s_i < \theta_i$ and $\theta_i + \frac{F(\theta_i)}{f(\theta_i)}$ if $s_i > \theta_i$.

Using ex-post efficiency, this implies that the expected payoff for a given type s_i is given by

$$
\begin{aligned}
&\bar{\Pi}_i(t, y|s_i) = \\
= \quad & \int_0^1 \bar{t}_i(\theta_i) f(\theta_i) d\theta_i - (2+d) \int_0^1 \bar{y}_i(\theta_i) \Psi(\theta_i, s_i) f(\theta_i) d\theta_i \\
= \quad & \int_0^1 \bar{t}_i(\theta_i) f(\theta_i) d\theta_i - (2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i + \int_0^{s_i} \bar{y}_i(\theta_i) F(\theta_i) d\theta_i - \int_{s_i}^1 (1 - F(\theta_i)) \bar{y}_i(\theta_i) d\theta_i \right] \\
= \quad & \int_0^1 \bar{t}_i(\theta_i) f(\theta_i) d\theta_i - (2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i + \int_0^1 (1 - F(\theta_i)) F(\theta_i) d\theta_i - \int_{s_i}^1 (1 - F(\theta_i)) d\theta_i \right] \\
= \quad & \int_0^1 \bar{t}_i(\theta_i) f(\theta_i) d\theta_i + (2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i - [E(\theta_i|\theta_i \le s_i) + s_i(1 - F(s_i))] \right].
\end{aligned}
$$

Hence, the expected payoff of type s_i is equal to the average pay-off for player i plus the surplus his information creates.

Now, let $s_i = 0$ for all i. That is we consider the type of firms that have the least benefit from merging as they are the most efficient. Total transfers are then given by

$$
\begin{aligned}
\int t_1(\theta) + t_2(\theta) f(\theta) d\theta \quad &= \quad \int \bar{t}_1(\theta_1) f(\theta_1) d\theta_1 + \int \bar{t}_2(\theta_2) f(\theta_2) d\theta_2 \\
&= \quad \bar{\Pi}_1(t, y|0) + \bar{\Pi}_2(t, y|0) - 2(2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i \right].
\end{aligned}
$$

From feasibility we have $t_1(\theta) + t_2(\theta) = (2+d)\bar{p}$ for all θ so that

$$
\int t_1(\theta) + t_2(\theta) f(\theta) d\theta = (2+d)\bar{p}.
$$

This implies that

$$
\bar{\Pi}_1(t, y|0) + \bar{\Pi}_2(t, y|0) - 2(2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i \right] = (2+d)\bar{p}.
$$

Since both firms have zero cost, the expected profit from an ex-post efficient merger to be shared is the full return $(2+d)\bar{p}$. Therefore, when both firms have zero cost it must be that $\bar{\Pi}_1(t, y|0) + \bar{\Pi}_2(t, y|0) = (2+d)\bar{p}$. This gives a contradiction since $\bar{\Pi}_1(t, y|0) + \bar{\Pi}_2(t, y|0) = (2+d)\bar{p} + 2(2+d) \left[\int_0^1 \bar{y}_i(\theta_i) \theta_i f(\theta_i) d\theta_i \right] > (2+d)\bar{p}$. □

This result shows that an ex-post efficient merger can not be implemented between the two firms because the incentives of misrepresenting their own costs are too strong. The intuition of the result is simple. A feasible mechanism that implements an ex-post efficient merger must specify a transfer that will redistribute the *overall* profit from production while ensuring that the lowest cost producer will carry out production. Eliciting truth-telling is however costly. For instance, a low cost firm, has an incentive to announce higher than its true costs. In doing so, it is still likely to produce and, by pretending that costs are higher, it causes total profits from the cost savings to appear lower than they are. This difference between apparent profits and true profits fully accrues to the producing firm. Hence misrepresenting costs affects the transfers, but also the remaining profit that a firm can keep for itself.

Our assumption on limited liability implies that truth-telling can only be elicited using the revenue from the merger $(2 + d)\bar{p}$. This is independent of costs. Hence, what is promised to one firm to elicit truthful revelation is not available to set up the incentives of the other firm right. As a consequence, for certain combinations of costs, the total revenue from the merger may not be enough to elicit truth-telling for both firms. In other words, as the mechanism has to distribute *all* the revenue between the two firms, it is impossible to design transfers that distribute all the revenue while giving both firms appropriate incentives to truthfully reveal their costs.

An interesting property is that the impossibility result does not depend on the magnitude of the additional demand d. The reason is that d is known by both firms and is not affected by the true costs of the producing firm. Since the total revenue from merging including the additional revenue $\bar{p}d$ must be split between the two firms, transfers always have to include all revenue. As firms are risk neutral, the severity of the incentive problem is unaffected by the magnitude of d. Hence, the costs of eliciting the truth is independent of d. Therefore, the efficient merger is as difficult to implement when $d > 0$ as when $d = 0$.

From the proof of Proposition 1, we can infer, however, that a subsidy can implement a merger ex-post efficiently. Since a subsidy can depend on the firms' announcements, the revenue from the merger plus the subsidy can vary with the announced costs. Whenever the subsidy is decreasing with the cost one can counteract the incentive to report a high cost in order to get a higher payoff. Hence, by changing the total revenue that can be shared between the firms, a subsidy will enable the firms to overcome the informational problem. This is what we show in the next result, where we assume for simplicity that f is the uniform distribution on $[0,1]$.

Proposition 2. *There exists a subsidy schedule $s_i(\theta)$ for all θ and all i, such that an ex-post efficient merger is implementable. Furthermore, there exists $d^*(\bar{p}) > 0$ such that, for $d > d^*(\bar{p})$, an ex-post efficient merger can be implemented with $s_i(\theta) \leq 0$ for all θ and all i. Finally, $d^*(\bar{p}) \to \infty$ as $\bar{p} \to 1$.*

Proof. We now set the transfers to be $t_i(\theta) = \tau_i(\theta) + s_i(\theta)$, where $\tau_i(\cdot)$ is the sharing rule of the return from the merger and $s_i(\cdot)$ is the subsidy received. Hence, $\bar{\tau}_i(\theta_i) + \bar{\tau}_j(\theta_j) = (2+d)\bar{p}$ for all θ_i and θ_j. Using a standard result of implementation theory an ex-post efficient merger is implementable if and only if, for all i

- the function $(2+d)\bar{y}_i(\theta_i)$ is non-increasing,
- $\bar{\Pi}_i(t,y|\theta_i) = \bar{\Pi}_i(t,y|0) - \int_0^{\theta_i}(2+d)\bar{y}_i(v_i)dv_i$ for all $\theta_i \in [0,1]$ and
- $\bar{\Pi}_i(t,y|\theta_i) \geq \bar{p} - \theta_i$.

where $y_i(\theta)$ is ex post efficient. Since $y_i(\theta)$ is ex post efficient, the first condition is clearly fulfilled.

We will now derive conditions on $t_i(\cdot)$ such that the last two conditions hold. The second condition implies for $y_i(\theta)$ being ex-post efficient that $\bar{\Pi}_i(t,y|\theta_i) - \bar{\Pi}_i(t,y|0) = -(2+d)(\theta_i - \theta_i^2/2)$. Furthermore, by definition of the average pay-off for type θ_i we have $\bar{\Pi}_i(t,y|\theta_i) = \bar{t}_i(\theta_i) - \theta_i(2+d)(1-\theta_i)$ for all θ. Thus the second condition is equivalent to

$$\bar{t}_i(\theta_i) = \bar{t}_i(0) - (2+d)\frac{\theta_i^2}{2}.$$

Hence,

$$\begin{aligned}
\bar{t}_i(\theta_i) + \bar{t}_j(\theta_j) &= \bar{t}_i(0) + \bar{t}_j(0) - \frac{\theta_i^2 + \theta_j^2}{2}(2+d) \\
&= \bar{s}_i(0) + \bar{s}_j(0) + (2+d)\left[\bar{p} - \frac{\theta_i^2 + \theta_j^2}{2}\right].
\end{aligned}$$

Since, by definition, $\bar{t}_i(\theta_i) + \bar{t}_j(\theta_j) = (2+d)\bar{p} + \bar{s}_i(\theta_i) + \bar{s}_j(\theta_j)$, we obtain

$$\bar{s}_i(\theta_i) + \bar{s}_j(\theta_j) = \bar{s}_i(0) + \bar{s}_j(0) - \frac{\theta_i^2 + \theta_j^2}{2}(2+d),$$

where $\bar{s}_i(\theta_i)$ is the expected subsidy received by type θ_i. Using symmetry, we can then set the subsidy equal to

$$\bar{s}_i(\theta_i) = \bar{s}_i(0) - \frac{\theta_i^2}{2}(2+d)$$

and the sharing rule equal to

$$\bar{\tau}_i(\theta_i) = \frac{(2+d)\bar{p}}{2}.$$

For the third condition to be fulfilled, we need $\bar{s}_i(0)$ to be large enough for all i. Indeed, using the expressions for $\bar{s}_i(\theta_i)$ and $\bar{\tau}_i(\theta_i)$, the individual rationality constraint of firm i can be rewritten as

$$\bar{\tau}_i(0) + \bar{s}_i(0) \geq \bar{p} + (1+d)\theta_i - (2+d)\frac{\theta_i^2}{2}$$

where the right hand side is maximized at $\theta^* = (1+d)/(2+d)$. Since $\bar{\tau}_i(0) = (2+d)\bar{p}/2$, we get

$$\bar{s}_i(0) \geq \frac{(1+d)^2}{2(2+d)} - \frac{d}{2}\bar{p}.$$

Hence, an ex-post efficient merger is implementable with a schedule of transfers $\{t_1(\theta), t_2(\theta)\}$ such that $\bar{t}_i(\theta_i) = \bar{\tau}_i(\theta) + \bar{s}_i(\theta)$ where $\bar{\tau}_i(\theta_i)$ and $\bar{s}_i(\theta_i)$ satisfy the expressions given above. This proves the first part of Proposition 2. To prove the second part, notice that so far we imposed no restriction on the sign of $\bar{s}_i(\theta_i)$. Hence, we obtain the result by setting $\bar{s}_i(0) \leq 0$ and using the expression above to define $\bar{s}_i(\theta_i)$. Since $\bar{s}_i(0) \geq \frac{(1+d)^2}{2(2+d)} - \frac{d}{2}\bar{p}$, we must have $\frac{(1+d)^2}{2(2+d)} - \frac{d}{2}\bar{p} \leq 0$, where the left hand side is decreasing in d. The remainder of the result then follows. $\square$

This proof clarifies further the impossibility result by fully characterizing the symmetric subsidy needed for establishing ex-post efficiency. To balance the incentives of obtaining a higher share of revenue by claiming higher costs, one has to decrease payoffs net of settlement costs just fast enough with the announced costs. This is best demonstrated when looking at a negative subsidy or a tax.

Taxing the revenues after the merger reduces the total revenue available for the two players. By decreasing the pay-offs net of costs appropriately with the announced costs, players do not have an incentive to lie anymore. This was not possible when revenues were constant at $(2 + d)\bar{p}$. There, decreasing the share for one player means increasing the share of the other player. Hence, it is impossible to design the incentive structure simultaneously for both players if all revenues have to be shared. In other words, with a tax (or subsidy) one can separate the effects of an announcement of one player on the other and vice versa.

Of course, when taxing the players one might violate individual rationality. Given $\bar{p}$, this is the case when the gains in revenue from the merger as expressed by d are sufficiently low. Whenever this is the case, however, a subsidy can still achieve ex-post efficiency, because one can just make participation more attractive by adding a constant lump sum transfer without affecting incentives.

5 Achieving Efficiency: Market Solutions

In this section, we explore a second way to implement an ex-post efficient merger. The key idea is here to rely on market solutions where competition leads to prices fully revealing costs. We assume here that each player can delegate settlement activities to an insider who knows the costs and competes for carrying out settlement of all post-merger trades. If these agents have an incentive to reveal the costs when competing for the market, efficient settlement will occur.

We also show in this section that alternatively a regulator can *force* the two vertically integrated firms to compete for the total market. This is important for two reasons. First, it provides an alternative to splitting up the two silos which might not be optimal if there are gains from vertical integration. Second, it demonstrates that splitting up the silos is key for getting the two firms participating voluntarily in a merger.

5.1 A Bertrand game between settlement platforms

We first study whether agents that compete for the market choose a pricing strategy that fully reveals costs of settlement. Let p_i be the price set by agent i running settlement platform

i. For later reference, we assume that agent i can retain a share $\alpha_i \in (0,1]$ of profits. Since the platform with the lowest price will get all the demand for settlement, the payoff of agent i is then given by

$$u_i(p_i,p_j) = \alpha_i(2+d)\begin{cases}(p_i-\theta_i) & \text{if } p_i < p_j\\ (p_i-\theta_i)/2 & \text{if } p_i = p_j\\ 0 & \text{if } p_i > p_j.\end{cases} \tag{7}$$

We consider the Bayesian Nash equilibria of a game where both agents simultaneously announce a price p_i: For all θ_i, agent i has to choose a price $p_i(\theta_i)$ that is a best response to the price schedule $p_j(\cdot)$ of agent j given the distribution of θ_j which we choose to be uniform for this section. Hence, agent i chooses $p_i(\theta_i)$ to solve

$$\begin{aligned} p_i(\theta_i) &= \arg\max_{p_i} \quad \int_{\{\theta_j : p_j(\theta_j) > p_i\}} (p_i-\theta_i)d\theta_j + \int_{\{\theta_j : p_j(\theta_j) = p_i\}} \frac{1}{2}(p_i-\theta_i)d\theta_j \\ &= \arg\max_{p_i} \quad (p_i-\theta_i)P\big(p_j(\theta_j) > p_i\big) + \frac{1}{2}(p_i-\theta_i)P\big(p_j(\theta_j) = p_i\big), \end{aligned} \tag{8}$$

where $P(\mathcal{A})$ denotes the probability of event $\mathcal{A}$. We show next that the price schedule in equilibrium is strictly increasing and, hence, reveals the settlement costs.

Lemma 1. *The equilibrium pricing strategy $p_i(\theta_i)$ is continuous and strictly increasing on $[0,1]$ for all i.*

Proof. See Appendix. □

Even though this result is sufficient to establish that the market solution reveals the costs, we derive a closed form solution for the equilibrium pricing strategies. This will simplify the exposition further. As $p_i(\cdot)$ is strictly increasing, we can define $\phi(p) = p_i^{-1}(p) = \theta_i$ as the inverse function of $p_i(\cdot)$. Since it is monotonic, $\phi(\cdot)$ is differentiable almost everywhere. Setting a price p_i, agent i supplies the whole market if $p_j(\theta_j) > p$, i.e., if $\theta_j > \phi_j(p)$. This occurs with probability $1 - F(\phi_j(p))$, where F is the distribution of θ_j. Hence, we can rewrite agent i's problem (8) as follows

$$\max_p \quad (p-\theta_i)[1-F(\phi_j(p))]. \tag{9}$$

Using the fact that $\theta_i = \phi_i(p)$, that $F(\cdot)$ is uniform and the first order condition for the above problem, we obtain

$$\phi_j(p) = 1 + (\phi_i(p) - p)\phi_j'(p). \tag{10}$$

Lemma 2. *The equilibrium strategies are symmetric, i.e., $\phi_i(p) = \phi_j(p) \equiv \phi(p)$ for all p and $\phi(1) = 1$.*

Proof. See Appendix. □

Given symmetry, equation (10) can be written as $\phi(p) = 1+(\phi(p)-p)\phi'(p)$ and since $\phi(1) = 1$ we obtain that the unique solution to this differential equation is $\phi(p) = 2p - 1$. Hence, the best response function for all agents satisfies $p_i(\theta_i) = (\theta_i + 1)/2$.

5.2 Implementing the market solution

We investigate whether it is optimal for the players to separate trading from settlement in order to fully realize the gains from merging. A market mechanism specifies an action set A_i for each player i and a market outcome function. The market outcome function describes whether a merger takes place and whether the players separate trading and settlement. Furthermore, it specifies transfers to the players, the allocation of production in terms of the prices quoted by the agents and the profit share the agents obtain. Hence, we denote the outcome function by a quadruple $(m, t, y, \alpha)(a, p)$, that expresses all these variables as functions of the players' actions $a = (a_1, a_2) \in A_1 \times A_2$ and the prices $p = (p_1, p_2) \in I\!R_+^2$ resulting from the Bertrand Game between the agents.

The function $m(a, p) \in \{0, 1\}$ describes then whether players delegated the operation of the settlement platform to agents and whether a merger takes place. We let $m(a, p) = 1$ express the fact that a merger takes place and agents are hired to operate the settlement platforms.

A market outcome is *feasible for* $m = 0$ if, for all $a \in A$ such that $m = 0$, $t_i(a, p) = \bar{p}$, $\alpha_i(a, p) = 0$ and $y_i(a, p) = 1$ for all i. Hence, if a merger does not take place, each firm settles its own trades and transfers are given by the revenue from trading.

Note that after the merger and after splitting off the settlement platforms, total profits (and, hence, transfers) consist of the revenue from trading, $(2+d)\bar{p}$ and the profits from the settlement operations minus the costs from paying for settlement p_i and the fees paid to the agents. A market outcome is *feasible for* $m = 1$ if, for all $a \in A$ such that $m = 1$, transfer schedules are restricted by limited wealth, i.e.,

$$t_i(a, p) \geq 0 \tag{11}$$

for all i,

$$\sum_{i=1}^{2} y_i(a, p) = 1 \tag{12}$$

and transfer schedules distribute all revenues from the merger between the players,

$$t_1(a, p) + t_2(a, p) = (2 + d)[\bar{p} - \sum_{i=1}^{2} y_i(a, p)p_i + \sum_{i=1}^{2}(1 - \alpha_i(a, p))y_i(a, p)(p_i - \theta_i))]. \tag{13}$$

Finally, we say that a market outcome is *feasible* if it is feasible for $m = 0$ and $m = 1$. We then have the following definition.

Definition 1. *A market outcome* (m, t, y, α) *is strongly implementable if it is feasible and the unique perfect equilibrium of a market mechanism.*

Note that this definition requires that the market outcome is the equilibrium outcome *for all* strategies of the players that form an equilibrium that is trembling-hand perfect. Whenever the settlement systems are run separately by agents that obtain a strictly positive share of the profit $(m = 1)$, we have shown that prices $p_i(\theta_i)$ are strictly increasing in θ_i. Hence, prices fully reveal the costs of settlement. Hence, ex-post efficiency requires that $y_i(a, p) = 1$ if and only if $p_i < p_j$. This fact allows us to implement an ex-post efficient merger for all θ.

Proposition 3. *An ex-post efficient merger is strongly implementable as a market outcome.*

Proof. Consider the following mechanism. Define the action sets of player i to be $A_i = \{0, 1\}$ for all i. If any player i chooses $a_i = 0$, set $m((0, a_j), p) = 0$ (i.e. no merger takes place and no agent is hired), $t_i((0, a_j), p) = \bar{p}$, $y_i((0, a_j), p) = 1$ and $\alpha_i((0, a_j), p) = 0$. Player i's payoff is then $\bar{p} - \theta_i$. We have to show that player i obtains a strictly higher pay-off from choosing $a_i = 1$ if the other player also chooses $a_j = 1$.

If both players choose 1, set $m(\mathbf{1}, p) = 1$. Set $\alpha_1 = \alpha_2 = \alpha > 0$. Given agent i obtains a share of profits from settlement equal to $\alpha > 0$, she strictly prefers to maximize profits and quote the Bertrand equilibrium price p_i which is strictly increasing in θ_i by Proposition 1. Hence, we can express transfers and settlement decisions equivalently as functions of θ, where $p_i = \frac{\theta_i + 1}{2}$ for all i. Hence, we can set $y_i(a, p) = 1$ if and only if $p_i < p_j$.

Consider transfers for both players given by

$$t_i(\mathbf{1}, \theta) = \frac{(2+d)}{2}(\bar{p} - \theta_i) + \Delta(\theta)/2$$

for all i, where $\Delta(\theta)$ is the total net gain from paying the agents and realizing the cost savings given by

$$\begin{aligned}
\Delta(\theta) &\equiv (2+d) \sum_{i,j} \left[\frac{1}{2}\theta_i - y_i(\mathbf{1}, \theta) p_i + (1 - \alpha_i)[y_i(\mathbf{1}, \theta)(p_i - \theta_i) \right] \\
&= (2+d) \sum_{i,j} \left[\frac{1}{2}\theta_i - y_i(\mathbf{1}, \theta)\theta_i - \alpha_i y_i(\mathbf{1}, \theta) \frac{(1 - \theta_i)}{2} \right].
\end{aligned}$$

Then, independent of d, $t_i(\mathbf{1}, \theta) > 0$ for all θ as long as α is close enough to 0, since $\bar{p} > 1$. Note also, that by definition of $\Delta(\theta)$ all revenue is distributed among the two players. Hence, the market mechanism we specified is feasible.

Finally, strong implementation in perfect Bayesian Nash equilibrium requires strong individual rationality. Hence, we have to verify that

$$\int t_i(\mathbf{1}, \theta) d\theta_j = (1 + \frac{d}{2})(\bar{p} - \theta_i) + \int \frac{\Delta(\theta)}{2} d\theta_j > (\bar{p} - \theta_i)$$

for all θ_i. Since ex-post efficiency requires $y_i(\mathbf{1}, \theta) = 1$ if and only if $\theta_i \leq \theta_j$, we have

$$\begin{aligned}
\int \Delta(\theta) d\theta_j &= (2+d) \left[\frac{1}{4} - \frac{\theta_i}{2}(1 - \theta_i) - \alpha \left(\int_{\{\theta_i < \theta_j\}} \frac{(1 - \theta_i)}{2} d\theta_j + \int_{\{\theta_i > \theta_j\}} \frac{(1 - \theta_j)}{2} d\theta_j \right) \right] \\
&= \frac{2+d}{2} \left[\frac{1}{2} - \theta_i(1 - \theta_i) - \alpha(1 - \theta_i + \frac{\theta_i^2}{2}) \right]
\end{aligned}$$

for all θ_i. This expression is minimized for $\theta_i^* = (1 - \alpha)/(2 - \alpha)$. Hence, for α low enough this expression is strictly positive for θ_i^* which concludes the proof. □

The intuition for this result is as follows. If the firms decide to cast off their settlement platforms and merge, the merged platform will purchase settlement as an input in its production for a price $\min\{p_i, p_j\}$. Provided their profit share is strictly positive, the agents prefer to truthfully reveal the costs by quoting the Bertrand price. Hence, settlement can be provided efficiently at the lowest cost and total profits can be shared within the merged firm through transfers depending on the true costs.

It is crucial here that the agent has an incentive to quote the Bertrand price while the players do not have to monitor the agent. This is achieved by giving the agent a strictly positive share of the profits. Furthermore, this also allows the players to tie their hands, i.e., they can credibly commit not to exploit their informational advantage. Hence, by delegating the operation of settlement platforms to agents that share the profits, the players are able to overcome the barriers that prevented the ex-post efficient merger.

Finally, observe that the result is true even if there are only gains from cost savings when the firms merge, i.e., if $d = 0$. Even though there are no gains in revenue if $\theta_i = \theta_j$, this event has measure 0 *for all* $\theta_i \in [0, 1]$. Hence, the expected gain from merging is always strictly positive and the agent can be promised a strictly positive share ($\alpha > 0$) of profits from settlement without making an expected loss from separating trading and settlement. The agents also will participate, since their expected payoff from running the settlement platform *before* they learn θ_i is strictly positive. This is due to the fact that the event $\theta_i = 1$ has measure 0 and serving all the market has positive probability for all $\theta_i < 1$.

5.3 An alternative: cross-listing

These results raise the question whether direct competition between the vertically integrated firms could also lead to efficiency. Such competition could for example be implemented by requiring that both firms can serve the whole market with demand $(2 + d)$ without merging. The analog in the context of securities exchanges would be the cross-listing of securities. This allows for switching trading and clearing from one to another exchange.

Suppose for the moment that the two firms are *forced* to compete for the whole market, i.e. are required to cross-list the securities.[10] Then, taking total demand $(2 + d)$ as given, if firm i quotes a price p_i for trading and settlement, its profits are given by equation (7) with $\alpha_i = 1$. Hence, Proposition 1 applies without changes and the optimal strategy of the resulting Bertrand game between the two firms is again $p_i(\theta_i) = (\theta_i + 1)/2$. This shows that inducing Bertrand competition between the two firms (through requiring cross-listing of securities with full access for market participants to the exchanges) will result in the efficient solution.

However, it is crucial that participation in such a scheme is *not* voluntary. Otherwise, we fall back to the impossibility result. To see why, consider the following game between the two firms. In the first stage, each firm decides whether or not to cross-list. If both firms cross-list, each firm can attract all the demand. If one of the two firms does not cross-list, it can exclude the other firm from bidding for its own demand.

But this implies that we can map this game back into a mechanism which specifies $y_i(\theta) = 1$ if and only if $\theta_i \leq \theta_j$ and $t_i(\theta) = (2 + d)p_i \leq (2 + d)\bar{p}$. Hence, it is not possible to ensure participation of both firms in such a scheme for all θ, since for certain θ one of the firms will block cross-listing.

In other words, if participating in crosslisting is voluntary and a single firm can block cross-listing, there are values for (θ_i, θ_j) such that at least one of the firms does not cross-list or equivalently, does not participate in this mechanism. Hence, the two firms must be forced to participate in the competition while they voluntarily participate in splitting up the silos provided α is low enough.

Requiring competition between silos can nevertheless be a valid alternative to vertical disintegration and merging one layer of the two firms. This is especially true if there are gains from vertical integration in the first place which we do not model. Such a solution also avoids the problem that the profit share α that agents require might be too high rendering an ex-post inefficient merger between the platforms better than merging via a market mechanism.

[10] This is equivalent to letting demand choose between both exchanges.

6 Conclusion

We presented a simple model where ownership structures matter for the efficient consolidation of trading, clearing and settlement platforms, when costs for clearing and settlement are private information. We have purposely abstracted from details pertaining to trading, clearing and settlement operations, as we believe they would not increase our understanding of why efficient consolidation does not take place in this industry, under the circumstances we highlight. Our results are robust to more general specifications of demand functions. Crucial is here only that the true costs of the vertical silos is not immediately fully revealed through the price quoted on the market. Similarly, additional costs from merging will not change our results provided these costs are not too large relative to the expected gains from merging.

Even though we analyze the effect of private information regarding settlement costs, our framework applies directly to a setting where the costs for trading are private information. The interpretation of this paper is then that vertical silos prevent the efficient consolidation of settlement structures. The experiences of the US consolidation of the settlement structures can be seen as evidence for this interpretation of our findings. In the 1970s, the New York Stock Exchange, the American Stock Exchange as well as the National Association of Securities Dealers all operated their own clearing and settlement structures for exchanges originating from their trading platforms. In 1976, these were merged into a new company called the National Securities Clearing Corporation. Over time, the clearance and settlement operations of other regional vertical silos were separated from trading platforms and consolidated with the NSCC.

A different example presents the case of the Nordic exchange, Norex, which is a joint venture of Scandinavian and Icelandic exchanges. Here, only the trading operations are merged, whereas the settlement arrangements are separate and still owned by the respective exchanges. Given our results, this may be interpreted as evidence that a full merger of vertical silos is not possible due to vested interests arising precisely in the area of settlement. The merger of trading operations nevertheless took place due to the prospect of an increase in trading volumes.

To our knowledge, this paper is the first to show that issues of clearing and settlement can be indeed crucial for understanding new developments in the overall organization of financial infrastructures, in particular security exchanges. Similar to payment systems and the monetary system, clearing and settlement operations lie at the heart of efficient financial organization and, thus, will naturally have to receive more attention in the near future.

7 Appendix

Proof of Proposition 1:

Proof. Let $\hat{\theta}_i > \theta_i$. Let $p_i(\theta_i)$ be the equilibrium strategy of agent i having costs θ_i. Then it must be that

$$\begin{aligned}&(p_i(\theta_i)-\theta_i)P\big(p_j(\theta_j)>p_i(\theta_i)\big)+\frac{1}{2}(p_i(\theta_i)-\theta_i)P\big(p_j(\theta_j)=p_i(\theta_i)\big)\\&\quad\geq(p_i(\hat{\theta}_i)-\theta_i)P\big(p_j(\theta_j)>p_i(\hat{\theta}_i)\big)+\frac{1}{2}(p_i(\hat{\theta}_i)-\theta_i)P\big(p_j(\theta_j)=p_i(\hat{\theta}_i)\big)\end{aligned}$$

which is equivalent to

$$\begin{aligned}&(p_i(\theta_i)-\theta_i)P\big(p_j(\theta_j)>p_i(\theta_i)\big)+(p_i(\theta_i)-\theta_i)P\big(p_j(\theta_j)\geq p_i(\theta_i)\big)\\&\quad\geq(p_i(\hat{\theta}_i)-\theta_i)P\big(p_j(\theta_j)>p_i(\hat{\theta}_i)\big)+(p_i(\hat{\theta}_i)-\theta_i)P\big(p_j(\theta_j)\geq p_i(\hat{\theta}_i)\big).\end{aligned}$$

similarly we must have

$$\begin{aligned}&(p_i(\hat{\theta}_i)-\hat{\theta}_i)P\big(p_j(\theta_j)>p_i(\hat{\theta}_i)\big)+(p_i(\hat{\theta}_i)-\hat{\theta}_i)P\big(p_j(\theta_j)\geq p_i(\hat{\theta}_i)\big)\\&\quad\geq(p_i(\theta_i)-\hat{\theta}_i)P\big(p_j(\theta_j)>p_i(\theta_i)\big)+(p_i(\theta_i)-\hat{\theta}_i)P\big(p_j(\theta_j)\geq p_i(\theta_i)\big).\end{aligned}$$

Subtracting the terms of the second inequality from the ones of the first to preserve inequality, we obtain after collecting terms

$$(\hat{\theta}_i-\theta_i)\Big[P\big(p_j(\theta_j)>p_i(\theta_i)\big)-P\big(p_j(\theta_j)>p_i(\hat{\theta}_i)\big)+P\big(p_j(\theta_j)\geq p_i(\theta_i)\big)-P\big(p_j(\theta_j)\geq p_i(\hat{\theta}_i)\big)\Big]\geq 0.$$

This implies p_i is non-decreasing, since the inequality is only fulfilled if $p_i(\hat{\theta}_i)\geq p_i(\theta_i)$.

Next, we show that the equilibrium strategy $p_i(\theta_i)$ is continuous. Suppose not. Then, there exists $\hat{\theta}_i$ such that $\lim_{\theta_i\uparrow\hat{\theta}_i} p_i(\theta_i)=p'\neq p''=\lim_{\theta_i\downarrow\hat{\theta}_i} p_i(\theta_i)$. Assume that $p_i(\hat{\theta}_i)=p'$. The proof for the other case is identical. Since there is no θ_i that sets $p_i \in (p', p'']$, there does not exist a θ_j that sets $p_j \in (p', p'')$.

Suppose now, $\hat{\theta}_i$ sets a price $p' + \varepsilon < p''$, where $\varepsilon > 0$ and sufficiently small. The additional pay-off for $\hat{\theta}_i$ is given by

$$(p' + \varepsilon - \hat{\theta}_i)P\big(p_j(\theta_j) \geq p''\big) - (p' - \hat{\theta}_i)P\big(p_j(\theta_j) \geq p''\big) - \frac{(p' - \hat{\theta}_i)}{2}P\big(p_j(\theta_j) = p'\big).$$

If $P\big(p_j(\theta_j) = p'\big) = 0$, the additional pay-off is strictly positive.

Suppose $P\big(p_j(\theta_j) = p'\big) > 0$. Then, consider $\hat{\theta}_i$ choosing $p' - \delta$, where $\delta > 0$ and sufficiently small. The additional pay-off is then given by

$$\begin{aligned}
&(p' - \delta - \hat{\theta}_i)P\big(p_j(\theta_j) > p' - \delta\big) + \frac{(p' - \delta - \hat{\theta}_i)}{2}P\big(p_j(\theta_j) = p' - \delta\big) - \\
&\qquad (p' - \hat{\theta}_i)P\big(p_j(\theta_j) > p'\big) - \frac{(p' - \hat{\theta}_i)}{2}P\big(p_j(\theta_j) = p'\big) \\
&\geq (p' - \delta - \hat{\theta}_i)P\big(p' \geq p_j(\theta_j) > p' - \delta\big) - \delta P\big(p_j(\theta_j) > p'\big) - \frac{(p' - \hat{\theta}_i)}{2}P\big(p_j(\theta_j) = p'\big) \\
&\equiv \Gamma(\delta).
\end{aligned}$$

Letting $\delta \to 0$, $\Gamma(\delta) \to \frac{(p' - \hat{\theta}_i)}{2}P\big(p_j(\theta_j) = p'\big) > 0$ by assumption. Hence, for δ close to 0, $\hat{\theta}_i$ is better off setting $p' - \delta$. This implies that it was not optimal for $\hat{\theta}_i$ to set p' in the first place. A contradiction.

Finally, to show that the equilibrium strategy $p_i(\theta_i)$ is strictly increasing, note first that $p_i(\theta_i) \geq \theta_i$ for all θ_i. Otherwise, some θ_i would obtain a negative pay-off which he could improve upon by setting $p_i(\theta_i) = \theta_i$ irrespective of players j strategy. Suppose now that $p_i(\theta_i)$ is constant on some interval, i.e., $p_i(\theta_i) = \tilde{p}$ for $\theta_i \in [\underline{\theta}_i, \overline{\theta}_i]$, $\underline{\theta}_i < \overline{\theta}_i \leq \tilde{p}$. Note that $\tilde{p} > 0$ since otherwise some type in the interval will have a strictly negative pay-off. Consider any type θ_j that sets his best response to $p_j(\theta_j) = \tilde{p} > \theta_j$.

If type θ_j sets a price equal to $\tilde{p} - \varepsilon > \theta_j$, where $\varepsilon > 0$, he obtains an additional payoff equal to

$$\begin{aligned}
&(\tilde{p} - \theta_j)\big[P\big(\tilde{p} \geq p_i(\theta_i) > \tilde{p} - \epsilon\big) + P\big(\tilde{p} > p_i(\theta_i) \geq \tilde{p} - \varepsilon\big)\big] - \\
&\qquad \varepsilon\big[P\big(p_i(\theta_i) > \tilde{p} - \epsilon\big) + P\big(p_i(\theta_i) \geq \tilde{p} - \epsilon\big)\big] > (\tilde{p} - \theta_j)P\big(\tilde{p} \geq p_i(\theta_i) > \tilde{p} - \epsilon\big) - 2\varepsilon.
\end{aligned}$$

Since $\tilde{p} - \theta_j > \varepsilon$ and $P\big(\tilde{p} \geq p_i(\theta_i) > \tilde{p} - \epsilon\big) > P\big(\tilde{p} = p_i(\theta_i)\big) > 0$, the additional payoff is strictly positive for ϵ sufficiently close to 0. Hence, setting $p_j(\theta_j) = \tilde{p}$ can not be optimal for $\theta_j < \tilde{p}$ given the best response $p_i(\cdot)$ of i and we have $p_j(\theta_j) < \tilde{p}$ for all θ_j.

If $\tilde{p} \geq 1$, it follows that for some $\theta_i \in [\underline{\theta}_i, \overline{\theta}_i]$ it is better to set $p_i(\theta_i) < \max_{\theta_j} p_j(\theta_j) \leq \tilde{p}$ for any strategy $p_j(\theta_j) \leq \tilde{p}$. Thus, $p_i(\theta_i) = \tilde{p}$ was not optimal for some θ_i, a contradiction.

Let $\tilde{p} < 1$. Suppose $\theta_j = \tilde{p}$ sets a price equal to $p_j(\tilde{p}) = \tilde{p}$. Then, increasing his price by $\varepsilon > 0$ yields an additional pay-off equal to

$$\varepsilon P\big(p_i(\theta_i) > \tilde{p} + \varepsilon\big) + \frac{\varepsilon}{2} P\big(p_i(\theta_i) = \tilde{p} + \varepsilon\big)$$

which is strictly positive for $\varepsilon < 1 - \tilde{p}$ since there is strictly positive mass of type i above $\tilde{p} + \varepsilon$. Hence, $p(\tilde{p}) > \tilde{p}$ and for all $\theta_j < \tilde{p}$ we have $p(\theta_j) < \tilde{p}$. Thus, $p_i(\theta_i)$ is discontinuous at $\theta_j = \tilde{p}$, a contradiction. □

Proof of Lemma 2:

Proof. Define $\tilde{\phi}_i(p) = \phi_i(p) - 1$ for all i. Then, equation (10) can be written as $\tilde{\phi}_j(p) = (\tilde{\phi}_i(p) - p + 1)\tilde{\phi}_j'(p)$. The result then follows from Fudenberg-Tirole (1991), p. 225. □

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