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# Competition between Clearing Houses on the European Market

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## Abstract

Few years ago, the market of clearing became strongly competitive with the arrival of new Pan European clearing houses. The latter turn to be the only supplier of bundle accesses to several European clearing markets, meeting with the demand of most investors (*i.e.* banks). Confronted to this competition, the incumbent houses lost huge market shares in a short time as large banks went to those new houses. This paper addresses the question of why the incumbent clearing houses did not merged or built simple or mutual links of interoperability to also supply bundle accesses and, then, faces the Pan European competition. To answer this question, we develop a two stages game analysing bundling strategies on such imperfect competitive markets (Thanassoulis, 2011). Clearing leads to complex markets characterised by risk management and congestion issues inducing respectively positive and negative network effects. We therefore capture the impact of the interoperability strategies and the consequences of network effects (Navon, and al. 1995) on pricing strategies and on the SNPE market structures. Our highlight results show that the interoperability equilibria relies on irrelevant conditions on clearing markets, despite that the "European Code of Conduct for Clearing and Settlement" promotes such agreements.

**JEL classification:** L10 ; G15 ; G20 ; G34.

**Key words:** bundling, clearing house, interoperability, merger, post-market organisation.

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# 1 Introduction

Clearing is a service to which appeal investors after a negotiation led on a financial market. This service is sold by clearing houses<sup>1</sup> and consists of a clearing of flows, which reduces the exchanges and the liquidity needs of investors. Besides, the clearing allows to assure the counterparties default risk by asking them to make deposits in cash or in securities (Mendelson, 1982, Wendt, 2006, Bernanke, 2008). Houses counting more members clear orders more frequently and better pool risks. As underlined by the recent financial crisis, members hope either a less important default risk or weaker collateral calls for a given risk<sup>2</sup>. Therefore, positive network effects can impact the clearing market. In counterpart, an important number of clearing members may create a congestion of the clearing tool and then generate negative network effects. These two forces taking place together, they can either be fully compensated, which lead to the absence of network effect, or one can dominate the other. In the latter case, clearing occurs in a positive or negative network environment.

Since a few years, the clearing market has evolved with the arrival of new actors in Europe, such as Pan European clearing houses. The adoption in 2004 of the MiFID<sup>3</sup> allowed new multilateral trading platforms which give access to several European markets. The new clearing houses were born to offer exactly these cross-board services of clearing, that did not offer incumbent houses.<sup>4</sup> Two types of houses appeared : branches of pre-existing houses, as for instance, Euro CCP, which is a subsidiary of the American house DTCC and some houses created *ex nihilo* like EMCF. These new houses specialise themselves on some types of securities. The incumbent houses, from their part, generally handle a wide range of products but are settled in a single country. The new clearing houses can amortise their fixed costs on several countries, so that they develop aggressive pricing policies (see European Commission report, 2011). We can so observe that in a few months, the incumbent French house LCH Clearnet, leader of the equities market, lost its first place for the benefit of alternative platforms such as EMCF.

This market structure will be modelised in the benchmark of our paper. It results of the failure of incumbent houses to implement the "European Code of Conduct for Clearing and Settlement" set up in 2006. This last one requests the houses to open their clearing tools to foreign houses and to charge them this service at cost price in order to develop the interoperability in Europe (Schaper, 2008). An alternative solution to ease cross-board operations would have been mergers between incumbent houses, that did not occur despite the European commission incentives. Surprisingly, the only merger on clearing market occured in 2013 between two new Pan European houses, EMCF and Euro CCP, to form EuroCCP NV. Moreover, the broad consolidation of European financial

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<sup>1</sup>There exists two types of clearing houses : securities clearing houses and payment clearing houses (cash transfers between banks). Our paper is focused on the first ones.

<sup>2</sup>"Collateral" is a set of assets, securities or cash, given as a guarantee, in order to hedge default risk of financial transactions.

<sup>3</sup>The MiFID (Markets in Financial Instruments Directive) promotes harmonization and opening up of the European markets, in particular by means of a greater integration of their infrastructures.

<sup>4</sup>Leaning on these new clearing houses in full development, some stock exchanges are questioning their privileged link with their incumbent clearing houses. For example NYSE has recently forced LCH Clearnet to renegotiate its trade agreement.

markets mainly concerned stock exchanges (Milne, 2007). For example, we can quote LSE / Turquoise in 2009 & BATS / CHI-X in 2011.<sup>5</sup>

The main objective of this paper is to understand firstly the interoperability links failure between incumbents and secondly the lack of mergers. To this end, clearing is modelised as an imperfect market in different network environments (Katz and Shapiro, 1985, Navon and al., 1995). Indeed, each incumbent clearing house has a privileged link with a domestic stock exchange, so that the European market is segmented. Clearing houses might disregard this segmentation by supplying bundles connected to several markets. To take into account these two characteristics, we adapt a model analysing bundling strategies (Thanassoulis, 2011), with two incumbents and one Pan European house. Then, we take into consideration several market structures for which we determine prices, market shares and clearing houses profits as well as the consequences for investors. We develop a two stages non cooperative game to determine the equilibrium market structures.

The outline of our paper is that the competitive reference situation is favourable to the Pan European clearing house in the absence of network effect. Any strategy modifying this situation has a strongly negative effect on the Pan European house profit. For the incumbent houses, it depends widely on their fixed costs. From investors perspective, merger and interoperability are equally profitable in terms of gross surplus. By introducing network effects, market shares, prices and profits are significantly altered. However, the equilibrium market structures are quite similar.

The paper is organised as follows : section 2 presents the litterature and the benchmark of our model. Section 3 considers the alternative competitive frameworks, interoperability links and merger. Section 4 solves the two stages game and determines the equilibrium market structures. Negative and positive network effects are introduced in section 5. Finally, section 6 analyses the total surplus for all market configurations and section 7 concludes.

## 2 Literature and basic model

### 2.1 Related literature

To provide multiple accesses on the European clearing market, some Pan European houses offers a bundle of their services to banks. There is an important literature about this type of sales<sup>6</sup> which focuses on the incentives to practice bundles and their effects on profit and consumer surplus.<sup>7</sup> As we analyse competitive markets with several houses, we disregard bundles in a monopolistic situation.<sup>8</sup> One crucial point for our study is the industry convergence degree, *i.e.* the number of firms which are active on several markets at the same time. Thus, a merger between two companies

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<sup>5</sup>In contrast, the European Commission rejected the connection between the two main continental stock exchanges, Deutsche Börse and NYSE Euronext.

<sup>6</sup>When a firm sells its products only in the form of bundles, it is a pure bundling strategy. When a company sells also its products separately, it is a mixed bundling strategy.

<sup>7</sup>Note that several papers from these two categories focus on non linear tariffs. Refer to Armstrong (1996), Armstrong and Vickers (2001 and 2010).

<sup>8</sup>Adams and Yelen ( 1976 ), McAfee and al. (1989), Whinston ( 1990 ), Nalebuff ( 2004 ) and Peitz ( 2008 ).

modifies the convergence degree and can even lead to a total convergence, if only one firm remains on the market. Moreover, a differentiation can occur between products and all consumers buy all the goods (see Matutes and Regibeau, 1992, Anderson and Leruth, 1993, and Reisinger, 2006). In an alternative model, Thanassoulis (2007) assumes a differentiation between firms as well as between groups of consumers.<sup>9</sup> We also consider an horizontal differentiation because we suppose that accesses are not qualitatively different on the clearing market.<sup>10</sup> The clearing offers are similar from one house to the other, what explains that they compete also on the associated services or on the clearing accessibility.<sup>11</sup> The incumbent houses benefit from the consumption habits of investors, which justifies a differentiation between houses and not between accesses. Moreover, we take into account several types of buyers. Some banks clear their orders only on one market while the others do it on several markets.

Contrary to the previous models, we face a partial convergence on the clearing markets, as Pan European houses act on several markets whereas the others one remain on their own market (see Nalebuff, 2000).<sup>12</sup> The convergence process is crucial in such analyses. Granier and Podesta (2010) and Thanassoulis (2011) study the incentives to achieve partial or total convergence through mergers. They consider two markets with two firms on each of them. For Granier and Podesta, the differentiation is then between products and all consumers purchase systematically on both markets. Nonetheless, Thanassoulis (2011) sets up groups of buyers and assumes a differentiation between firms which match with our market structures.<sup>13</sup>

In our reference situation, two clearing houses are competitors, each of them on a different market, a third one acting on both markets. This last type of clearing houses allows to clear stock exchange orders from several markets.<sup>14</sup> In this case, we so make the hypothesis of a partial convergence, as far as the latter is bundling its clearing accesses. In our paper, the convergence strategy are not only the consequence of a merger between houses, but can also result from interoperability agreements. Thanks to these agreements, the "mono-market" houses can disregard the segmentation of their market by supplying bundles. These interoperability agreements can be reciprocal or not and are specific of this type of activity.<sup>15</sup> Total convergence is never achieved as only the incumbents can merge between themselves, the Pan european remaining apart, and the same in case of interoperability.

Finally, the maintenance and the improvement of market infrastructures are the backbone of clearing, inducing huge investments in complex software updates and dataset backups. For this reason, we also introduce high fixed costs to characterise our clearing market. To analyse the

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<sup>9</sup>Armstrong and Vickers (2010) extend this analysis to a more general demand.

<sup>10</sup>Considering that the cleared securities are similar, we can reasonably assume that risks are identical between clearing houses. So banks cannot differentiate them according to their risks management.

<sup>11</sup>For example, clearing houses can favour the compatibility of their information systems with some of their customers.

<sup>12</sup>In Nalebuff, all consumers buy systematically on every market and a differentiation appears between products.

<sup>13</sup>Thanassoulis studies a market structure in which four firms compete two by two, on two different markets. Bundling strategies are then possible as soon as two firms at least merge.

<sup>14</sup>See for example, the EMCF clearing house which gives an access to fourteen different markets.

<sup>15</sup>Remember that these interoperability links are encouraged by the "European Code of Conduct for Clearing and Settlement".

impact of network effects on clearing, we rely on Navon et al. (1995) which introduce network effects in an horizontal differentiation framework.<sup>16</sup>

## 2.2 Model and benchmark

We build a non cooperative game in two stages, in which we assume that positive and negative network effects are totally compensated. Section 5 will rule out this assumption. In the first stage, the incumbent clearing houses choose between several strategies leading to the competitive situations mentioned previously; then, in the second stage, the houses set their prices. We suppose that three houses give access to clearing onto two physically separated markets, named  $X$  and  $Y$ . These markets clear similar securities,<sup>17</sup> such that incurred risks are identical. A Pan European clearing house can clear orders on both markets while the two other incumbent houses confine themselves to their respective markets. Banks are the clearing houses customers and they divide up into three types. The banks clearing only on market  $X$  (respectively on market  $Y$ ) are quoted by proportion  $X$  (respectively  $Y$ ). We quote  $B$  the banks proportion dealing on both markets.<sup>18</sup> Banks  $B$  can purchase separate accesses to incumbent houses but not to the Pan European one. Each market is horizontally differentiated and represented by a segment of a unit length as in the Hotelling model.<sup>19</sup> Banks are uniformly distributed between clearing houses and each of them has a location  $\theta$ , with  $\theta \in [0, 1]$ . The incumbent houses (named  $X_1$  and  $Y_1$ ) are located at the point 0 of each segment, the Pan European house ( $XY_2$ ) being located at the opposite, *i.e* at point 1. Banks localisation can be notably explained by the compatibility of their information systems with those of the three houses. Figure 1 allows visualizing these locations:

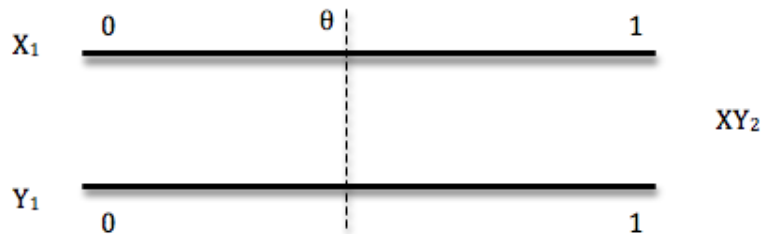


Figure 1: Clearing houses localisation .

As in the Hotelling model, banks endure transportation costs, respectively quoted  $t_X$  and  $t_Y$  for markets  $X$  and  $Y$ . Those which want to clear orders coming from the two markets can so realise economies of scope by addressing the same clearing house (the Pan European one in our

<sup>16</sup>For an interesting discussion on network effects in payment clearing houses, see Guibourg (2001).

<sup>17</sup>For instance, we can suppose that it is about equities.

<sup>18</sup>In Europe, banks' proportion needing to clear orders on several markets is about 72 %. They are well identified and differentiated by the clearing houses, which can perfectly discriminate them.

<sup>19</sup>Let us remind that the differentiation is horizontal, at firms level, because there is no qualitative difference between clearing services (see section 2.1).



benchmark). So, transportation cost is paid only once for the clearing of both orders and is named  $t_B$ , with  $t_B < t_X + t_Y$ . It is the "one stop shopping" principle. It allows in particular to save adaptation costs between information systems. As the competition degree (*i.e.* the differentiation degree) is similar on both markets, we standardise these three transportation costs at 1. Finally, each clearing house endures fixed costs<sup>20</sup> quoted  $F_1$  for the incumbent clearing houses and  $F_2$  for the Pan European house.

In our benchmark, the Pan European house follows a mixed bundling strategy as far as it proposes clearing on both markets either as a bundle or separately. It is the only strategy allowing it to capture the three types of banks,  $X$ ,  $Y$  and  $B$ .<sup>21</sup> The quotations for prices are as follows :  $p_{x_1}$  for the incumbent house on market  $X$  , (rec.  $p_{y_1}$  on market  $Y$  ) ,  $p_{x_2}$  for the Pan European house on market  $X$  (rec.  $p_{y_2}$  on market  $Y$  ) and finally  $p_b$  for the Pan European bundle supply.

On each market, every bank is indifferent to buy from an incumbent or from the Pan European (*i.e.* at point 0 or at point 1). Afterward, this bank is called the marginal bank. We quote them  $\tilde{\theta}$  indexed by  $X$ ,  $Y$  or  $B$  according to the banks type, with  $\tilde{\theta}_X = \frac{1+p_{x_2}-p_{x_1}}{2}$ ,  $\tilde{\theta}_Y = \frac{1+p_{y_2}-p_{y_1}}{2}$  and  $\tilde{\theta}_B = \frac{1+p_b-p_{x_1}-p_{y_1}}{3}$ .<sup>22</sup>

House  $X$  profit is  $\Pi_{X_1} = p_{x_1} \left( X\tilde{\theta}_X + B\tilde{\theta}_B \right) - F_1$ , (and rec.  $\Pi_{Y_1}$  for house  $Y$ <sup>23</sup>) and profit has the following shape for the Pan European  $\Pi_{XY_2} = p_{x_2}X \left( 1 - \tilde{\theta}_X \right) + p_{y_2}Y \left( 1 - \tilde{\theta}_Y \right) + p_bB \left( 1 - \tilde{\theta}_B \right) - F_2$ .

The equilibrium prices are deduced from first order conditions on profits and the market sharing conditions are defined by the marginal banks (see appendix A1).

**Lemma 1** *At the equilibrium, prices are given by  $p_{x_1}^* = p_{x_2}^* = p_{y_1}^* = p_{y_2}^* = 1$ ,  $p_b^* = 2$  and the marginal banks by  $\tilde{\theta}_X^* = \tilde{\theta}_Y^* = \frac{1}{2}$  and  $\tilde{\theta}_B^* = \frac{1}{3}$ .*

The market shares for each clearing house are reported in table 1 .

Market shares	House X1	House Y1	House XY2
Market X	1/2		1/2
Market Y		1/2	1/2
Market B	1/3		2/3

Table 1 : Clearing houses market shares in the benchmark

**Proposition 1** *The Pan European clearing house does not offer discounts on its bundles. Nevertheless, it gets two thirds of banks appealing to clearing on the two markets.*

<sup>20</sup>Fixed costs are high and variable costs can be considered null for such institutions.

<sup>21</sup>This mixed strategy allows the Pan European to make benefit from banks  $B$  and to compete directly with houses  $X_1$  and  $Y_1$  for banks  $X$  and  $Y$ .

<sup>22</sup>We find here a particular case of the partial convergence equilibrium of Thanassoulis (2011). He shows that, at the equilibrium, consumers  $B$  cannot ask for hybrid purchases, *i.e.* at the same time in 0 for a market segment and in 1 for the other segment. Furthermore, the equilibrium exists if  $t_X = t_Y$ , in accordance with our hypotheses. For more details, please refer to lemmas 1 and 2 of Thanassoulis (2011).

<sup>23</sup> $\Pi_{Y_1} = p_{Y_1} \left( X\tilde{\theta}_Y + B\tilde{\theta}_B \right) - F_1$ ,

The Pan European house monopolises  $2/3$  of banks  $B$  because the latter save transportation costs by addressing to it. So, at the equilibrium, profits are  $\Pi_{X_1}^* = \frac{1}{2}X + \frac{1}{3}B - F_1$  for house  $X$  (rec.  $\Pi_{Y_1}^*$  for house  $Y$ <sup>24</sup>) and  $\Pi_{XY_2}^* = \frac{1}{2}X + \frac{1}{2}Y + \frac{4}{3}B - F_2$  for the Pan European.<sup>25</sup>

At the equilibrium, the total banks surplus is given by <sup>26</sup> :

$$S^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y) - \frac{59}{27}B. \quad (1)$$

with  $\phi_X$  and  $\phi_Y$  the banks gross utilities on market  $X$  and  $Y$  (see appendix B1). To conclude, the Pan European activity has a dramatic impact on incumbents in terms of prices, markets shares and profits.

### 3 Interoperability and Merger

To resist to the Pan European competitive pressure, the incumbent houses may adopt three strategic options. As most of the banks ask for multiple accesses (*i.e.* banks  $B$ ), they look for consumption cost savings. To answer the banks demand, the incumbent houses can develop interoperability agreements between themselves<sup>27</sup>, as recommended by the European Union. First, an incumbent opens its market to the other one through a simple interoperability link, without reciprocity. Secondly, both houses offer themselves mutual accesses to their respective markets, through a bilateral interoperability agreement. Such arrangements induce additional fixed costs, as compatibility and access costs. The Code of Conduct encourages clearing houses to accept interoperability requests and recommends “not for profit” access prices. In our model, an incumbent house cannot refuse its market access, even if this opening does not get it an additional profit. Note that the financial sector respects the european “recommendations”, so that it is a realistic hypothesis. Thirdly, the incumbent houses can decide to merge their activities in order to reduce their costs, thanks to synergy effects.

These three alternative strategies allow the incumbent houses to offer an acces to banks  $B$  on both markets and so to compete directly with the Pan European one. These rival alternatives should allow the incumbent houses to widden their offer, but the fixed costs level conditions their presence on the bundle market.

#### 3.1 Simple interoperability agreement

In this first strategy, an incumbent house asks for an interoperability link to the other one. Let’s suppose that house  $X_1$  requires for such a link to  $Y_1$ .<sup>28</sup> The bundle is henceforth proposed to banks

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<sup>24</sup> $\Pi_{Y_1}^* = \frac{1}{2}Y + \frac{1}{3}B - F_1$

<sup>25</sup>Profit equilibrium and banks surplus are compared in section 4.

<sup>26</sup>The discussions on surplus are postponed to section 6 .

<sup>27</sup>Please refer to the Code of Conduct of the European Commission, which incites to open up national markets.

<sup>28</sup>We do not deal with the symmetric case, as results are obviously the same.

$B$  by the incumbent house  $X_1$  besides the Pan European one  $XY_2$ .<sup>29</sup> House  $X_1$  is then going to endure an interoperability fixed cost quoted  $f$ . As house  $X_1$  does not need to build complex links with a new market, we suppose that  $f < F_1$ . Nevertheless,  $f$  cannot be neglected, as infrastructure costs remain significant, even if links with house  $Y_1$  are rather simple.

The bundle price that house  $X_1$  sells is noted  $p_{b_1}$  and those sold by the Pan European house  $XY_2$  is  $p_{b_2}$ . In the following,  $I$  refers to simple interoperability. The banks distribution between clearing houses is :<sup>30</sup>  $\tilde{\theta}_{X_I} = \frac{1+p_{x_2}-p_{x_1}}{2}$  for house  $X_1$  (and rec.  $\tilde{\theta}_{Y_I}$  for house  $Y_1$ <sup>31</sup>) and  $\tilde{\theta}_{B_I} = \frac{1+p_{b_2}-p_{b_1}}{2}$

Profit functions are for houses  $X_1$  and  $Y_1$ :  $\Pi_{X_1 I} = p_{x_1} X \tilde{\theta}_{X_I} + p_{b_1} B \tilde{\theta}_{B_I} - F_1 - f$  and  $\Pi_{Y_1 I} = p_{y_1} Y \tilde{\theta}_{Y_I} - F_1$ . For the Pan European it becomes :  $\Pi_{XY_2 I} = p_{x_2} X (1 - \tilde{\theta}_{X_I}) + p_{y_2} Y (1 - \tilde{\theta}_{Y_I}) + p_{b_2} B (1 - \tilde{\theta}_{B_I}) - F_2$ .

**Lemma 2** *The equilibrium prices are identical and equal to 1, with  $p_{x_1}^* = p_{x_2}^* = p_{y_1}^* = p_{y_2}^* = p_{b_1}^* = p_{b_2}^* = 1$  and the marginal banks are defined by  $\tilde{\theta}_{X_I}^* = \tilde{\theta}_{Y_I}^* = \frac{1}{2}$  and  $\tilde{\theta}_{B_I}^* = \frac{1}{2}$  (see appendix A2).*

Market shares are reported in table 2 :

Market shares	House X1	House Y1	House XY2
Market X	1/2		1/2
Market Y		1/2	1/2
Market B	1/2		1/2

Table 2: Clearing houses market shares in the simple interoperability case.

**Proposition 2** *The simple interoperability agreement creates a discount on the bundles prices so that all services are supplied at the same price. As a result, the incumbent one which accepts interoperability is excluded from the bundle market, to the benefit of the two others which are sharing equally this market. Finally, the separated services are not impacted by this agreement.*

The competition on the bundle market lowers the bundle prices to the separated services level. However, houses  $X_1$  and  $XY_2$  continue to supply separated accesses to both markets. If one of them decided not to supply any more separated accesses, the other one could lower its separate sales prices and would capture all banks  $X$  or  $Y$ . Expectations being symmetric, such an unilateral deviation is impossible. Both houses carry on to propose both types of sales, *i.e.* bundled or separated (type  $X$  and  $B$  by  $X_1$  and type  $X$ ,  $Y$  and  $B$  by  $XY_2$ ).

At the equilibrium, profits are :  $\Pi_{X_1 I}^* = \frac{1}{2}X + \frac{1}{2}B - F_1 - f$ ,  $\Pi_{Y_1 I}^* = \frac{1}{2}Y - F_1$  and  $\Pi_{XY_2 I}^* = \frac{1}{2}X + \frac{1}{2}Y + \frac{1}{2}B - F_2$ . The market exit conditions depend on the fixed costs. For  $F_1 > \frac{1}{2}Y$ , the clearing house  $Y_1$  leaves the market, because its profit becomes negative. As a consequence, the interoperability agreement is inactive and house  $X_1$  cannot anymore offer clearing on market  $Y$ .

<sup>29</sup>Note that houses can perfectly discriminate banks from the others.

<sup>30</sup>In the benchmark, hybrid purchases have been withdrawn aside. Given that bundles are now available on the location 0, hybrid purchases are less likely to occur in this configuration. It is the same in sections 3.2 and 3.3. In fact, the bundles price cannot be upper than the separate sales price.

<sup>31</sup> $\tilde{\theta}_{Y_I} = \frac{1+p_{y_2}-p_{y_1}}{2}$

Then two cases can occur. For  $F_1 > \frac{1}{2}X$ , the Pan European house monopolises all markets and house  $X_1$  also disappears. If, on the contrary,  $F_1 < \frac{1}{2}X$ , house  $X_1$  shares equally market  $X$  with the Pan European, whereas this last one monopolises market  $Y$ .

At the equilibrium, the banks total surplus is (see appendix B2) :

$$S_I^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y + B). \quad (2)$$

### 3.2 Double interoperability agreement

In this alternative scenario, both incumbent houses ask for a mutual interoperability agreement. Thus, each house offers a bundle to banks  $B$ . Both incumbent houses endure an additional fixed cost  $f$  and are in competition on the bundle market. As they have the same location, they cannot differ anymore from each others on the bundle market. A Bertrand paradox occurs which would result in null profits for these two houses on this market. So these last ones should rather agree on an identical price, noted  $p_{b1}$ ,<sup>32</sup> and share equally the part of market  $B$  left vacant by the Pan European house. This will be our assumption for the following. In the remainder of the section,  $DI$  refers to Double Interoperability.

The two houses  $X_1$  and  $Y_1$  sharing their sales on the bundle market, profits are :  $\Pi_{X_1DI} = p_{x_1}X\tilde{\theta}_{XDI} + \frac{1}{2}p_{b_1}B\tilde{\theta}_{BDI} - F_1 - f$  for house  $X_1$  (and rec.  $\Pi_{Y_1DI}$  for house  $Y_1$ <sup>33</sup>) and  $\Pi_{XY_2DI} = p_{x_2}X(1 - \tilde{\theta}_{XDI}) + p_{y_2}Y(1 - \tilde{\theta}_{YDI}) + p_{b_2}B(1 - \tilde{\theta}_{BDI}) - F_2$  for the Pan European.

As in the previous case, the equilibrium prices are identical and equal to 1 (see appendix A3). The banks distribution between the three clearing houses is synthesized in table 3 :

Market shares	House X1	House Y1	House XY2
Market X	1/2		1/2
Market Y		1/2	1/2
Market B	1/4	1/4	1/2

Table 3: Clearing houses market shares in the double interoperability case

**Proposition 3** *Clearing houses adopt the same pricing strategies in the simple and the double interoperability agreements and the Pan-European market share remains unchanged. By contrast, the two incumbent houses are active on the bundle market and each of them capture one fourth of this market.*

Profits differ from the simple interoperability because, in this market configuration, both incumbent houses are acting on the bundle market. At the equilibrium, we obtain the following profits:

<sup>32</sup>Furthermore, an unilateral deviation of one house from this price would provoke the exclusion of its rival from this market. In this case, the interoperability agreement can not anymore exist.

<sup>33</sup> $\Pi_{Y_1DI} = p_{y_1}Y\tilde{\theta}_{YDI} + \frac{1}{2}p_{b_1}B\tilde{\theta}_{BDI} - F_1 - f$

$\Pi_{X_1DI}^* = \frac{1}{2}X + \frac{1}{4}B - F_1 - f$  for house  $X_1$  (and rec.  $\Pi_{Y_1DI}^*$  for house  $Y_1$ <sup>34</sup>) and  $\Pi_{XY_2DI}^* = \frac{1}{2}X + \frac{1}{2}Y + \frac{1}{2}B - F_2$  for the Pan European.

As a result, the banks total surplus is the same in both market configurations (for details, see appendix B3):

$$S_{DI}^* = S_I^* \quad (3)$$

### 3.3 Merger

A merger between the incumbent houses provides economies of scales for the latter and economies of consumption for banks  $B$ . Let's quote  $F_M$  the fixed cost endured by the merged houses. Because of economies of scales, we suppose that  $F_M < 2F_1$ . The bundle prices are now  $p_{b_2}$  for the Pan European and  $p_{b_1}$  for the merged houses called  $X_1Y_1$ . In the following,  $M$  refers to Merger.

The banks distribution is made in the same way as for the previous interoperability agreements for the merged houses :  $\tilde{\theta}_{XM} = \frac{1+p_{x_2}-p_{x_1}}{2}$  on market  $X$  (rec.  $\tilde{\theta}_{YM}$  on market  $Y$ <sup>35</sup>), and  $\tilde{\theta}_{BM} = \frac{1+p_{b_2}-p_{b_1}}{2}$  on the bundle market.

Profit functions are the following:  $\Pi_{X_1Y_1M} = p_{x_1}X\tilde{\theta}_{XM} + p_{y_1}Y\tilde{\theta}_{YM} + p_{b_1}B\tilde{\theta}_{BM} - F_M$  for the merged houses and  $\Pi_{XY_2M} = p_{x_2}X(1 - \tilde{\theta}_{XM}) + p_{y_2}Y(1 - \tilde{\theta}_{YM}) + p_{b_2}B(1 - \tilde{\theta}_{BM}) - F_2$ , for the Pan European.

At the equilibrium, prices are indetical and equal to 1. Each market ( $X$ ,  $Y$  et  $B$ ) is equally shared (see appendix A4), as indicated in table 4 :

Market shares	Merger X1 and Y1	House XY2
Market X	1/2	1/2
Market Y	1/2	1/2
Market B	1/2	1/2

Table 4: Clearing houses market shares in the merger case.

**Proposition 4** *For all the alternative market configurations to the benchmark (simple or bilateral interoperability agreements or merger), the equilibrium prices are identical and equal to 1. The Pan European has always half of the three markets. The remaining is captured by the incumbent houses.*

The equilibrium profits are :  $\Pi_{X_1Y_1M}^* = \frac{1}{2}X + \frac{1}{2}Y + \frac{1}{2}B - F_M$  for the merged houses and  $\Pi_{XY_2M}^* = \frac{1}{2}X + \frac{1}{2}Y + \frac{1}{2}B - F_2$  for the Pan European.

At the equilibrium, the banks total surplus is identical to the interoperability cases (see appendix B4):

$$S_M^* = S_I^* = S_{DI}^* \quad (4)$$

<sup>34</sup> $\Pi_{Y_1DI}^* = \frac{1}{2}Y + \frac{1}{4}B - F_1 - f$

<sup>35</sup> $\tilde{\theta}_{YM} = \frac{1+p_{y_2}-p_{y_1}}{2}$

## 4 Strategic incentives

Let us solve the first stage of the non-cooperative game, in order to look for the Subgame Perfect Nash Equilibrium (SPNE). The Pan European clearing house does not take part in the first stage, because it just reacts to the incumbent houses choices in maximizing its profit, being given the competitive situation (see Table 5).

In this first step, the incumbent houses  $X_1$  and  $Y_1$  can choose to merge, request an interoperability agreement, or stay in the status quo. This subgame is non cooperative as their decision-making are simultaneous. The merger occurs at the first stage only if the two incumbent houses propose it. The merger profit is then simply shared in two. If a house asks for an interoperability agreement, this one is necessarily accepted, considering the Code of Conduct on Clearing and Settlement in Europe. Finally, if both houses ask for interoperability, the bilateral interoperability occurs. In all other cases, we observe the status quo, corresponding to our benchmark. This non cooperative game can be summarised as :

$$\langle N = 2, \{status\ quo, interoperability, merger\}, \Pi = (\Pi_i) \text{ with } i = X_1, Y_1 \rangle$$

On the clearing market, we suppose that 72 % of banks wish to make operations on the bundle market, the remaining 28 % being equally distributed on markets  $X$  and  $Y$ , so that the markets sizes  $X$  and  $Y$  are identical and equal to 14 %. These figures have been induced from discussions with professionnals.<sup>36</sup> We so obtain houses profits and banks surplus, as summarised in table 5 <sup>37</sup> :

	$\Pi_{X_1}^*$	$\Pi_{Y_1}^*$	$\Pi_{XY_2}^*$	$S^*$
Benchmark	$0,31 - F_1$	$0,31 - F_1$	$1,10 - F_2$	$0,86(\phi_X + \phi_Y) - 1,89$
Interoperability X	$0,43 - F_1 - f$	$0,07 - F_1$	$0,50 - F_2$	$0,86(\phi_X + \phi_Y) - 1,12$
Merger	$0,25 - \frac{F_M}{2}$	$0,25 - \frac{F_M}{2}$		
Bilateral interoperability	$0,25 - F_1 - f$	$0,25 - F_1 - f$		

Table 5: Houses profits and banks surplus

**Proposition 5** *The benchmark is favourable to the Pan European clearing house and unfavourable to banks.*

**5.1** *Any alternative strategy has a widely negative effect on the Pan European house profits and an ambiguous effect on those of the incumbent houses.*

**5.2** *The banks surplus increases in an identical way with the merger and the interoperability agreements.*

<sup>36</sup>AFTI, Association Française des professionnels des Titres, <http://afti.asso.fr/>.

<sup>37</sup>Thereafter, we only present results for the interoperability requested by the house X and not for the house Y because these cases are symmetrical.

The game equilibria depend on fixed costs level. On the one hand, the Pan European house operates on both markets while every incumbent house is initially settled on one market, such that  $F_1 < F_2$ . On the other hand, the Pan European house benefits from economies of scale so that  $2F_1 > F_2$ . This is also the case for the merged incumbent houses, with  $2F_1 > F_M$ . But there is no empirical evidence to order  $F_M$  and  $F_2$ . Hence, nothing allows to suppose *a priori* that  $F_M$  and  $F_2$  are identical. Moreover, as mentioned in section 3.1,  $f < F_1$ . It is then possible to rank the fixed costs in the following way :

$$f < F_1 < F_M < 2F_1 \text{ and } F_1 < F_2 < 2F_1. \quad (5)$$

Knowing that the benchmark existence condition is  $F_1 < 0,31$ , we establish the incumbent earnings matrix in table 6.

X1 / Y1	<i>Status quo</i>	Interoperability	Merger
<i>Status quo</i>	$0,31 - F_1 / 0,31 - F_1$	$0,07 - F_1 / 0,43 - F_1 - f$	$0,31 - F_1 / 0,31 - F_1$
Interoperability	$0,43 - F_1 - f / 0,07 - F_1$	$0,25 - F_1 - f / 0,25 - F_1 - f$	$0,43 - F_1 - f / 0,07 - F_1$
Merger	$0,31 - F_1 / 0,31 - F_1$	$0,07 - F_1 / 0,43 - F_1 - f$	$0,25 - \frac{F_M}{2} / 0,25 - \frac{F_M}{2}$

Table 6: Earnings matrix

**Lemma 3** *The SPNE depends on the fixed costs conditions. The bilateral interoperability equilibrium appears in two cases: 1) if  $F_1 \leq 0,07$  or 2) if at the same time  $f < 0,12$  and  $\frac{F_M}{2} \geq F_1 + f - 0,18$ . In other cases, if merger synergies are not too important, the benchmark is the game equilibrium. If not, the merger is the equilibrium (see appendix C).*

**Proposition 6** *Simple operability is never an equilibrium. Bilateral agreements may occur but for very restrictive conditions on fixed costs. The merger can come true if it generates enough fixed costs savings.*

Simple interoperability is never an equilibrium, because such an agreement is too harmful for the incumbent house which grants it. By accepting this arrangement, this last one is automatically relegated to market  $X$  or  $Y$ . Moreover, it does not decrease the competitive pressure exerted by the Pan European one. This last one remains active on all markets ( $X$ ,  $Y$  and bundle). On the opposite, the other incumbent house offers bundled accesses to banks  $B$ , while reducing its handicap on fixed costs.

The bilateral interoperability equilibrium is a credible alternative for the incumbent houses even if these strategies do not allow them to differ themselves. Nevertheless, the fixed costs conditions to obtain such an equilibrium are very restrictive. Either the incumbents initial fixed cost  $F_1$  is very low. Or, the merger does not create strong synergies and the interoperability cost  $f$  is low. As mentioned previously, these two conditions are not representative of the clearing market. This explains why implementing an interoperability link is so difficult despite the regulator incentives in terms of pricing.

So the merger can be the game equilibrium if fixed costs savings are rather big. When it occurs, it is beneficial for incumbent houses and banks, but unfavourable to the Pan European house. In all other cases, the market structure is unchanged (benchmark), what represents the best situation for the Pan European house but the worst for banks. All these reasons explain the empirical lack of interoperability links and the failure of merger proposals in Europe.

## 5 Network effects

Network effects can occur on clearing market, because one of the main functions of clearing houses is to internalise risks. Houses counting more members clear orders more frequently and **better manage risks**. On the one hand, members expect a less important default risk and weaker collateral calls for a given risk. As a result, positive network effects must be considered. On the other hand, more members create a congestion of clearing tools, generating negative network effects. These two effects can be fully compensated as assumed previously. We now consider that it is not anymore the case and we examine how strategic interactions are affected by positive and negative network effects.

### 5.1 Benchmark

In order to modelise network effects, we define an exogenous variable  $a$ . This parameter sums up the two opposite effects, preference for risk management versus congestion aversion. The  $a$  value is exogeneous because it relies on macroeconomics conditions and on systemic risk. Most of the time,  $a$  is positive, because banks value risk management. Nevertheless, risk concerns may decrease such that  $a$  is negative or null. Because of these two opposite effects, the network effect strength will never be strong. So we introduce a consumption externality in the banks utility function. We define a linear externality in the spirit of Navon et al. (1995) for a Hotelling model with linear transportation costs<sup>38</sup>. We extend their model to our game with two markets, three types of banks and three houses. For banks  $X$ , the market sharing rule becomes :

$$a(\theta_X X + \theta_B B) - \theta_X - p_{x_1} = a[(1 - \theta_X) X + (1 - \theta_Y) Y + 2(1 - \theta_B) B] - (1 - \theta_X) - p_{x_2} \quad (6)$$

Externality is measured by  $a$  time the clearing orders on one house, so  $a(\theta_X X + \theta_B B)$  for house  $X$  (on the left hand of equation 6) and  $a[(1 - \theta_X) X + (1 - \theta_Y) Y + 2(1 - \theta_B) B]$  for the Pan-European house (on the right hand). Banks  $B$  clear two orders, one on market  $X$  and another one on  $Y$ . So that their impact is twice more important for the Pan-European one, which sells bundles. We obtain a similar rule for banks  $Y$ . For banks  $B$ , the sharing rule is:

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<sup>38</sup>Grilo et al. (2001) and Di Cintio (2007)



$$\frac{a}{2} (2\theta_B B + \theta_X X + \theta_Y Y) - 2\theta_B - p_{x_1} - p_{y_1} = a [(1 - \theta_X) X + (1 - \theta_Y) Y + 2(1 - \theta_B) B] - (1 - \theta_B) - p_b \quad (7)$$

On the right hand (equation 7), banks  $B$  clear orders on houses  $X$  and  $Y$ , so we assume that the global externality is the average externality of the two incumbents. The resolution of those three sharing rules gives us the marginal banks  $\tilde{\theta}_X$ ,  $\tilde{\theta}_Y$  and  $\tilde{\theta}_B$  (see appendix D1 for the marginal banks computation).

We now solve the first order conditions on the clearing houses profits, with the functions defined in section 2.2 (benchmark). From the second order conditions (see appendix D2), it is easy to show that, if  $a \in [-\frac{1}{2}; \frac{1}{2}]$  profit functions are concave. Figures 2 and 3 plot the equilibrium prices and the marginal banks for the separate sales ( $\tilde{\theta}_X^*$ ,  $\tilde{\theta}_Y^*$ ) as well as for the bundling sales ( $\tilde{\theta}_B^*$ ). The houses profits are represented in figure 4.

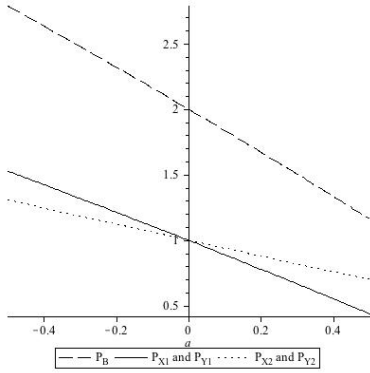


Figure 2 : Equilibrium prices

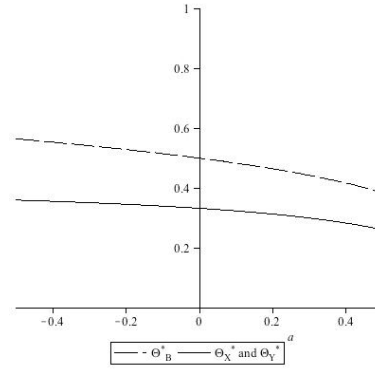


Figure 3 : Equilibrium market shares

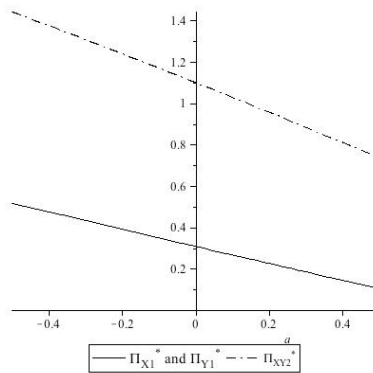


Figure 4 : Equilibrium profits with network effects

1) In case of positive networks effects ( $a > 0$ )

We show that the network effects are weak, because they do not dominate differentiation effects (*i.e.* transportation cost), as defined in Navon et al.. Equation (8) defines  $R_X$ , which is the sum of the network effects for banks clearing on market  $X$ , *i.e.* on houses  $X$  and  $XY$  (rec.  $R_Y$  with equation 9).  $R_B$  defined by equation (10) measures the network effects for banks  $B$  clearing on both markets, which is the weighted average of  $R_X$  and  $R_Y$ .

$$R_X = a[\theta_X X + \theta_B B] + a[(1 - \theta_X) X + (1 - \theta_Y) Y + 2(1 - \theta_B) B], \quad (8)$$

$$R_Y = a[\theta_Y Y + \theta_B B] + a[(1 - \theta_X) X + (1 - \theta_Y) Y + 2(1 - \theta_B) B], \quad (9)$$

$$R_B = \frac{1}{2}[R_X + R_Y]. \quad (10)$$

With  $B = 72\%$ ,  $X = 14\%$  and  $Y = 14\%$ , the equilibrium values are ( $Z_4$  being defined in appendix K):

$$R_X^*(a) = R_Y^*(a) = R_B^*(a) = \frac{-2a}{25Z_4} (0.7a^3 + 45.2a^2 - 513.2a + 515.5) 10^6. \quad (11)$$

Given the second order conditions,  $a = \frac{1}{2}$  is the extreme positive value of the parameter, so that :

$$R_X^*\left(\frac{1}{2}\right) = R_Y^*\left(\frac{1}{2}\right) = R_B^*\left(\frac{1}{2}\right) = R^*\left(\frac{1}{2}\right) \approx 0,74,$$

Hence, the network effects are weak in the sense of Navon et al., because  $R^*\left(\frac{1}{2}\right)$  do not exceed the transportation cost normalized to 1.

2) In case of negative networks effects ( $a < 0$ )

For the extreme negative value of  $a$ ,  $a = -\frac{1}{2}$ , the equilibrium values become :

$$R_X^*\left(-\frac{1}{2}\right) = R_Y^*\left(-\frac{1}{2}\right) = R_B^*\left(-\frac{1}{2}\right) = R^*\left(-\frac{1}{2}\right) \approx -0,69.$$

Even if risk concerns of the banks decrease, they do not completely disappear, so that the negative effects must be slightly negative. As  $-1 < R^*\left(-\frac{1}{2}\right) < 0$ , this result is consistent with our assumption.

When the positive and the negative network effects are fully compensated, there is no distortion between the prices set by houses, such that the bundle price is twice the price of one separated access. If the positive network effects dominate, houses must lower all their prices in order to attract as much banks as possible. By lowering its bundle price, the Pan European house  $XY_2$  can attract more banks  $B$  (figure 3). The higher are the positive network effects, the lower is the bundle price (figure 2). To remain competitive on the separated accesses, the incumbent houses must decrease their prices. So, banks  $X$  and  $Y$  are also impacted, despite a lower decrease of the separated accesses prices. This pricing is costly for houses, especially for the higher positive network effects. This fully applies for the Pan European one (figure 4) whose profit sharply declines. If the negative network effects dominate, the opposite pricing applies, which allows to reduce congestion of the clearing tools. As higher prices are set by all houses, all profits increase.

## 5.2 The other market structures

The network effects are now introduced in the three other market structures. More precisely, we compute prices, market shares (see appendix E), profits and surplus levels for  $a = \frac{1}{2}$  and  $a = -\frac{1}{2}$ .

The equilibrium values are reported in table 7 for global positive network effects (with  $a = \frac{1}{2}$ ):

	$p_{x_1}^*, p_{y_1}^*$	$p_{x_2}^*, p_{y_2}^*$	$p_{b_1}^*$	$p_{b_2}^*$	$\tilde{\theta}_X^*$	$\tilde{\theta}_Y^*$	$\tilde{\theta}_B^*$
Benchmark	0, 44	0, 70	--	1, 16	0, 38	0, 38	0, 26
Interoperability X	$p_{x_1}^* = 0, 51$	$p_{x_2}^* = 0, 58$	0, 09	0, 09	0, 44	0, 38	0, 40
	$p_{y_1}^* = 0, 66$	$p_{y_2}^* = 0, 90$					
Merger	0, 5	0, 5	0	0	0, 5	0, 5	0, 5
Bilateral interoperability	0, 62	0, 76	0, 17	0, 30	0, 39	0, 39	0, 39

Table 7: Prices and marginal banks for  $a = \frac{1}{2}$

The positive network effects modify the prices strategies so that all houses lower their prices. Remember that, without network effects, all the prices are equal to 1, except the bundle price which is equal to 2 in our benchmark. In addition, the incumbents lose market shares on the bundle market, except in the merger case. The global positive network effects strengthen competition and incite the houses to hardy compete for banks  $B$ , that forces them to set very attractive prices. By asking for double accesses, these banks allow houses to better manage risks by concentrating flows.

We now compare the four market structures with positive network effects between themselves. In the bilateral interoperability, the incumbents can propose bundles to banks  $B$ . Thus, they can set higher bundle prices than in simple interoperability because they better internalize the competition between the bundled services and the separated ones. In the simple interoperability, the Pan European house sets rather high prices on market  $Y$ , because the incumbent house providing this access is negatively affected by network effects. This last one can only offer an access to this market, so that banks are attracted by the Pan European, which better manage risks. Thus the prices competition moves to the bundle market and becomes fierce between the Pan European house and the other incumbent.

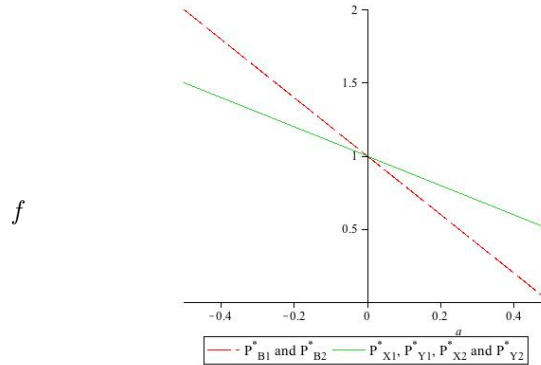


Figure 5 : Equilibrium prices in the merger case

When the two incumbents merge, the competition degree raises, generating a drop off in prices for the Pan European house, as pointed in figure 5. Indeed, this one loses its advantage as the merged houses also offer bundle services. For the highest value of network effects ( $a = \frac{1}{2}$ ), competition becomes so strong that the bundle prices drop to zero.

For global negative network effects, equilibrium values are reported in table 8 (with  $a = -\frac{1}{2}$ ):

	$p_{x_1}^*, p_{y_1}^*$	$p_{x_2}^*, p_{y_2}^*$	$p_{b_1}^*$	$p_{b_2}^*$	$\theta_X^*$	$\theta_Y^*$	$\theta_B^*$
Benchmark	1, 53	1, 31	--	2, 79	0, 56	0, 56	0, 36
Interoperability X	$p_{x_1}^* = 1, 44$	$p_{x_2}^* = 1, 44$	1, 88	1, 88	0, 51	0, 59	0, 51
	$p_{y_1}^* = 1, 26$	$p_{y_2}^* = 1, 08$					
Merger	1, 5	1, 5	2	2	0, 5	0, 5	0, 5
Bilateral interoperability	1, 32	1, 24	1, 80	1, 66	0, 55	0, 55	0, 52

Table 8: Prices and marginal banks for  $a = -\frac{1}{2}$

Contrary to the previous case, the global negative network effects ( $a = -\frac{1}{2}$ ) weaken competition in all the market configurations. As a consequence, all the prices are higher in comparison with the positive network effects situations, (*i.e.*  $a = -\frac{1}{2}$ ) or with  $a = 0$  (*i.e.* the positive and the negative network effects are fully compensated). Because of the negative network effects, houses are less reluctant to lose their market shares. This is especially true for bundles because congestion is more important on this market. By asking for double accesses, banks  $B$  generate more congestion than banks  $X$  and  $Y$ . Moreover, they are largely outweighed over banks  $X$  and  $Y$ .

We now compare the four market structures with negative network effects. The global negative network effects makes the Pan European clearing house less aggressive. When it loses its advantage, the congestion is reduced because banks  $B$  can buy bundles services to the incumbents. For the interoperability cases, the three houses lower their prices, except the Pan-European for  $p_{x_2}$  in the simple interoperability. In this last case, the Pan-European sets the same prices as the incumbent offering bundles, in order to limit the congestion on market  $X$  and on the bundle market. For the bilateral interoperability, the impact of the negative network effects is weakened as all houses offer separated and bundled clearing services. Thus, the competition is slightly reinforced compared to the simple interoperability such that clearing houses set lower prices. When the incumbents merge, all houses set the same prices on markets  $X$  and  $Y$  but also on the bundle market, in order to limit congestion by splitting markets equally. On the bundle market, the competitive effect is stronger than the congestion effect and the bundles prices decrease because of the entrance of a new competitor on this market. On markets  $X$  and  $Y$ , the congestion is stronger because the two incumbents have merged, forcing the Pan European to increase its prices for the separated accesses.

Which is the preferred scenario by the banks and the three houses? Table 9 sums up the banks surplus, in our different *scenarii*. In order to simplify the banks surplus presentation, we note  $\Phi = 0,86(\phi_X + \phi_Y)$ , with  $\phi_X = \phi_Y = \phi$ . Tables 10 and 11 report the Pan European and the incumbent houses profits.

	with $a = 0$	with $a = \frac{1}{2}$	with $a = -\frac{1}{2}$
Benchmark	$1,72\phi - 1,888$	$1,72\phi - 0,73$	$1,72\phi - 2,96$
Interoperability X	$1,72\phi - 1,125$	$1,72\phi$	$1,72\phi - 2,28$
Merger		$1,72\phi + 0,06$	$1,72\phi - 2,38$
Bilateral interoperability		$1,72\phi - 0,16$	$1,72\phi - 2,1$

Table 9: Banks surplus<sup>39</sup>

	with $a = 0$	with $a = \frac{1}{2}$	with $a = -\frac{1}{2}$
Benchmark	$1, 1 - F_2$	$0,74 - F_2$	$1,44 - F_2$
Interoperability "for" X	$0,5 - F_2$	$0,16 - F_2$	$0,83 - F_2$
Merger		$0,07 - F_2$	$0,93 - F_2$
Bilateral interoperability		$0,26 - F_2$	$0,73 - F_2$

Table 10: Pan European house profit

	with $a = 0$	with $a = \frac{1}{2}$	with $a = -\frac{1}{2}$
Benchmark	$0,31 - F_1$	$0,11 - F_1$	$0,52 - F_1$
Interoperability "for" X	$0,43 - F_1 - f$	$0,06 - F_1 - f$	$0,79 - F_1 - f$
"from" Y	$0,07 - F_1$	$0,03 - F_1$	$0,1 - F_1$
Merger	$0,25 - \frac{F_M}{2}$	$0,03 - \frac{F_M}{2}$	$0,46 - \frac{F_M}{2}$
Bilateral interoperability	$0,25 - F_1 - f$	$0,06 - F_1 - f$	$0,44 - F_1 - f$

Table 11: Incumbent houses profit

**Proposition 7** *For every network effects, the benchmark is always favourable to the Pan European clearing house and unfavourable to banks. When network effects are globally compensated ( $a = 0$ ), banks are in favour of a new market design, but they are indifferent to the three alternatives. In the other cases, they are not indifferent:*

- if  $a = \frac{1}{2}$ , the merger is the best situation for the banks, but the worse for the Pan European house,
- if  $a = -\frac{1}{2}$ , the bilateral interoperability is the preferred situation for the banks and the worse for the Pan European one.

However, the game resolution depends on the strategic interactions between the incumbent houses, that will be analysed below.

### 5.3 Strategic incentives with network effects

The two earnings matrices allow to solve the first stage of the game by discussing the fixed costs. To remain on their markets, clearing houses have to make a null or positive profit. Therefore, the benchmark existence condition is  $F_1 < 0,11$ . Under this hypothesis, table 12 represents the earnings matrix of the incumbent houses for  $a = \frac{1}{2}$  :

X1 / Y1	Status quo	Interoperability	Merger
Status quo	$0, 11 - F_1/0, 11 - F_1$	$0, 03 - F_1/0, 06 - F_1 - f$	$0, 11 - F_1/0, 11 - F_1$
Interoperability	$0, 06 - F_1 - f/0, 03 - F_1$	$0, 06 - F_1 - f/0, 06 - F_1 - f$	$0, 06 - F_1 - f/0, 03 - F_1$
Merger	$0, 11 - F_1/0, 11 - F_1$	$0, 03 - F_1/0, 06 - F_1 - f$	$0, 03 - \frac{F_M}{2}/0, 03 - \frac{F_M}{2}$

Table 12: Earnings matrix for positive network effects

We now establish the Subgame Perfect Nash Equilibrium (SNPE).

**Lemma 4** *The SPNE depends on fixed costs conditions. The merger equilibrium appears if  $\frac{F_M}{2} < F_1 - 0,08$ , with  $F_1 > 0,08$ . In all other cases, the benchmark is the game equilibrium (see appendix F1).*

**Proposition 8** *First, the clearing houses strategies never lead to interoperability agreements in case of positive network effects. Second, the merger comes true if it generates enough fixed costs savings.*

As seen in section 5.2, the positive network effects exacerbate competition once the incumbents can bundle their offers. The bilateral interoperability is not anymore a credible alternative for the incumbent houses, because, in this case, their profit is always the lowest, whatever the fixed costs conditions. This explains the absence of bilateral interoperability at the equilibrium. So, if the incumbents want to offer bundles, they have to merge. Thus, thanks to the positive network effects, the conditions conducive to merger are less restrictive.

For  $a = -\frac{1}{2}$ , the incumbent houses earnings matrix becomes :

X1 / Y1	Status quo	Interoperability	Merger
Status quo	$0, 52 - F_1/0, 52 - F_1$	$0, 10 - F_1/0, 79 - F_1 - f$	$0, 52 - F_1/0, 52 - F_1$
Interoperability	$0, 79 - F_1 - f/0, 10 - F_1$	$0, 44 - F_1 - f/0, 44 - F_1 - f$	$0, 79 - F_1 - f/0, 10 - F_1$
Merger	$0, 52 - F_1/0, 52 - F_1$	$0, 10 - F_1/0, 79 - F_1 - f$	$0, 46 - \frac{F_M}{2}/0, 46 - \frac{F_M}{2}$

Table 13: Earnings matrix for negative network effects

**Lemma 5** *The SPNE also depends on fixed costs conditions. The bilateral interoperability equilibrium appears if  $F_1 < 0,165$  or, if  $\frac{F_M}{2} > F_1 + f - 0,33$  with  $f < 0,27$ . In all other cases, the merger is the game equilibrium if merger synergies are quite important. If not, the benchmark is the equilibrium (see appendix F2).*

**Proposition 9** *First, the clearing houses strategies can lead to interoperability agreements but for very restrictive conditions on fixed costs and only for bilateral agreements. Second, the merger can come true if it generates enough fixed costs savings. Thus, the negative network effects do not modify qualitatively our results.*

In this case, the risk concern is dominated by congestion which induces higher prices. As a consequence, the houses profits are always higher whatever the fixed costs. Such that the conditions conducive to the bilateral equilibrium are less restrictive.

## 6 Global surplus analysis

We now compute the global surplus, including the net utility of banks  $X$ ,  $Y$  and  $B$ , as well as the clearing houses profits (see table 14, with  $a = 0$ ,  $a = \frac{1}{2}$  and  $a = -\frac{1}{2}$ ). The global surplus are ranked for each network effect, in order to obtain the pareto-optimal market configuration.

	with $a = 0$	with $a = \frac{1}{2}$	with $a = -\frac{1}{2}$
Benchmark	$-0,168 + 1,72\phi - 2F_1 - F_2$	$0,23 + 1,72\phi - 2F_1 - F_2$	$-0,48 + 1,72\phi - 2F_1 - F_2$
Interoperability "for" X	$-0,425 + 1,72\phi - 2F_1 - F_2 - f$	$0,25 + 1,72\phi - 2F_1 - F_2 - f$	$-0,56 + 1,72\phi - 2F_1 - F_2 - f$
Merger	$-0,125 + 1,72\phi - F_M - F_2$	$0,19 + 1,72\phi - F_M - F_2$	$-0,53 + 1,72\phi - F_M - F_2$
Bilateral interoperability	$-0,125 + 1,72\phi - 2F_1 - F_2 - 2f$	$0,22 + 1,72\phi - 2F_1 - F_2 - 2f$	$-0,49 + 1,72\phi - 2F_1 - F_2 - 2f$

Table 14: Global surplus

**Proposition 10** *The merger is the first best market structure, since all banks can choose between two clearing houses for every access type, except for negative network effect when fixed costs ( $F_M$ ) are high. In this last case, the benchmark becomes the first best, because the banks earning is not sufficient to compensate the clearing houses profit drop.*

In most cases, the merger is the SNPE and also the first best market structure, which is our main result. The crucial point relies on the expected saving fixed costs of the merger ( $F_M$  vs  $F_1$ ). Remember that, in the clearing industry, the main characteristic is the size and the complexity of information systems. The maintenance of these systems induces high fixed costs. In case of merger, two solutions can be implemented to make their systems compatible. Either, the incumbents adopt one unique system, or they keep their own systems and they build an interface to connect themselves. We can reasonably imagine that the incumbents will select the lowest maintenance costs solution (fixed costs). So the merger will occur if it is enough successful in decreasing these costs. In this case, the earnings increase for the banks and the incumbents, that overcompensates the profit decrease of the Pan-European.

In the current macroeconomic context, the preference for risk management dominates the congestion aversion. This concern is also shared by economic regulators, in Europe as in the US. So the global network effects are positive and the merger is the best market structure for banks and the worst for the Pan-European (see proposition 7). Note that, even if the banks concern for congestion would increase with a stronger concentration of flows, this would not modify this result. The merger would remain the SNPE and also the first best equilibrium, but banks would prefer the bilateral interoperability agreement which is also the worse situation for the Pan-European.

## 7 Conclusion

Surprisingly, the main result of our paper is that status quo may continue, despite it is the second best equilibrium. So, the incumbent houses might endure the competitive pressure exerted by the

Pan European, which is the best situation for the latter but the worst for banks. Interoperability agreements should never be reached at equilibrium, in spite of the European Code of Conduct for Clearing and Settlement. Our model explains this failure because of very demanding conditions on fixed costs, which seems unrealistic. So, it will be difficult to unify the clearing market with such links. No merger will occur for similar reasons.

The Pan european strenght is its bundle offer, which fits well with banks demand for multiple accesses. The incumbents can also propose bundles, with interoperability links or by merging. An interoperability link seems at first sight interesting because it reduces fixed costs and it also avoids locking agreements thanks to the Code of Conduct. Nevertheless, a simple interoperability agreement is hardly possible for the incumbent clearing houses which cannot stay isolated on their markets. So they ask for reciprocity. Such a bilateral agreement makes the incumbent houses loose partially their specificities. A fierce competition appears between them besides the one exerted by the Pan European house. It is important to underline that, in this case, all clearing houses, the incumbent and the Pan European, see their profits decreasing to the advantage of banks. The merger is also a very efficient means of supplying bunddles. This is even the first best market structure if the savings in fixed costs are rather big. When the merger occurs, it is so beneficial for the incumbent clearing houses and for the banks but it is unfavorable to the Pan European house.

To date, the clearing market structure is still unchanged in Europe, such that the european clearing market is close to our benchmark. In Germany, the vertical integration between Deutsche Börse and Eurex Clearing remains identical. The arrival of new Pan european forced LCH Clearnet to renegotiate its agreement with NyseEuronext on cash equity clearing until 2018.

By introducing positive or negative network effects, we obtain the same equilibria. But global positive network effects strengthen competition in all our market configurations, such that all the prices decrease. At the opposite, global negative effects increase the prices. In these two cases, the banks are not anymore indifferent between these alternative market structures.

Several extensions of this model could be envisaged, in terms of merger occurences and in terms of risks management. Firstly, we do not consider a merger between an incumbent and the Pan-European. Note that such a merger should be at least as harmful for the remaining incumbent than in the simple interoperability case. The main difference is that this new house would concentrate most flows, which might not be allowed by the European authorities. Secondly, we consider that the risks management technology is identical between houses and thus no vertical differentiation may occur. This is an interesting question and, in a forthcoming study, we shall focus on the arbitration between prices and quality of risks management for such given market structures.

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## Appendices

### Appendix A: First and second order conditions without network effects.

**A1- Benchmark equilibrium (proof of lemma 1):** The first order conditions are:

$$\begin{cases} \frac{\partial \Pi_{X_1}}{\partial p_{x_1}} = \frac{1}{2}X(1 + p_{x_2} - 2p_{x_1}) + \frac{1}{3}B(1 - 2p_{x_1} - p_{y_1} + p_b) = 0 \\ \frac{\partial \Pi_{Y_1}}{\partial p_{y_1}} = \frac{1}{2}Y(1 + p_{y_2} - 2p_{y_1}) + \frac{1}{3}B(1 - 2p_{y_1} - p_{x_1} + p_b) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_{x_2}} = \frac{1}{2}X(-2p_{x_2} + 2p_{x_1}) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_{y_2}} = \frac{1}{2}Y(1 - 2p_{y_2} + 2p_{y_1}) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_b} = \frac{1}{3}B(2 - 2p_b + p_{x_1} + p_{x_2}) = 0 \end{cases} \quad (12)$$

The second order conditions are obviously verified for house  $X$  with  $\frac{\partial^2 \Pi_{X_1}}{\partial p_{x_1}^2} = -X - \frac{2}{3}B < 0$  and respectively for house  $Y$  with  $\frac{\partial^2 \Pi_{Y_1}}{\partial p_{y_1}^2} = -Y - \frac{2}{3}B < 0$ . The Hessian matrix of the Pan European  $XY_2$  profit is  $H_{XY_2} = \begin{pmatrix} -X & 0 & 0 \\ 0 & -Y & 0 \\ 0 & 0 & -\frac{2}{3}B \end{pmatrix}$ . The second order conditions for the Pan European are also verified with  $|-X| < 0$ ,  $\begin{vmatrix} -X & 0 \\ 0 & -B \end{vmatrix} = XB > 0$  and  $|H_{XY_2}| = -\frac{2}{3}XYB < 0$ . The problem is then globally concave.

**A2- Simple interoperability equilibrium (proof of lemma 2):** The incumbent house  $X$  supplies bundles as it benefits from an access to market  $Y$  though the interoperability link provided by house  $Y$ . At the opposite, the incumbent house  $Y$  faces competition from the two other houses on its market. The first order conditions on the houses profits are then:

$$\begin{cases} \frac{\partial \Pi_{X_1}}{\partial p_{x_1}} = \frac{1}{2}X(1 + p_{x_2} - 2p_{x_1}) = 0 \\ \frac{\partial \Pi_{X_1}}{\partial p_{b_1}} = \frac{1}{2}B(1 + p_{b_2} - 2p_{b_1}) = 0 \\ \frac{\partial \Pi_{Y_1}}{\partial p_{y_1}} = \frac{1}{2}Y(1 + p_{y_2} - 2p_{y_1}) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_{x_2}} = \frac{1}{2}X(1 + p_{x_1} - 2p_{x_2}) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_{y_2}} = \frac{1}{2}Y(1 + p_{y_1} - 2p_{y_2}) = 0 \\ \frac{\partial \Pi_{XY_2}}{\partial p_{b_2}} = \frac{1}{2}B(1 + p_{b_1} - 2p_{b_2}) = 0 \end{cases} \quad (13)$$

The house  $X$  Hessian is  $H_{X_1} = \begin{pmatrix} -X & 0 \\ 0 & -B \end{pmatrix}$ . The second order conditions for the latter are also verified with  $|-X| < 0$ ,  $\begin{vmatrix} -X & 0 \\ 0 & -B \end{vmatrix} = XB > 0$ . The Hessian matrix of the Pan European  $XY_2$  profit is the same as in appendix A1 (i.e. the benchmark case). So all the second order conditions are then verified.

**A3- Double interoperability equilibrium:** In this specific case, the incumbent houses  $X$  and

Y seek a price agreement leading to the following first order conditions :

$$\begin{cases} \frac{\partial(\Pi_{X_1} + \Pi_{Y_1})}{\partial p_{x_1}} = \frac{1}{2}X(1 + p_{x_2} - 2p_{x_1}) = 0 \\ \frac{\partial(\Pi_{X_1} + \Pi_{Y_1})}{\partial p_{y_1}} = \frac{1}{2}Y(1 + p_{y_2} - 2p_{y_1}) = 0 \\ \frac{\partial(\Pi_{X_1} + \Pi_{Y_1})}{\partial p_{b_1}} = \frac{1}{2}B(1 + p_{b_2} - 2p_{b_1}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{x_2}} = \frac{1}{2}X(1 + p_{x_1} - 2p_{x_2}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{y_2}} = \frac{1}{2}Y(1 + p_{y_1} - 2p_{y_2}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{b_2}} = \frac{1}{2}B(1 + p_{b_1} - 2p_{b_2}) = 0 \end{cases} \quad (14)$$

The Hessian matrix of the houses  $X$  and  $Y$  is  $H_{X_1Y_1} = \begin{pmatrix} -X & 0 & 0 \\ 0 & -Y & 0 \\ 0 & 0 & -B \end{pmatrix}$ . The second order conditions for the two incumbents are also verified with  $|-X| < 0$ ,  $\begin{vmatrix} -X & 0 \\ 0 & -B \end{vmatrix} = XB > 0$  and  $|H_{X_1Y_1}| = -XYB < 0$ .

The Hessian matrix of the Pan European profit is identical to the latter matrix. We conclude that the second order conditions are verified leading to a globally concave problem.

**A4- Merger equilibrium:** The incumbent houses merge leading to the first order conditions reported below :

$$\begin{cases} \frac{\partial\Pi_{X_1Y_1}}{\partial p_{x_1}} = \frac{1}{2}X(1 + p_{x_2} - 2p_{x_1}) = 0 \\ \frac{\partial\Pi_{X_1Y_1}}{\partial p_{y_1}} = \frac{1}{2}Y(1 + p_{y_2} - 2p_{y_1}) = 0 \\ \frac{\partial\Pi_{X_1Y_1}}{\partial p_{b_1}} = \frac{1}{2}B(1 + p_{b_2} - 2p_{b_1}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{x_2}} = \frac{1}{2}X(1 + p_{x_1} - 2p_{x_2}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{y_2}} = \frac{1}{2}Y(1 + p_{y_1} - 2p_{y_2}) = 0 \\ \frac{\partial\Pi_{XY_2}}{\partial p_{b_2}} = \frac{1}{2}B(1 + p_{b_1} - 2p_{b_2}) = 0 \end{cases} \quad (15)$$

All the second order conditions are the same as the double interoperability case.

## Appendix B: Details on the banks surplus computation.

**B1- Benchmark:** On market  $X$ , the banks surplus is  $S_X^* = \tilde{\theta}_X^* X \left[ \phi_X - \int_0^{\tilde{\theta}_X^*} x dx - p_{x_1}^* \right] + (1 - \tilde{\theta}_X^*) X \left[ \phi_X - \int_{\tilde{\theta}_X^*}^1 (1-x) dx - p_{x_2}^* \right] = X \left( \phi_X - \frac{9}{8} \right)$  and by symmetry<sup>40</sup>  $S_Y^* = Y \left( \phi_Y - \frac{9}{8} \right)$  for market  $Y$ . On the bundle market<sup>41</sup>, we obtain  $S_B^* = B(\phi_X + \phi_Y) - \frac{59}{27}B$ . At the equilibrium, the banks total surplus becomes:

$$S^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y) - \frac{59}{27}B. \quad (16)$$

Setting  $\phi_X = \phi_Y = \phi$ , the existence condition of this problem is such that  $\phi \geq \frac{243X + 243Y + 472B}{216(X + Y + 2B)}$ .

<sup>40</sup>  $S_Y^* = \tilde{\theta}_Y^* Y \left[ \phi_Y - \int_0^{\tilde{\theta}_Y^*} x dx - p_{y_1}^* \right] + (1 - \tilde{\theta}_Y^*) Y \left[ \phi_Y - \int_{\tilde{\theta}_Y^*}^1 (1-x) dx - p_{y_2}^* \right]$

<sup>41</sup>  $S_B^* = \tilde{\theta}_B^* B \left[ \phi_X + \phi_Y - \int_0^{\tilde{\theta}_B^*} 2x dx - p_{x_1}^* - p_{y_1}^* \right] + (1 - \tilde{\theta}_B^*) B \left[ \phi_X + \phi_Y - \int_{\tilde{\theta}_B^*}^1 (1-x) dx - p_b^* \right]$

**B2- Simple interoperability:** On market  $X$ , the banks surplus is:

$S_{XI}^* = \tilde{\theta}_{XI}^* X \times \left[ \phi_X - \int_0^{\tilde{\theta}_{XI}^*} x dx - p_{x_1}^* \right] + \left( 1 - \tilde{\theta}_{XI}^* \right) X \times \left[ \phi_X - \int_{\tilde{\theta}_{XI}^*}^1 (1-x) dx - p_{x_2}^* \right] = X \left( \phi_X - \frac{9}{8} \right)$ . In the same way, it corresponds to  $S_{YI}^* = Y \left( \phi_Y - \frac{9}{8} \right)$  on market  $Y$ . On the bundle market, we obtain  $S_{BI}^* = B \left( \phi_X + \phi_Y - \frac{9}{8} \right)$ . At the equilibrium, the banks total surplus equals :

$$S_I^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y + B). \quad (17)$$

Fixing that  $\phi_X = \phi_Y = \phi$ , the existence condition of this problem is  $\phi \geq \frac{9}{8} \frac{X+Y+B}{X+Y+2B}$ .

**B3- Double interoperability:** On market  $X$ , the banks surplus is:

$S_{XDI}^* = \tilde{\theta}_{XDI}^* X \times \left[ \phi_X - \int_0^{\tilde{\theta}_{XDI}^*} x dx - p_{x_1}^* \right] + \left( 1 - \tilde{\theta}_{XDI}^* \right) X \times \left[ \phi_X - \int_{\tilde{\theta}_{XDI}^*}^1 (1-x) dx - p_{x_2}^* \right] = X \left[ \phi_X - \frac{9}{8} \right]$  and, by symmetry,  $S_{YDI}^* = Y \left( \phi_Y - \frac{9}{8} \right)$  on market  $Y$ . On the bundle market, we obtain  $S_{BDI}^* = B \left( \phi_X + \phi_Y - \frac{9}{8} \right)$ . At the equilibrium, the banks total surplus equals :

$$S_{DI}^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y + B) = SB_I^*. \quad (18)$$

Fixing that  $\phi_X = \phi_Y = \phi$ , the existence condition of this problem is:  $\phi \geq \frac{9}{8} \frac{X+Y+B}{X+Y+2B}$ .

**B4- Merger:** On market  $X$ , the banks surplus is  $S_{XM}^* = \tilde{\theta}_{XM}^* X \times \left[ \phi_X - \int_0^{\tilde{\theta}_{XM}^*} x dx - p_{x_1}^* \right] + \left( 1 - \tilde{\theta}_{XM}^* \right) X \times \left[ \phi_X - \int_{\tilde{\theta}_{XM}^*}^1 (1-x) dx - p_{x_2}^* \right] = X \left( \phi_X - \frac{9}{8} \right)$  and, by symmetry,  $S_{YM}^* = Y \left[ \phi_Y - \frac{9}{8} \right]$  on market  $Y$ . On the bundle market, we obtain  $S_{BM}^* = B \left( \phi_X + \phi_Y - \frac{9}{8} \right)$ . At the equilibrium, the banks total surplus equals :

$$S_M^* = X\phi_X + Y\phi_Y + B(\phi_X + \phi_Y) - \frac{9}{8}(X + Y + B) = SB_I^* = SB_{DI}^*. \quad (19)$$

By supposing that  $\phi_X = \phi_Y = \phi$ , the existence condition of this problem is such that  $\phi \geq \frac{9}{8} \frac{X+Y+B}{X+Y+2B}$ .

## Appendix C: Subgame perfect equilibrium without network effects

**Proof of lemma 3.** The earnings matrix without network effects is as follows :

$X1/Y1$	<i>Status quo</i>	<i>Interoperability</i>	<i>Merger</i>
<i>Status quo</i>	$0, 31 - F_1/0, 31 - F_1$	$0, 07 - F_1/0, 43 - F_1 - f$	$0, 31 - F_1/0, 31 - F_1$
<i>Interoperability</i>	$0, 43 - F_1 - f/0, 07 - F_1$	$0, 25 - F_1 - f/0, 25 - F_1 - f$	$0, 43 - F_1 - f/0, 07 - F_1$
<i>Merger</i>	$0, 31 - F_1/0, 31 - F_1$	$0, 07 - F_1/0, 43 - F_1 - f$	$0, 25 - \frac{1}{2}F_M/0, 25 - \frac{1}{2}F_M$

To solve the game, we establish several cases, in which  $Sq$  stands for Statuts quo,  $I$  for Interoperability and  $M$  for merger respectively.

If  $F_1 < 0,07$ , bilateral interoperability is the dominant strategy equilibrium.

If  $F_1 \geq 0,07$ , several sub-cases must be considered, some of them conducing to multiple equilibria.

In this case, we use the Pareto-dominant criterium to select an equilibrium.

- If  $f < 0,12$ , the bilateral interoperability is the game equilibrium, provided that  $\frac{1}{2}F_M \geq F_1 + f - 0,18$ . Otherwise, two equilibria emerge:  $(M/M)$  and  $(I/I)$ . The merger is the selected equilibrium.
- If  $0,12 \leq f \leq 0,18$ , we must distinguish two sub-cases:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,06$ ), there are two equilibria:  $(Sg/Sg)$  and  $(I/I)$ . The status quo is the selected equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,06$ ), there are three equilibria:  $(M/M)$ ,  $(Sg/Sg)$  and  $(I/I)$ . The merger equilibrium is selected.
- If  $f > 0,18$ , we consider two sub-cases:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,06$ ), the status quo is the game equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,06$ ), there are two equilibria:  $(M/M)$  and  $(Sg/Sg)$ . The merger is the selected equilibrium.

## Appendix D: Benchmark with network effects.

### D1 - Marginal banks

On the three markets, the marginal banks  $\tilde{\theta}_X$ ,  $\tilde{\theta}_Y$  and  $\tilde{\theta}_B$  are given by the following equations, with  $X = 14\%$ ,  $Y = 14\%$  and  $B = 72\%$ .

$$\tilde{\theta}_X = \frac{[126(p_{x_1} + p_{x_2} + p_{y_1} + p_{y_2} - 2p_b) + 602]a^2}{(100 - 93a)(7a - 100)} + \frac{50(72p_b + 14p_{x_1} - 86p_{x_2} - 79p_{y_1} + 7p_{y_2} - 179)a + 5000(1 + p_{x_2} - p_{x_1})}{(100 - 93a)(7a - 100)}, \quad (20)$$

$$\tilde{\theta}_B = \frac{[21(p_{x_1} + p_{y_1} + p_{x_2} + p_{y_2} - 2p_b) - 344]a + 200(1 + p_b - p_{x_1} - p_{y_1})}{100 - 93a}. \quad (21)$$

Note that  $\tilde{\theta}_Y$ , the marginal bank on market  $Y$ , is reciprocally the same as  $\tilde{\theta}_X$ .

### D2 - Second order conditions

If  $-\frac{1}{2} \leq a \leq \frac{1}{2}$ , the second order conditions are verified for house  $X$ , and reciprocally for house  $Y$ :  $\frac{\partial^2 \Pi_{X_1}}{\partial p_{x_1}^2} = \frac{4(259a - 1550)}{(93a - 100)(7a - 100)} < 0$ .

The Hessian matrix of the Pan European  $XY_2$  is:

$$H_{XY_2} = \frac{1}{25(93a - 100)} \begin{pmatrix} 14 \left( \frac{-63a^2 + 2150a - 2500}{7a - 100} \right) & 14 \left( \frac{-63a^2 - 175a}{7a - 100} \right) & 189a \\ 14 \left( \frac{-63a^2 - 175a}{7a - 100} \right) & 14 \left( \frac{-63a^2 + 2150a - 2500}{7a - 100} \right) & 189a \\ 189a & 189a & -12(21a - 100) \end{pmatrix}. \quad \text{The second order con-}$$

ditions are verified with:  $\left| 14 \left( \frac{-63a^2 + 2150a - 2500}{7a - 100} \right) \right| < 0$ ,

$$\frac{14}{25(93a-100)} \left| \left( \frac{-63a^2+2150a-2500}{7a-100} \right) \left( \frac{-63a^2-175a}{7a-100} \right) \right| = \frac{196}{25} \left( \frac{25-18a}{(93a-100)(7a-100)} \right) > 0 \text{ and}$$

$$|H_{XY_2}| = -\frac{588}{625} \left[ \frac{189a^2+9300a-10000}{(93a-100)^2(7a-100)} \right] < 0. \text{ So, the problem is globally concave for } -\frac{1}{2} \leq a \leq \frac{1}{2}.$$

The equilibrium prices are  $p_{x_1}^* = p_{y_1}^* = \frac{Z_1}{50Z_4}$ ,  $p_{x_2}^* = p_{y_2}^* = \frac{Z_2}{50Z_4}$ ,  $p_b^* = \frac{3Z_3}{25Z_4}$ , with :

$$\begin{cases} Z_1 = (1, 8a^4 + 81, 4a^3 - 1734, 4a^2 + 3128, 7a - 1462, 5) 10^6, \\ Z_2 = (1, 8a^4 + 60, 5a^3 - 1112, 5a^2 + 2435, 6a - 1462, 5) 10^6, \\ Z_3 = (0, 6a^4 + 22, 3a^3 - 443, 2a^2 + 908, 2a - 487, 5) 10^6, \\ Z_4 = (-0, 05a^3 - 3a^2 + 30, 7a - 29, 2) 10^6. \end{cases}$$

At the equilibrium, marginal banks are:  $\tilde{\theta}_X^* = \tilde{\theta}_Y^* = \frac{2(0,009a^3 - 2a^2 + 10a - 7,3)10^6}{Z_4}$  and

$$\tilde{\theta}_B^* = \frac{5(-0,008a^3 - 0,3a^2 + 2,5a - 1,9)10^6}{Z_4}.$$

Finally, equilibrium profits are:

$$\begin{aligned} \Pi_{X_1}^* = \Pi_{Y_1}^* &= \frac{(100 - 93a)(7a - 100)(259a - 1550) (2, 7a^2 + 166, 6a - 146, 2)^2 10^6}{1250 (Z_4)^2} - F_1, (22) \\ \Pi_{X_2}^* &= \frac{(-1, 2a^7 - 134, 8a^6 - 1368, 9a^5) 10^{12}}{1250 (Z_4)^2} \\ &+ \frac{(1, 1a^4 + 1151, 1a^4 - 11489, 1a^3) 10^{14}}{1250 (Z_4)^2} \\ &+ \frac{(3, 1a^2 - 3, 2a + 1, 2) 10^{18}}{1250 (Z_4)^2} - F_2. \end{aligned} \quad (23)$$

### D3 - Bank surplus

On market  $X$ , the banks surplus is as follows:

$$\begin{aligned} S_X^* &= \tilde{\theta}_X^* X \left[ \phi_X + a (\tilde{\theta}_X^* X + \tilde{\theta}_B^* B) - \int_0^{\tilde{\theta}_X^*} x dx - p_{x_1}^* \right] \\ &+ (1 - \tilde{\theta}_X^*) X \left[ \phi_X + a [(1 - \tilde{\theta}_X^*) X + (1 - \tilde{\theta}_Y^*) Y + 2(1 - \tilde{\theta}_B^*) B] - \int_{\tilde{\theta}_X^*}^1 (1 - x) dx - p_{x_2}^* \right], \end{aligned} \quad (24)$$

It is the same on the bundle market:

$$\begin{aligned} S_B^* &= \tilde{\theta}_B^* B \left[ \phi_X + \phi_Y + a \left( \tilde{\theta}_B^* B + \frac{1}{2} \tilde{\theta}_X^* X + \frac{1}{2} \tilde{\theta}_Y^* Y \right) - \int_0^{\tilde{\theta}_B^*} 2x dx - p_{x_1}^* - p_{y_1}^* \right] \\ &+ (1 - \tilde{\theta}_B^*) B \left[ \phi_X + \phi_Y + a [2(1 - \tilde{\theta}_B^*) B + (1 - \tilde{\theta}_X^*) X + (1 - \tilde{\theta}_Y^*) Y] - \int_{\tilde{\theta}_B^*}^1 (1 - x) dx - p_b^* \right]. \end{aligned} \quad (25)$$

Note that the banks surplus on market  $Y$  is reciprocally the same as on market  $X$ .

## Appendix E: Alternative market structures with network effects.

**E1 - Simple interoperability:** The market sharing rules are:

$$a(\theta_X X + 2\theta_B B) - \theta_X - p_{x_1} = a[(1 - \theta_X)X + (1 - \theta_Y)Y + 2(1 - \theta_B)B] - (1 - \theta_X) - p_{x_2},$$

$$a(\theta_Y Y) - \theta_Y - p_{y_1} = a[(1 - \theta_Y)Y + (1 - \theta_X)X + 2(1 - \theta_B)B] - (1 - \theta_Y) - p_{y_2},$$

$$a(2\theta_B B + \theta_X X) - 2\theta_B - p_{b_1} = a[2(1 - \theta_B)B + (1 - \theta_X)X + (1 - \theta_Y)Y] - (1 - \theta_B) - p_{b_2}.$$

With  $X = 14\%$ ,  $Y = 14\%$  and  $B = 72\%$  the marginal banks  $\tilde{\theta}_X$ ,  $\tilde{\theta}_Y$  and  $\tilde{\theta}_B$  become:

$$\tilde{\theta}_X = \frac{[756(p_{x_2} - p_{x_1} + p_{b_1} - p_{b_2}) + 602] a^2}{1659a^2 - 17200a + 10000} + \frac{50[144(p_{b_2} - p_{b_1}) + 158(p_{x_1} - p_{x_2}) - 7(p_{y_2} - p_{y_1}) - 179] a + 5000(1 + p_{x_2} - p_{x_1})}{1659a^2 - 17200a + 10000}, \quad (26)$$

$$\tilde{\theta}_Y = \frac{6794a^2}{1659a^2 - 17200a + 10000} + \frac{50[72(p_{b_2} - p_{b_1}) + 158(p_{y_1} - p_{y_2}) + 7(p_{x_2} - p_{x_1}) - 251] a + 5000(1 + p_{y_2} - p_{y_1})}{1659a^2 - 17200a + 10000}, \quad (27)$$

$$\tilde{\theta}_B = \frac{[147(p_{x_1} - p_{x_2} + p_{b_2} - p_{b_1}) + 1204] a^2}{2(1659a^2 - 17200a + 10000)} + \frac{50\{[7[4(p_{b_1} - p_{b_2}) + (p_{y_2} - p_{y_1}) + 2(p_{x_2} - p_{x_1})] - 179] a + 100(1 + p_{b_2} - p_{b_1})\}}{(1659a^2 - 17200a + 10000)}. \quad (28)$$

The second order conditions have been checked for  $-\frac{1}{2} \leq a \leq \frac{1}{2}$  (for further details, please contact the authors). The equilibrium values are presented in table 7 and 8 for  $a = \frac{1}{2}$  and  $a = -\frac{1}{2}$  respectively.

**E2 - Bilateral interoperability:** The market sharing rules are on market  $X$  (and reciprocally for market  $Y$ ) and on the bundle market :

$$a(\theta_X X + \theta_B B) - \theta_X - p_{x_1} = a[(1 - \theta_X)X + (1 - \theta_Y)Y + 2(1 - \theta_B)B] - (1 - \theta_X) - p_{x_2},$$



$$a(\theta_B B + \frac{1}{2}\theta_X X + \frac{1}{2}\theta_Y Y) - 2\theta_B - p_{b_1} = a[2(1 - \theta_B)B + (1 - \theta_X)X + (1 - \theta_Y)Y] - (1 - \theta_B) - p_{b_2}.$$

With  $X = 14\%$ ,  $Y = 14\%$  and  $B = 72\%$  the marginal banks  $\tilde{\theta}_X$  (reciprocally  $\tilde{\theta}_Y$ ) and  $\tilde{\theta}_B$  become:

$$\tilde{\theta}_X = \frac{\{189[p_{x_1} - p_{x_2} + p_{y_1} - p_{y_2} + 2(p_{b_2} - p_{b_1})] - 602\}a^2}{(100 - 129a)(7a - 100)} + \frac{50[108(p_{b_1} - p_{b_2}) + 7(p_{y_1} - p_{y_2}) + 122(p_{x_2} - p_{x_1}) + 179]a - 5000(1 + p_{x_2} - p_{x_1})}{(100 - 129a)(7a - 100)} \quad (29)$$

$$\tilde{\theta}_B = \frac{(21(+p_{x_2} - p_{x_1} + p_{y_2} - p_{y_1} + 2(p_{b_1} - p_{b_2})) - 344)a + 200(1 + p_{b_2} - p_{b_1})}{4(100 - 129a)}. \quad (30)$$

The second order conditions have been checked for  $-\frac{1}{2} \leq a \leq \frac{1}{2}$  (for further details, please contact the authors). The equilibrium values are presented in table 7 and 8 for  $a = \frac{1}{2}$  and  $a = -\frac{1}{2}$  respectively.

**E3 - Merger:** The market sharing rules are on market  $X$  (and reciprocally for market  $Y$ ) and on the bundle market :

$$a[\theta_X X + \theta_Y Y + 2\theta_B B] - \theta_X - p_{x_1} = a[(1 - \theta_X)X + (1 - \theta_Y)Y + 2(1 - \theta_B)B] - (1 - \theta_X) - p_{x_2}$$

$$a[2\theta_B B + \theta_X X + \theta_Y Y] - 2\theta_B - p_{b_1} = a[2(1 - \theta_B)B + (1 - \theta_X)X + (1 - \theta_Y)Y] - (1 - \theta_B) - p_{b_2}.$$

With  $X = 14\%$ ,  $Y = 14\%$  and  $B = 72\%$  the marginal banks  $\tilde{\theta}_X$  (reciprocally  $\tilde{\theta}_Y$ ) and  $\tilde{\theta}_B$  become:

$$\tilde{\theta}_X = \frac{[72(p_{b_1} - p_{b_2}) + 79(p_{x_2} - p_{x_1}) - 7(p_{y_1} - p_{y_2}) + 86]a + 50(1 + p_{x_2} - p_{x_1})}{4(43a - 25)}, \quad (31)$$

$$\tilde{\theta}_B = \frac{[72(p_{b_2} - p_{b_1}) + (p_{x_1} - p_{x_2} + p_{y_1} - p_{y_2}) + 86]a + 50(1 + p_{b_2} - p_{b_1})}{4(43a - 25)}. \quad (32)$$

The second order conditions have been checked for  $-\frac{1}{2} \leq a \leq \frac{1}{2}$  (for further details, please contact the authors). The equilibrium values are presented in table 7 and 8 for  $a = \frac{1}{2}$  and  $a = -\frac{1}{2}$  respectively.

## Appendix F: The subgame perfect equilibrium with network effects

**F1- Proof of lemma 4:** The earnings matrix for positive network effects is as follows with  $a = \frac{1}{2}$  :

$X1/Y1$	<i>Status quo</i>	Interoperability	Merger
<i>Status quo</i>	$0, 11 - F_1/0, 11 - F_1$	$0, 03 - F_1/0, 06 - F_1 - f$	$0, 11 - F_1/0, 11 - F_1$
Interoperability	$0, 06 - F_1 - f/0, 03 - F_1$	$0, 06 - F_1 - f/0, 06 - F_1 - f$	$0, 06 - F_1 - f/0, 06 - F_1$
Merger	$0, 11 - F_1/0, 11 - F_1$	$0, 03 - F_1/0, 06 - F_1 - f$	$0, 03 - \frac{1}{2}F_M/0, 03 - \frac{1}{2}F_M$

To solve the game, we establish several cases, in which *Sq* stands for Statuts quo, *I* for Interoperability and *M* for merger respectively. Some cases conduce to multiple equilibria, so that we use the Pareto-dominant criterium to select an equilibrium.

If  $F_1 < 0,03$ , there are six equilibria:  $\{(Sq/Sq); (I/I); (Sq/I), (M/M); (Sq/M); (M/Sq)\}$ , but  $(Sq/M)$  and  $(M/Sq)$  lead to  $(Sq/Sq)$  market structure. The status quo is the selected equilibrium.

If  $0,03 \leq F_1 \leq 0,08$ , there are two sub-cases to consider:

- If  $f < 0,03$ , there are five equilibria:  $\{(Sq/Sq); (I/I); (Sq/I); (Sq/M); (M/Sq)\}$ . The status quo is the selected equilibrium.
- If  $0,03 \leq f \leq F_1$ , there are three equilibria:  $\{(Sq/Sq); (Sq/M); (M/Sq)\}$ . The industry is so in the status quo situation.

If  $0,08 < F_1 < 0,11$ , there are two sub-cases to consider:

- If  $f < 0,03$ , there are two sub-cases to consider:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,08$ ), there are four equilibria:  $\{(Sq/Sq); (Sq/I); (Sq/M); (M/Sq)\}$ . The status quo is the selected equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,08$ ), there are three equilibria:  $\{(Sq/Sq); (I/I); (M/M)\}$ . In this case, the merger is the selected equilibrium.
- If  $0,03 \leq f \leq F_1$ , we consider two sub-cases:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,08$ ), there are three equilibria:  $\{(Sq/Sq); (Sq/M); (M/Sq)\}$ . The status quo is the selected equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,08$ ), there are two equilibria:  $\{(Sq/Sq); (M/M)\}$ . In this case, the merger is the selected equilibrium.

**F2- Proof of lemma 5:** The earnings matrix for negative network effects is as follows with  $a = -\frac{1}{2}$  :

$X1/Y1$	<i>Status quo</i>	Interoperability	Merger
<i>Status quo</i>	$0, 52 - F_1/0, 52 - F_1$	$0, 10 - F_1/0, 79 - F_1 - f$	$0, 52 - F_1/0, 52 - F_1$
Interoperability	$0, 79 - F_1 - f/0, 10 - F_1$	$0, 44 - F_1 - f/0, 44 - F_1 - f$	$0, 79 - F_1 - f/0, 10 - F_1$
Merger	$0, 52 - F_1/0, 52 - F_1$	$0, 10 - F_1/0, 79 - F_1 - f$	$0, 46 - \frac{1}{2}F_M/0, 046 - \frac{1}{2}F_M$

To solve the game, we establish several cases, in which  $Sq$  stands for Statuts quo,  $I$  for Interoperability and  $M$  for merger respectively. Once again, the merger being Pareto dominant, it is then the selected equilibrium.

If  $F_1 < 0,165$ , the bilateral interoperability is the the dominant strategy equilibrium of the game.

If  $F_1 \geq 0,165$ , there are several sub-cases to consider:

- If  $f < 0,27$ , bilateral interoperability is the game equilibrium, with  $\frac{1}{2}F_M > F_1 + f - 0,33$ . Otherwise, two equilibria can occur:  $\{(I/I); (M/M)\}$ . The merger is the selected equilibrium.
- If  $0,27 \leq f \leq 0,34$ , we must distinguish two sub-cases:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,06$ ), there are four equilibria:  $\{(Sq/Sq); (I/I); (Sq/M) (M/Sq)\}$ . The status quo is the selected equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,06$ ), there are three equilibria:  $\{(M/M); (Sq/Sq); (I/I)\}$ . The merger equilibrium is selected.
- If  $f > 0,34$ , we consider two sub-cases:
  - If the merger synergies are not too important (that is  $\frac{1}{2}F_M \geq F_1 - 0,06$ ), there are three equilibria:  $\{(Sq/Sq); (Sq/M) (M/Sq)\}$ . The status quo is the selected equilibrium.
  - If the merger synergies are quite important (that is  $\frac{1}{2}F_M < F_1 - 0,06$ ), there are two equilibria:  $\{(M/M); (Sq/Sq)\}$ . In this case, the merger equilibrium is selected.