FUNDACION BBV

SHARED ATM NETWORKS AND BANKING COMPETITION

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ESTUDIOS BANCARIOS

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Otras contribuciones son: «Consumer Switching Costs: A Survey», *Investigaciones Económicas*, 1991; «Mixed Pricing in Oligopoly with Consumer Switching Costs», *International Journal of Industrial Organization*, 1992; «Shared ATM Network and Banking Competition», *European Economic Review*, 1993; y «Delegation in International Monetary Policy Games», *European Economic Review*, 1993.

ABSTRACT

In this paper we study the incentives of banks to share their Automatic Teller Machines (ATMs) when they are competitors in the market for deposits. We construct a stylized model of banking competition which emphasises the distinctive features of ATM compatibility. We find that in equilibrium either a strict subset of banks share their ATMs or total incompatibility prevails. We also derive the implications on ATM compatiblity of withdrawal fees, interchange bank fees, entry, and depositor switching costs. Finally, we investigate the normative implications of our model and draw some policy conclusions.

SHARED ATM NETWORKS AND BANKING COMPETITION

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I. Introduction

The use of ATM networks as a competitive device in retail banking is widely aknowledged. A cursory look at financial magazines, newspapers, and banks' own brochures reveals that banks heavily advertise the size of the network that their customers can access. As an instance of the growing importance of ATMs, the number of debit cards in the U.S. has tripled during the 1980s. Drawing again on the U.S. experience, banks have followed different strategies over time with respect to their ATM facilities. In an initial moment (during the 70's) they invested large amounts to establish their own proprietary networks. More recently, banks' proprietary networks started a process of consolidation through sharing agreements that still continues today [1, 2]. The forces underlying this latter development constitute the object of our analysis.

In this paper we study the incentives of banks to share their ATM networks when they are imperfect competitors in the market for deposits. We also consider the implications on ATM compatibility of fixed withdrawal fees, interchange bank fees, and depositor switching costs. Finally, we assess the impact of potential entry and public regulation on compatibility decisions.

In our model, depositors value a lager ATM network for two reasons: First, because it facilitates a better access to their deposits when they need cash unexpectedly. Depositors are therefore willing to accept lower interest rates on their deposits in order to have access to a larger network (the *network effect*). Second, compatibility between banks' ATMs implies that depositors can simultaneously benefit from the convenient location of a bank ATM and the high rates paid by a rival compatible bank. Thus, compatible banks become better substitutes for each other (*substitution effect*).

The network effect encourages banks to invest in their ATM network and also favours the signature of agreements to share privately owned ATM networks [3]. On the other hand, the substitution effect enhances price rivalry in the market for deposits, and hence makes banks less willing to establish compatibility agreements [4]. This latter effect is more important, and hence compatibility less likely, the more transactions with banks can be done through ATMs.

We investigate the trade-off between the network and the substitution effects in a setting where rival banks first agree on a compatibility regime and then

[1] See James J. McAndrews (1991).

[2] See «End of the line for the ATM?». *The Banker*, page 61, May 1992.

[3] Heffernan (1992) reports evidence that shows how the provision of ATM facilities lowers the interest rate offered on current accounts. In fact, for some deposits, depositors forego 0.1 percent in interest for this reason.

[4] To illustrate the substitution effect, suppose for instance that bank A is the only one to have an ATM in a given neighborhood of a town. In the presence of positive transport costs, bank A has a clear competitive advantage in that neighborhood with respect to any other bank operating in the same town. However, if bank A allows customers of rival banks to use its ATM that competitive edge disappears. This is because the accessibility to the funds deposited by the inhabitants of that neighborhood becomes identical whether they patronize bank A or any other bank with which A shares its ATM.

compete in deposit rates. We find that, in equilibrium, either a strict subset of banks share their networks (i.e., *partial compatibility*) or total *incompatibility* prevails. Of course, partial compatibility is more likely when the network effect is large and the substitution effect not very important. Interestingly, *full compatibility* does not obtain in equilibrium despite the absence of explicit costs of standardization and the *ex ante* symmetry of banks' ATM networks [5]. This is because under full compatibility no bank obtains a network advantage over its rivals, but simply all banks become better substitutes for each other. Therefore, competition is made tougher and banks' profits lower than under incompatibility.

We also show that banks can use compatibility agreements to exclude rivals from the market when the network effect is sufficiently large. Similarly, incumbent banks may choose to become compatible to obtain a network advantage over potential entrants and so deter further *entry* into the market. Interestingly, the threat of entry may lead to full compatibility among incumbent banks in equilibrium even in the presence of laws preventing exclusion from the compatible network. This is because full compatibility allows incumbent banks to credibly commit to fierce post-entry competition thus lowering the expected profits of any potential entrant.

Full compatibility may also characterise the equilibrium outcome of our two-stage game when banks impose positive *withdrawal fees* (that is, transaction fees charged to depositors of other compatible banks for the use of one's own ATM), or *interchange fees* (that is, the fees paid to the owner of an ATM by another network member whenever the depositors of the latter bank use the former's ATMs) are established. Banks can use both kinds of fees to limit the substitution effect of compatibility, and also to appropriate part of the network externality that they generate on depositors, i.e., to make compatibility agreements more attractive [6].

An important feature of our analysis is that it incorporates *switching costs* for depositors [7]. Switching costs relax competition in the market for deposits which helps banks to appropriate the network externality generated through compatibility [8]. However, their relaxation effect on the strength of competition is greater when all banks remain incompatible, which makes compatibility agreements less compelling. We prove that when the proportion of locked-in depositors in the market is not too large, the second effect dominates and thus switching costs reduce the incentives of banks to become compatible.

The introduction of switching costs also allows us to distinguish betwen banks with asymmetric customer bases. In this case, numerical computations show that a large bank [9] prefers compatibility with a small bank rather than with another large bank when the substitution effect induced by compatibility is small and the network effect large enough. That is, when in terms of increased competition, it is more costly to let the *a priori* more aggressive bank (with switching costs, the bank with a smaller captive market) outside the compatibility agreement.

Our paper is related to the literature on strategic competition in the market for deposits, and also to the existing studies on compatibility and standardization. With respect to banking competition, our paper

[5] Of course, it is well known that (Katz and Shapiro 1985) a large firm may reject a compatibility proposal because it could lead to a loss of the competitive advantage derived from its relatively larger network.

[6] Withdrawal fees, however, are not much used in practice. For instance, the withdrawal fees among Lloyds Bank, Barclays Bank and other compatible U.K. banks are set equal to zero (see the booklet «Our Bank Charges for Personal Customers» edited by Lloyds Bank, November 1992). Section III.4 provides a potential explanation for the lack of use of these fees in networks where banks already pay interchange fees.

[7] The importance of switching costs in banking has been extensively recognised by both practitioners and theorists. As an example of the view of practitioners, see the *Financial Times* 15 & 16 June 1991 and Calem (1992). Examples of the theoretical approach are Klemperer (1987), Grilli (1990), Ausubel (1991), Padilla (1992) and references therein.

[8] Klemperer (1987) and Padilla (1992) show that, in a mature market, switching costs do relax competition since they make market demand less elastic. Sharpe (1991) shows that the predictions of this theory are consistent with the evidence from the U.S. bank deposit market.

[9] There are many different ways of defining a bank's size. Here, we considered that the size of the bank is given by the size of its captive market.

is one of the first to include non-price competition elements in the market for deposits and to study banking competition when some depositors are locked-in [10].

In relationship to previous studies on compatibility, ATM compatibility presents several distinctive features relative to compatibility in other industries: First, the number of ATMs determines the relevant size of the network as opposed to the number of users [11]. Indeed, one should expect an inverse relationship between the number of users per ATM and the utility of a depositor (diseconomies of congestion) [12]. Second, sharing agreements involve important competitive effects which are independent of the relative size of proprietary networks. Namely, for a given network size, ATM compatibility makes banks better substitutes for one another. The extent to which competition is strengthened depends on the proportion of the transactions with banks that depositors can do through ATMs. As long as not all transactions can be done using ATMs, compatible banks remain partially differentiated. On the contrary, in Farrell and Saloner (1986) compatibility necessarily leads to an absence of differentiation, while in Matutes and Regibeau (1988) compatibility leaves the degree of differentiation unchanged.

The fact that we do not impose compatibility differentiates our model from other studies on ATMs. For instance, Gilbert (1990) studies optimal transfer payments within a compatible network. Likewise, Economides and Salop (1992) consider the welfare implications of alternative market structures in a framework where consumers derive utility fom the services of a system and compatibility prevails.

The rest of the paper is organized as follows. Section II presents the model. Section III discusses the main results of the paper. In section IV we consider the normative implications of our analysis and we draw some policy conclusions. Section V concludes.

II. The model

There are three banks A, B, and C symmetrically located in a circle [13]. We assume that each bank has a single branch and a single ATM located at its branch. The circle represents a town which is subdivided into three neighborhoods, each of unit length. Each bank competes for the deposits of individuals located in two of these neighborhoods. Accordingly, neighborhood ij is the neighborhood where banks i and j compete with each other.

[10] Nelson (1985) is another study on non-price competition in banking. The importance of non-price competition elements in banking has been tested empirically by Heffernan (1992).

[11] Most of the literature on compatibility, see for instance Katz and Shapiro (1985) and Farrell and Saloner (1985, 1986), focused on network externalities that depend on the number of users of a given technology.

[12] The number of potential users of an ATM may determine, however, the willingness of a bank to adopt or enlarge its network through its effect on costs. Saloner and Shepard (1991) investigate how a firm's expected time until adoption of ATM technology depends on both the number of locations it serves (network effect) and the number of its users (production scale effect). Their empirical findings support that the former has a larger impact than the latter. In the same vein, *The American Banker* (6 October 1990) concludes that the introduction of ATMs attempts to provide a better service rather than to reduce costs.

[13] See section III.2 and note 22 for a discussion of the general n-bank case.

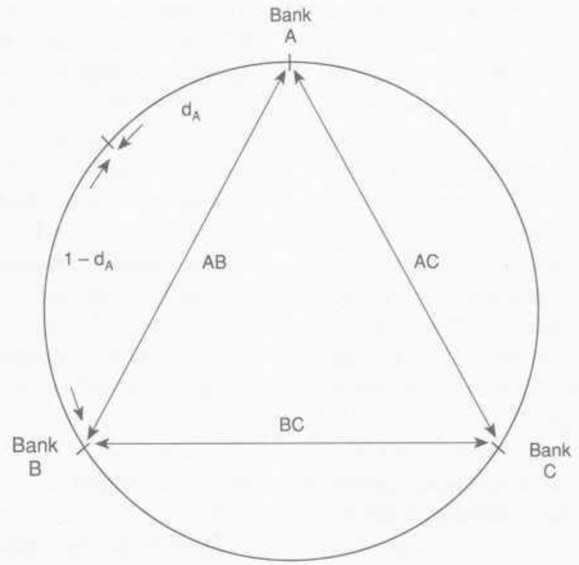

Figure 1. The model

Banks play a two stage game. At *stage one*, each bank proposes a compatibility agreement which states the banks with which it is willing to share its ATM. The set of feasible compatibility proposals for bank i is $\{(i);\ (i,j);\ (i,j,m)\}$ where $i, j, m = A, B, C$ and $i \neq j \neq m$. Proposal (i) implies that bank i's ATM remains incompatible. Proposal (i, j) indicates that bank i is only willing to share its ATM with bank j (a similar interpretation is given to (i, m)). Finally, bank i proposes (i, j, m) when it is only willing to share its ATMs if full compatibility prevails (that is, if all banks share their ATMs with each other). Compatibility between any subset of banks requires the agreement of all banks in that subset. Otherwise, incompatibility prevails.

At *stage two*, given the network configuration that arises from the previous stage, banks simultaneously (and independently) choose deposit rates, r_i [14]. Banks invest the proceedings of their deposits and obtain an identical safe rate of return R per dollar invested. A bank quoting r_i attracts σ_i deposits and obtains profits of $\pi_i = (R - r_i)\sigma_i$. Note that r_i is defined as the rate paid to deposits net of charge commissions and other fees [15].

There is a continuum [0, 1] of depositors uniformly distributed along the circle. Every depositor has only one dollar to invest in a bank which, for simplicity, we assume has to be one of the banks in her neighborhood. Given the absence of bankruptcy risk, and for a given ATM network size, depositors always prefer higher interest rates on their deposits.

However, depositors also value the size of the ATM network they can access. We assume that a depositor *regularly* visits her bank for two different reasons: to

[14] The order of our game reflects the fact that compatibility decisions are naturally long-term decisions that cannot be easily modified. On the contrary, interest rates are short-term decisions that may be subject to frequent revision.

[15] We neglect the double-sided nature of banking competition (i.e. competition for both loans and deposits) by assuming the existence of a perfectly competitive interbank market (see Repullo 1992). We also abstract from oth risk and asymmetric information to focus exclusively on banks' commercial strategies regarding ATMs.

withdraw cash, which can be done at any branch with a compatible ATM, and for some other activity (e.g. account management), which can only be done at the bank where her funds are deposited. The transport costs associated to each of these two activities are T and t respectively. T and t will generally differ because depositors visit banks for either of these reasons with different frequencies. In fact, $t/(t+T)$ measures the extent to which transactions with a bank must be done at the branch. We take $t+T$ to be 1, and thus t indicates the percentage of the transportation cost associated to activities that cannot be done using ATMs. We will see that the lower t (or, the higher T), the greater the degree of *substitution* among compatible banks [16].

In addition, each depositor needs cash *unexpectedly* with positive probability when she is travelling around the city. Suppose, for instance, that each depositor has a positive probability of spending some time (having a drink, socializing, or being in a business trip) at any location, in any of the three neighborhoods. (The same probability for each particular location, and each neighborhood). If banks' ATMs are compatible the expected travelling cost is lower because she can visit the nearest branch instead of having to go back to the office where her funds are deposited. The more banks share their ATMs with her bank, the lower is the expected cost of having access to her funds during the trip, and thus the greater the utility she derives from her account (the *network effect*).

Let $k_i = k(n_i)$ be the expected costs of having access to one's funds when deposited in bank i during these unexpected occasions (where n_i is the number of ATMs at which a customer of bank i can withdraw cash). These costs are equal to the product of the probability of «travelling around the city and needing cash», which equals p, the opportunity costs of time and associated unit transportation costs in these circumstances (which we denote by s), and the expected travelling distance when cash is needed during the city trip. This expected distance falls with each additional compatibility agreement established by bank i. Note that this distance equals 3/4 if bank i is incompatible with the remaining banks, 5/12 if it is compatible with just one bank, and 1/4 if full compatibility prevails. Therefore k_i is lower the more banks are compatible with bank i, i.e. $k(1) > k(2) > k(3)$. Notice that, the expected costs of withdrawing funds during a «trip» depend on the prevailing compatibility regime, but it is independent of the original location of the customer [17].

According to our previous assumptions, the utility of a depositor located at distances d_A, d_B from banks A and B respectively ($d_B = 1 - d_A$), and who patronized bank A depends on both whether A and B are compatible, and on whether A (or B) is compatible with bank C. If all banks are incompatible, the utility of depositing in A equals $r_A - k(2) - td_A - T \min(d_A, d_B)$. In the latter case, the depositor can withdraw cash at either bank A or B. As a result, when A and B are compatible T does not affect the choice of bank by the marginal depositor, even though it certainly determines the total transport cost that the depositor incurs. Indeed, when just A and B are compatible, the marginal depositor is one located at x such that,

$$\begin{aligned} r_A - k(2) - tx - T \min(x, 1-x) &= \\ = r_B - k(2) - t(1-x) - T \min(x, 1-x) & \end{aligned} \tag{1}$$

Thus, the term containing T cancels out. When compatible banks do not set equal rates, a depositor can benefit from the higher rate without having to incur as much additional travel costs as she would, were they incompatible. That is, our model captures the idea that when two banks have a compatible network, depositors can credibly threaten their banks to switch to a rival offering a better deposit rate and still benefit from their ATM services. As a result, the supply of funds to compatible banks becomes more elastic. In fact, if all business with banks could be done through ATMs ($t=0$), compatible banks at different locations would become perfect substitutes for each other.

[16] In this respect, the Spanish monetary authorities consider an ATM as half a branch for regulatory purposes, that is, $t = 1/2$.
[17] Therefore, $k(3) = ps/4$, $k(2) = ps5ps/12$, and $k(1) = 3ps/4$.

In addition, there is a network externality reflecting the expected benefit of patronizing a bank with a larger network on unpredictable occasions. This network externality constitutes a source of differentiation among otherwise identical banks. The extra quality, $K = k(1) - k(2)$, of a bank compatible with a rival relative to an incompatible bank equals the savings in the transportation costs paid when travelling around the city [18].

The marginal depositor between an incompatible bank (bank C) and a bank compatible with a rival (bank A) is located at x such that

$$r_A - k(2) - x = r_C - k(1) - (1 - x) \qquad (2)$$

Therefore, K has an impact on the marginal depositor whose choice is between an incompatible bank and a bank compatible with one rival. Depositors are willing to accept a lower rate from the latter since they benefit from lower transportation costs with positive probability. However, K has no impact on the choice between two compatible banks since they both offer the same network size (see equation (1)).

Finally, we look for the *Perfect Coalition-Proof Nash Equilibria* (P.C.N.E.) in pure strategies of our game [19]. Given that our purpose is to analyse stable coalitions among banks, coalition-proofness constitutes the most appropiate equilibrium concept.

III. Equilibrium Compatibility Agreements

III.1. *The second stage: competition for deposits*

There are three possible ATM network configurations according to our previous assumptions: *full compatibility*, i.e. each bank agrees to join a single ATM network; *partial compatibility*, where only a (strict) subset of banks choose to make their ATMs compatible; and finally, independent networks or *incompatibility*.

It will be convenient for the rest of the analysis to denote bank i's profits as $\pi(3, 0)$ under universal compatibility; $\pi(2, 1)$ when it shares its ATM with just another bank; $\pi(1, 2)$ when it competes against two compatible rivals; and $\pi(1, 1, 1)$ under incompatibility.

Let us first consider competition in deposit rates under partial compatibility. Suppose that, without loss of generality, banks A and B agree upon sharing their ATMs while bank C's network remains incompatible. Then, bank A sets a deposit rate r_A to maximise its total profits

$$\pi_A = (R - r_A) \left\{ \frac{r_A - r_B + t}{2t} + \frac{r_A - r_C + 1 + K}{2} \right\} / 3 \qquad (3)$$

where r_A, r_B and r_C are the deposit rates of banks A, B, and C, respectively. The first term between brackets gives the location of the marginal customer between two banks sharing their ATMs whereas the second term refers to the location of the marginal customer between banks A and C with different network sizes. Similarly, bank B's profits can be written as in (3) with r_A, r_B alternating positions, and finally, the incompatible bank C sets a rate r_C so as to maximise:

$$\pi_C = (R - r_C) \left\{ \frac{r_C - r_A + 1 - K}{2} + \frac{r_C - r_B + 1 - K}{2} \right\} / 3 \qquad (4)$$

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[18] Note that, $K = k(1) - k(2) = ps/3$. That is, the size of the network externality increases with the probability of an unexpected city tour and with the costs of time and transportation during this kind of tours.

[19] The concept of Coalition-Proof Nash Equilibrium was introduced by Bernheim, Peleg and Whinston (1987). The main feature of this equilibrium concept is that based on collective rationality. «An agreement is coalition-proof if and only if it is Pareto efficient within the class of self-enforcing agreements. In turn, an agreement is self-enforcing if and only if no proper subset (coalition) of players, taking the actions of its complement as fixed, can agree to deviate in a way that makes all of its members better off». (Bernheim, Peleg and Whinston 1987).

Solving the maximisation problem for each bank, we can show (see Lemma la in Appendix A) that if the size of the network externality, K, is not too large, all banks are active at the unique rate equilibrium with partial compatibility. Banks with compatible networks set equal rates ($r_A = r_B = R - t(5+K)/(2+3t)$) and hence equally share the depositors in the neighborhood where they compete with each other. As a result of this, their depositors only benefit from compatibility on special occasions; on a regular basis, they withdraw cash at the branch where they deposit.

The market shares of banks with different network sizes are asymmetric as they set different rates ($r_C = R-(3t+(t+1)(1-K) / (2+3t) \neq r_A$). The sign of such an asymmetry depends on the relative strength of the network and substitution effects (that is, on the precise values of K and t, respectively). Given rates, compatible banks tend to have a larger share than their incompatible rival. This effect tends to make them less aggressive. On the other hand, the fact that compatible banks become better subtitutes for each other makes them compete fiercerly. When the network effect is relatively large (large K) and the substitution effect moderate (large t), banks with a larger ATM network set lower rates and yet obtain a greater market share than their smaller counterparts. Otherwise, the opposite holds.

When the size of the network externality, K, is sufficiently large (see Lemma 1b in Appendix A), the market equilibrium results in the *exclusion* of the incompatible bank from the market.

The analysis of competition under total compatibility and independent networks is quite straightforward. In both cases, banks are undifferentiated along the ATM network dimension so that our model becomes the standard circular model of product differentiation under different unit transport costs in either case. These costs are equal to one under incompatibility and $t < 1$ under full compatibility. Therefore, using standard arguments, we have that banks' equilibrium profit are equal to $\pi(1, 1, 1) = 1/3$ under incompatibility, and to $\pi(3, 0) = t/3$ under full compatibility.

It can be shown that equilibrium profits under different compatibility structures are such that [20]

$$\begin{aligned} &\min\, [\pi(1, 1, 1), \pi(2, 1)] \geq \\ &\geq \pi(3, 0) \text{ for all } t, K \end{aligned} \tag{5}$$

that is, it is always in the interest of a subset of banks to deviate from a situation of full compatibility. Therefore, universal compatibility cannot constitute an equilibrium outcome for our game. If all banks share their networks none of them obtains an network advantage so that the only effect of compatibility is to reduce the effective degree of horizontal differentiation among banks. As a result, competition gets tougher and banks are unable to internalise the positive network externality which is then entirely appropriated by depositors. It follows that two compatible banks would always *veto* the entry of a third bank into their common network.

The issue remains as to whether at least two banks would be willing to share their ATMs under certain conditions. To address this question we need to compare the equilibrium profits under incompatibility and partial compatibility. This is done in the following proposition [21].

Proposition 1. For each value of the network externality K, $\pi(1, 1, 1) \leq \pi(2, 1)$ if and only if the proportion of the regular business of depositors not done through ATMs, t, is large enough. As the network externality rises, the previous inequality holds for a wider range of values of t (i.e., for each K, there exists $t^*(K)$, t^* (weakly) decreasing in K, such that for all $t \geq t^*$, $\pi(1, 1, 1) \leq \pi(2, 1)$. For $t \leq t$, the opposite holds).

[20] See Appendix A for the exact expression for $\pi(2, 1)$.
[21] We restrict our attention to those values of R, and $k(n_i)$ such that a pure strategy equilibrium exists for each compatibility regime.

Proof: See Appendix A.

To discuss the intuition behind Proposition 1, let $\psi(K, k)$ $(= \pi 2, 1) - \pi(1, 1, 1))$ be the difference in profits between the partial compatibility regime and the independent networks regime for a bank that shares its ATM under partial compatibility. This difference is positive when compatible banks set lower rates than they would in an equilibrium with incompatibility. That is, when the substitution and network effects interact so that compatible banks become less aggressive. It is easy to show that this occurs when the network effect is large enough compared to the substitution effect. More specifically, for those values of t such that $t \geq t^*$, where t^* is such that for each K, $\psi(K, t^*(K)) = 0$ (note that $\delta\psi / \delta t > 0$). Moreover, the stronger the substitution effect (low t), the larger network externality K has to be to ensure that a subset of banks is willing to share their ATMs (i.e. $dt^*/dK < 0$). This trade-off is shown in figure 2.

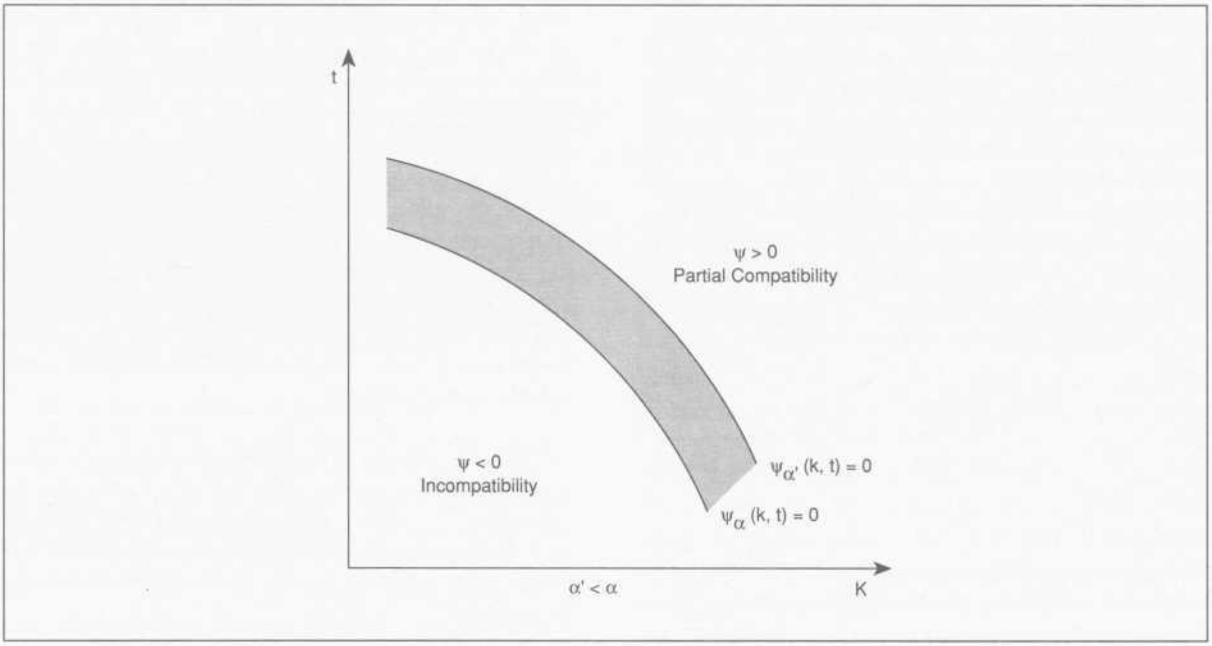

Figure 2. Equilibrium Outcomes

III.2. *The first stage: compatibility agreements*

The following proposition characterizes all possible Perfect Coalition-Proof Nash Equilibrium (P.C.N.E.) outcomes for the overall game. Its proof follows directly from equation (5) and Proposition 1 above.

Proposition 2. Partial compatibility is the unique Perfect Coalition-Proof Nash Equilibrium outcome for our game when depositors value relatively highly the accesibility to their funds (large K) and the proportion of business with banks done through ATMs is not too large (large t). Otherwise, incompatibility is the unique Perfect Coalition-Proof Nash Equilibrium outcome for our game.

Full compatibility is not a P.C.N.E. outcome for this game as we discussed above. This result extends more generally to the n-bank case. With n banks, profits under full compatibility are equal to t/n and thus lower than the level of profits under incompatibility, l/n. Hence, there is always at least one bank willing to deviate from the full compatibility agreement.

However, if banks were able to *collude* in deposit rates, full compatibility would be observed in equilibrium because banks could then fully extract the additional surplus generated by compatibility. This surplus could also be partially appropriated by banks through the use of withdrawal and interchange fees (see section III.4).

Another important reason why full compatibility is never an equilibrium outcome in our setting is that the network externality does not create a market expansion effect because the supply of funds is completely inelastic. If the network effect led to a larger supply of deposits (as it is likely to be the case since there is less need to hold cash to finance unexpected transactions), full compatibility might characterise the equilibrium outcome of our game.

Finally, there is a sense in which Proposition 2 understates the likelihood of partial compatibility agreements. We have assumed that each bank had a zero probability of *bankruptcy*. It can be argued that introducing failure probabilities would enhance the likelihood of partial compatibility. In a spatial model, Matutes and Vives (1991) show that banks perceived as safer have a quality advantage, set lower rates, and have larger market shares than their rivals, which in turn makes the perceived safety self-fulfilling. The network effect of compatibility would enlarge the compatible banks' market shares so that it would further decrease the probability of bankruptcy. Hence, banks would have additional incentives to become compatible.

III.3. *Compatibility, market foreclosure and entry deterrence*

Not surprisingly, compatibility agreements can be used to exclude rivals from the market even in the absence of economies of scale. Compatible banks may use their network advantage to steal depositors from their rivals and monopolise the market for deposits. We can show (see Appendix A) that when the network externality K is large, an incompatible bank facing compatible rivals is always excluded against its will from the compatibility agreement ($\pi(1,2) \leq \pi(3,0)$)[22]. Moreover, for K even larger, the incompatible bank is forced out of the market ($\pi(1,0) \leq 0$). For these latter values of K, banks in the compatibility club can profitably leverage their network advantage to foreclose their rival from the market.

Regarding new entry, one might expect that in principle, compatibility among *incumbent* banks need not have a negative impact on entry when there are laws that prevent ATM networks from excluding new applicants. This would be precisely the conclusion of models such as Katz and Shapiro (1985) where standardization simply means that quality differentials disappear. Remarkably, our model points out in a rather different direction. By committing to compatibility, incumbent banks lower the expected profits of the would-be entrant, even if exclusion is forbidden, and may thus foreclose entry.

To make the argument explicit, consider the following entry game. First, two incumbent banks decide on compatibility. Then, upon observing the compatibility configuration decided in the previous stage, a potential entrant decides whether to enter the market, and in case it enters, it may join (if that is its will) any existing network. Finally, rate competition takes place between the banks in the market.

For the sake of simplicity, assume that the location of banks depends upon entry, so that regardless of the number of competing banks, they are always symmetrically located. There is then a range of the sunk costs of entry, F, for which entry can only be successfully deterred when the incumbent banks are compatible ($\max[\pi(1,2), \pi(3,0)] < F < \pi(1,1,1)$). Furt-

[22] Of course, the exclusion result depends on the intrinsic asymmetry of the three banks case. With four banks, we conjecture that two competing networks will coexist, and more in general, that for any given number of banks there will be more than one compatibility agreement. These agreements will always include banks who operate in different neighborhoods. Nevertheless, exclusion will prevail as long as there is an *odd* number of banks.

hermore, entry deterrence through compatibility is profitable when the benefits from excluding a rival outweigh the cost of becoming a better substitute with the current rival, i.e., for t such that $\pi(2, 0) = t/2$, the profits under full compatibility and only two banks in the market, is larger than $\pi(1, 1, 1) = 1/3$, the level of profits for each of three incompatible banks [23].

III.4. *Withdrawal and interchange fees*

Suppose that banks charge fixed fees associated to cash wihtdrawals, or alternatively, that each bank compensates its compatible rivals for the use of their ATMs by its depositors. We show that, in both cases, banks find compatibility agreements more attractive so that incompatibility is no longer an equilibrium outcome.

Let us assume that banks' compatibility proposals include a withdrawal fee $w \geq 0$, that is a transaction fee charged to the depositors of other compatible banks for the use of one's own ATM. Banks can use this fee to reduce the substitution effect of compatibility, since it makes more expensive to withdraw cash from the ATMs of other compatible banks on a regular basis.

Of course, setting a positive withdrawal fee also reduces the incentives of depositors to withdraw cash at the rivals' compatible ATMs during their unexpected tours around the town. Depositors travelling around the city may find optimal to return to their own banks to withdraw cash rather than paying withdrawal fees at compatible banks. Consequently, the establishment of withdrawal fees diminishes the depositors' valuation for a larger network, and thus reduces the size of the network externality that banks can actually appropriate through these fees.

The introduction of withdrawal fees also has a strategic effect on banks' pricing decisions. These fees relax competition among compatible banks because they make it expensive to enlarge a bank's market share to the expense of its compatible rivals. The larger the market shares of the latter banks, the greater the revenue raised from withdrawal fees by the former bank.

In Appendix B.1 we develop an illustrative example where compatible banks completely eliminate the substitution effect through the use of withdrawal fees so that, on a regular basis, depositors always withdraw cash at their own banks. We show that banks' profits under full compatibility, $\pi_W(3, 0)$, are larger than their profits under incompatibility, $\pi_W(1, 1, 1)$, since now compatibility has a relaxing effect on the strength of competition, and compatible banks can extract part of the original network externality and share it among themselves. Every bank thus prefers full compatibility to incompatibility, contrary to what happened in the absence of withdrawal fees.

However, banks can do even better if they introduce as the compatibility stage *interchange fees* (the fees paid by a bank to its compatible rivals when its customers use the other banks' ATMs) rather than withdrawal fees. Interchange fees also relax competition among compatible banks but, contrary to the case of withdrawal fees, they do not have any negative effect on the depositors' willingness to pay for a larger ATM network. This allows banks to profit from a larger network externality than in the previous case and, therefore, makes compatibility agreements even more profitable.

More formally, consider the rate setting stage under full compatibility when banks agreed on an interchange fee, f. In this case, bank A earns profits equal to

$$\pi_A = (r - r_A)\,\sigma_A + f\{(\sigma_B - \sigma_A) + (\sigma_C - \sigma_A)\}\,p/3 + f(1/3 - \sigma_A) \tag{6}$$

[23] Consider the model of section II where only two banks compete for deposits. These two banks are assumed, for simplicity to be symmetrically located. If both banks share their ATMs, the unit transport cost that affects the choice of banks of the marginal depositors is $t < 1$. Therefore, standard arguments in circular models of product differentiation imply that banks' profits in these circumstances, $\pi(2, 0)$, equal $t/2$.

where $\sigma_A = [r_A - r_B + t]\ /6t + [r_A - r_C + t]\ /6t$; and σ_B and σ_C are similarly defined. The first term in (6) is the standard one in the absence of interchange fees. The second term represents the net payment of bank A to banks B and C for the use of their compatible ATMs during the trips of its depositors around the city and vice versa. Finally, the third term refers to the net payment made by A to its compatible rivals for the regular use of the latter ATMs by A's depositors and vice versa. (B's and C's profits can be similarly defined).

From equation (6) we can see that a larger market share (e.g., a larger σ_A) implies larger payments of interchange fees to compatible banks. Interchange fees therefore reduce the incentives of banks to compete aggressively for deposits, and consequently, act as a countervailing force to the substitution effect of compatibility. A suitable choice of f not only eliminates completely the substitution effect but also implements the joint profit maximising rate for this compatibility regime. As a result, full compatibility is always preferred to incompatibility, i.e., $\pi_f(3,0) > \pi_f(1,1,1)$, which can no longer be a coalition-proof outcome of our game.

Moreover, the profits of a fully compatible bank in a network with interchange fees, $\pi_f(3,0)$, are larger than its profits in a network with withdrawal fees, $\pi_W(3,0)$. The reason is that banks can internalise a larger network externality when using interchange fees since (as we discussed above and show in Appendix B.2) these fees do not reduce the depositors' valuation for a larger network. Therefore, we should expect to observe compatible networks imposing interchange fees rather than withdrawal fees [24].

A different issue is whether full compatibility itself defines a coalition-proof equilibrium. For that to be the case it is needed that no coalition of two banks prefer to deviate and exclude a third bank from their network. In Appendix B.2, we show that there are parameter constellations for which full compatibility is the unique coalition-proof outcome. However, whenever two banks can acquire (and profit from) a substantial network advantage over the third (that is when $K = k(1) - k(2)$ is large), they will refuse to accept the third bank into their network so that, for these cases, only partial compatibility can be sustained as a coalition-proof equilibrium outcome.

In our symmetric model, the impact of interchange fees hinges only upon how it modifies the pricing incentives of banks, since in equilibrium no actual transfers take place. In an asymmetric setting, however, these transfers would be observed in equilibrium making it more expensive for banks with small networks to join any compatible network. Moreover, interchange fees may induce banks to expand their proprietary networks to pay less fees and/or collect more of them from their compatible rivals. Competition in ATM network size may thus dissipate the profits obtained from the higher rates that prevail when f is positive, and make compatibility more difficult.

III.5. *The effect of switching costs on ATM compatibility*

In this section we explore the impact that the presence of locked-in depositors may have on banks' compatibility decisions. In order to conduct this analysis, we develop a version of our model where a proportion $(1-\alpha) \in (0, 1)$ of depositors face important costs of switching banks so that they are effectively locked in. (Each bank has a share of $(1-\alpha)/3$ locked-in depositors) [25].

Whether the existence of these depositors favors compatibility or not is *a priori* unclear. In principle, if there were many locked-in depositors, banks could appropriate to a larger extent the network externality generated by compatibility since locked-in depositors are less sensitive to interest rate competition. Ho-

[24] For some anecdotal evidence on this point, see note 6.

[25] We could understand locked-in customers as those who patronised a bank in a previous unmodelled period. These depositors are assumed, for simplicity, to be precisely located at their bank's branch.

wever, the relaxation effect of switching costs on the strength of competition is relatively more important when all banks remain incompatible which makes compatibility agreements less attractive.

In the absence of lock-in, we have shown above that competition is generally less fierce when a subset of banks shares their ATMs. Basically, given any set of interest rates, the share of depositors served by a bank increases when it establishes a compatibility agreement which makes it more costly for a compatible bank to compete fiercely. When a proportion of depositors are locked in, the increase in market share that can be obtained through compatibility is reduced, which in turn means that, at least in this sense, the compatible banks behave more aggressively.

We show (see Appendix C) that, when a pure strategy equilibrium exists for the competition stage, this second effect of switching costs dominates, and therefore, partial compatibility is unambiguously made more difficult by switching costs. (See figure 2 above. An increase in the number of locked-in depositors, i.e., a fall in α, shifts $\psi(K, t^*(K))$ to the right indicating that compatibility agreements become more unlikely). However, the existence of equilibrium requires that the proportion of locked-in depositors, $1-\alpha$, is not too large. On the contrary, if most depositors were locked into their respective banks, compatibility would be trivially achieved since there would not exist real competition between banks.

A setting where banks have captive depositors because of the switching costs allows us to address the question of whether a bank with a large captive market prefers to become compatible with a bank of equal size or with a smaller bank instead.

From the previous sections, we know that a bank with a smaller network sets higher interest rates. This aggressive behavior is tempered when its captive market is large, and therefore, it may be to a large bank's advantage to become compatible with a smaller bank leaving outside of the joint network a large bank who will behave less aggressively. However, compatibility with a smaller bank also implies to become a better substitute with a rival for whom being aggressive has relatively low costs.

To investigate these trade-offs, we focus on a version of our model where banks A and B have a captive market of equal size (i.e. $(1-\alpha)/2$) whereas bank C has no locked-in depositors. Numerical computations show that a large bank prefers to share its network with a small bank when the network effect is large enough and the substitution effect not too large. That is, when in terms of increased competition, leaving a small bank outside the compatibility agreement is more costly than to becoming a closer substitute for it [26].

IV. Public Regulation of ATM Compatibility Clubs

We turn now to consider the normative implications of our previous analysis. In particular, we consider the scope for public intervention regarding ATM networks.

It should be clear that full compatibility constitutes the *first-best* ATM structure since depositors benefit from the maximum accessibility to their funds when they travel around the city and regular transport costs are minimised. However, as discussed in section III, full compatibility is not an equilibrium outcome for our game [27].

Furthermore, unless K is sufficiently large, the market also fails to achieve the *second best*, that is, the maximum level of welfare that can be achieved under partial compatibility. The second best is such that the

[26] Compatibility between banks A and C is a more likely outcome when the proportion of transactions not done through ATMs, t, the proportion of free depositors, α, and the size of the network externality, K, are large. For lower t, bank C always prefers incompatibility even if bank A would regard as more desirable to become compatible with C than with bank B.

[27] Note that in the presence of interchange fees, however, full compatibility prevails under certain circumstances. In those cases the market does achieve the first best.

market share of the incompatible bank is smaller than its equilibrium value unless the incompatible bank is excluded from the market in equilibrium. Under partial compatibility, the bank left out of the compatibility agreement pays a higher interest rate than its compatible rivals. The incompatible bank manages to serve those depositors that prefer to trade a smaller ATM network for a higher rate on their funds, but only at the social cost of greater transport costs on unpredictable occasions. In addition, given that the supply of funds is inelastic, higher interest rates are only a transfer from banks to depositors and thus have no positive effect on total surplus. Therefore, efficiency would require to restrict the market share of the incompatible bank from its equilibrium value [28]. This explains why the exclusion of the incompatible bank from the market need not be detrimental from a social standpoint.

These market failures raise the issue as to whether public intervention can improve upon the market outcome, and in particular, whether it can positively affect the incentives of private banks to achieve full compatibility.

It should be obvious that the first best can be attained through *legislation enforcing compatibility*. In practice, some U.S. States have required shared ATM networks to let in any bank seeking membership [29]. These laws prevent exclusion from existing networks, but clearly do not yield full compatibility unless sharing is mandatory. In our simple framework and abstracting from entry deterrence, a law preventing exclusion form a shared network would always yield incompatibility as the unique equilibrium outcome (recall equation (5)); in a model with more banks, it would also fail to prevent the coexistence of several networks. Similarly, regulating the *access fees* that are charged to banks applying to a compatible network would not be enough to ensure full compatibility.

Mandatory sharing laws, on the other hand, would ensure compatibility. However, we should regard such a policy recommendation with some caution. In a dynamic framework, compatibility may be associated with excess momentum or excess inertia (see Farrell and Salone 1985) which cannot be studied in our static setting. In this respect, empirical studies (Hannan and McDowell 1984) provide evidence that shows how in those States with mandatory sharing laws, the introduction of ATMs was initially delayed.

An alternative measure is the introduction of *deposit rate ceilings*. Full compatibility is not a P.C.N.E. precisely because competition is made fiercer when all banks share their ATMs so that the benefits created by larger networks cannot be appropriated by banks. Imposing rate ceilings limits such an excessive competition allowing banks to profitably internalise part of the network externality created by their compatibility agreements. However, rate ceilings may again have negative side-effects if the supply of deposits is elastic. In addition, competition may be restored in different ways such as, for instance, through branch and/or ATM proliferation.

Finally, we showed in section III.3 that compatibility agreements among banks may be established just to deter future entry into the market. Conventional wisdom would suggest that in these circumstances compatibility should be welfare reducing. However, entry deterrence through compatibility need not be detrimental from a welfare point of view: Compatibility among incumbent banks benefits depositors since they pay lower transport costs on their unexpected trips around the city. Furthermore, some sunk costs of entry F are saved when entry is deterred. On the other hand, depositors have to pay greater transport costs on a regular basis because compatibility limits the number of banks in the market. The novel result is that there exist sufficiently large values of the net-

[28] See the Working Paper version of this paper for a formal derivation of the latter statement on welfare.

[29] According to McAndrews (1991), by the mid 80's, more than 20 U.S. States required shared ATM networks to accept all applications of banks seeking membership.

work externality, K, so that entry deterrence is welfare improving even in the absence of sunk costs of entry [30].

V. Conclusions

We have studied under which conditions banks are willing to share their ATMs, and how such conditions are modified by the existence of switching costs, fixed fees and public regulations concerning compatibility agreements. Our main results are consistent with the existing evidence. First, full compatibility is not observed except in countries where the banking system is very collusive (e.g., Belgium and France) and/or it is predominantly dominated by public banks (e.g., Italy). Otherwise, several ATM networks do compete (as in Spain, U.K. and U.S.). Our theory also predicts that compatibility is easier among banks competing in different geographical markets. In Spain, the first compatibility agreements took place between savings banks who had restricted geographical market areas by law.

The model that we have explored here is quite tailored to the case of ATM compatibility and so are the policies considered. Nonetheless, it has implications whenever the degree of differentiation between two firms is affected by the extent of compatibility.

The existing literature on compatibility has mostly taken the symplifying view that compatibility does not alter the degree of product differentiation in the market in order to highlight the role of network externalities. On the contrary, we have focused on cases where not only the network size matters but also the location of the firm's proprietary network is a source of differentiation. We have shown that in these instances compatibility generates a competitive effect independent from the network size. This effect points in various directions which depart from the existing literature and the conventional wisdom: First, even in a completely symmetric world, firms do not necessarily agree to reach full compatibility. Second, compatibility makes entry of new firms more difficult. Third, network fees, which mainly act as a countervailing force of our competitive effect, enhance the likelihood of compatibility.

Our model predicts that a strict subset of firms may have incentives to create adapters that render their own products compatible and that will not work with the remaining products available in the market. According to our theory, such adapters should be more common in industries where products are differentiated in ways unrelated to technical compatibility and among firms perceived as relatively distant substitutes. An example of such kind of agreements are the *frequent flyer program clubs*. Airlines belonging to these clubs accept the mileage that their frequent flyer card holders do in flights of other airlines in the club. Members of these clubs are usually airlines who do not compete on all city pairs and whose networks, to some extent, complement each other (e.g., British Airways and American Airlines) [31].

[30] The exact condition is $K > 1/9 - 8F/9$. Of course, the larger is F the easier is that entry turns out to be socially excessive for a given value of the network externality, K.

[31] For some recent literature on this issue see Farrell and Saloner (1992) and Farrell and Shapiro (1992).

Appendix A

Lemma 1. For all $K \in [(4t+1)/(t+1)), (3t+1)]$, there is no pure strategy equilibrium for the competition stage under partial compatibility. Otherwise, given K, there is a unique Nash Equilibrium which is characterised by the following deposit rates and associated profits:

(a) For all $K \leq (4t+1)/(t+1)$ and $R \geq$! $(12t+3+K(3t+1))/(4+6t)$;

$r_A = r_B =$

$r_C =$

$\pi_A = \pi_B =$

$\pi_C =$

(b) For all $K \geq 3t+1$;

$$r_A = r_B = R - 3t \qquad r_C = 0$$
$$\pi_A = \pi_B = \pi(2,1) = 3t/2 \qquad \pi_C = \pi(1,2) = 0$$

Proof. The profits of banks A and C are

$$\pi_A = (R - r_A)\left[\frac{r_A - r_B + t}{2t} + \frac{r_A - r_C + 1 + K}{2}\right]/3$$
$$\pi_C = (R - r_C)\left[\frac{r_C - r_A + 1 - K}{2} + \frac{r_C - r_B + 1 - K}{2}\right]/3 \tag{A1}$$

The expression for B's profits is identical to bank A's with r_A and r_B alternating their respective positions. Solving the f.o.c.'s associated to (A1) yields the following equilibrium rates and profits:

This equilibrium holds only if $R \geq (12t+3+K(3t+1))/(4+6t)$ and $K \leq (4t+1)/(t+1)$. The former restriction guarantees that marginal depositors earn non-negative surplus whereas the latter that $r_C \leq R$. (Finally note $r_A \leq R$, and $r_B \leq R$, for any $0 \leq K$). Second order conditions are clearly satisfied.

When $K > (4t+1)/(t+1)$, $r_C > R$ violating the initial constraint. Bank A maximizes

$$\pi_A = (R - r_A)\left[\frac{r_A - r_B + t}{2t} + \min\left(1, \frac{r_A - R + 1 + K}{2}\right)\right]/3 \tag{A3}$$

Equilibrium rates and profits for the large bank equal

$$r_A = r_B = R - 3t \qquad \pi_A = \pi_B = 3t/2$$

only if $K \geq 3t+1$. For K in this range, existence and uniqueness are guaranteed■.

Proof of Proposition 1.

Let $\psi(K,t) = \pi(2,1) - \pi(1,1,1)$. For any $K \leq (4t+1)/(t+1)$, $\psi(K,t) = (5+K)^2 - \dfrac{2(2+3t)^2}{t(1+t)}$. Therefore, we define $t^*(K)$ as such that $\psi(K, t^*(K)) = 0$. Note that, $\delta\psi/\delta K \geq 0$ so that $dt^*/dK \leq 0$. Finally, for $K \geq (3t+1)$, $\psi(K, t) \geq 0$ for all $t \geq t^* = 2/9$■.

Appendix A

B.1. Withdrawal fees

Consider our main model (section II) but amended so that banks' compatibility proposals include a fixed withdrawal fee $w \geq 0$. We show that full compatibility always dominates incompatibility so that the latter cannot constitute a coalition-proof equilibrium outcome of the game with withdrawal fees.

— Full Compatibility

The marginal depositor between two compatible banks (e.g., A and B) is located at x such that

$$r_A - k(3) - tx - \min[Tx, T(1-x)+w] = \\ = r_B - k(3) - t(1-x) - \min[Tx+w, T(1-x)]$$

We only consider equilibria for which $w \geq T$ so that on a regular basis depositors always withdraw at their own bank. Therefore, $\min[Tx, T(1-x)+w] = Tx$, and similarly, $\min[Tx+w, T(1-x)] = T(1-x)$ for all x. Note that $k(3)$ are the expected transport costs plus the fees paid by any given depositor during her tours around the city. These costs equal $ps/4 + pw(2-w/2s)/3$ where $w > s$ depositors do not value a larger network (i.e., $k(3) > k(1)$, where $k(1) = k(1)$ are the expected costs incurred during city tours if one patronises an incompatible bank).

Bank A's profits equal

$$\pi_A = (R-r_A\{(r_A-r_B+1)/6 + \\ + (r_A-r_C+1)/6\} + \\ + pw\{1-[(r_A-r_B+1)/6 + \\ + (r_A-r_C+1)/6]\}(1-2/ws)/3 \quad \text{(B1)}$$

where the last term in (B1) equals bank A's revenues from withdrawal fees and is the product of the market share of its compatible rivals and the probability that any of these depositors actually withdraw at its ATM, i.e., $pw(1-2/ws)/3$. (Banks B's and C's profits are similarly defined). Solving the first order conditions with respect to r_A, r_B and r_C, we obtain $r_A = r_B = r_C = R - 1 - pw(1-2/ws)/3$ and therefore, banks' profits of $\pi_W(3, 0) = 1/3 + pw(1-2/ws)/3$.

In stage one, banks will set w so as to maximise their profits but subject to the constraint that the withdrawal fee w is smaller than the maximum amount depositors are willing to pay to acces a compatible bank rather than visiting their own banks ATM, that is, $w \leq s$. Thence, banks set $w^* = s$ and profits equal $\pi_W(3, 0) = 1/3 + ps/6$. (Existence requires (i) $R \geq k(1) + 3/2 + ps/6$ and (ii) $s \geq T$).

Note that $\pi_W(3, 0) \geq 1/3 = \pi_W(1, 1, 1)$, where $\pi_W(1, 1, 1)$ are the profits of a bank under incompatibility. These profits are obviously unaffected by the introduction of withdrawal fees. To conclude, every bank prefers full compatibility to incompatibility which ensures that the latter is not a coaliton-proof equilibrium.

B.2. Interchange Fees

The basic model of Section II is now modified to allow banks to include interchange fees at the compatibility stage instead of withdrawal fees. We show that incompatibility is no longer an equilibrium outcome of our game. We also study what determines whether in equilibrium we observe partial or full compatibility. Finally, we show that the profits of a *fully* compatible bank in a network with interchange fees are larger than in a network with withdrawal fees.

a) Full Compatibility

Bank A's profits equal

$$\pi_A = (R-r_A)\,\sigma_A + fp\{(\sigma_B-\sigma_A) + \\ + (\sigma_C-\sigma_A)\}/3 + f(1/3-\sigma_A) \quad \text{(B3)}$$

where $\sigma_A = (r_A - r_B + t)/6t + (r_A - r_C + t)/6t$; and σ_B and σ_C are similarly defined. (Likewise, we can write the profit expressions for banks B and C).

Solving the first-order conditions associated to the maximisation problem of each bank, we have that banks set rates of $R - t - f(1+p)$. Banks can choose f to implement the fully collusive rate $r^m = k(3) + 1/2$ (i.e., the rate that extracts all surplus from the marginal depositor). Such fee equals $f^* = (R-t)/(1+p) - (2+ps)/4(1+p)$.

Hence, the equilibrium profits of each bank under full compatibility equal $\pi_f(3,0) = (R-1/2)/3 - ps/12 \geq 1/3 = \pi_f(1,1,1)$. (The latter inequality holds because R has to be larger than $3/3 + k(1)$ to guarantee existence under both regimes).

b) Partial Compatibility

Banks A and B are assumed to share their ATMs while bank C remains incompatible. The profits of bank A (and similarly, those of bank B) equal

$$\pi_A = (R-r_A)\sigma_A + fp(\sigma_B - \sigma_A)/2 + \\ + f(1/6 - \sigma_A^{AB}) \quad \text{(B4)}$$

where $\sigma_A^{AB} = (r_A - r_B + t)/6t$; $\sigma_A^{AC} = (r_A - r_B + 1 + K)/6t$ with $K = k(1) - k(2)$; and $\sigma_A = \sigma_A^{AB} + \sigma_A^{AC}$. Finally, $\sigma^B = \sigma_B^{AB} + \sigma_B^{BC}$. Bank C's profits are:

$$\pi_C = (R-r_C)\sigma_C \quad \text{(B5)}$$

where $\sigma_C = (r_C - r_A + 1 - K)/6 + (r_C - r_B + 1 - K)/6$.

Profit maximisation yields the following equilibrium profits for the two compatible banks (where we restrict ourselves to equilibria with the three banks active in the market):

$$\pi_A = \pi_B = \pi_f(2,1) = t(1+t)(5+K)^2 / 6(2+3t)^2 + \\ + f(2+t)(5+K)(1+p(1+t)/2) / 6(2+3t)^2 - \\ - 2f^2(1+p(1+t)/2)^2 / 6(2+3t)^2$$

Banks A and B choose f to maximise $\pi(2,1)$ which leads to an interchange fee of $f^* = (5+K)(2+t)/4(1+p(1+t)/2)$ and profits given by

$$\pi_f(2,1) = t(1+t)(5+K)^2 / 6(2+3t)^2 + \\ + ((2+t)(5+K))^2 / 48(2+3t)^2 \quad \text{(B6)}$$

Existence requires that $K \leq (14+21t)/(2+3t)$ and $R \geq (5+K) + k(2)$.

c) Equilibrium Compatibility Agreements

From the previous equations, $\min[\pi_f(2,1), \pi_f(3,0)] \geq \pi_f(1,1,1)$, and hence incompatibility never characterises the equilibrium outcome of the game with positive interchange fees. Let $\psi_f(K,t) = \pi_f(3,0) - \pi_f(2,1)$. Then after some algebraic manipulations we have that sign $[\psi_f(K,t)]$ = sign $[14K - K^2 - 9]$ which is positive for $K \leq 1.3$ and negative otherwise. In conclusion, when the network advantage under partial compatiiltiy K is small (≤ 1.3), full compatibility is the unique coalition-proof equilibrium. Otherwise, partial compatibility prevails.

d) $\pi_f(3,0) > \pi_W(3,0)$

Note that $\pi_f(3,0) = (R-1/2)/3 - ps/12$, where existene requires that $R \geq 3/2 + k(1)$. Then, $\pi_f(3,0) \geq 1/3 + ps/6 = \pi_W(3,0)$.

Appendix C

Consider our main model (section II) where a proportion $(1-\alpha)\,\varepsilon\,(0,1)$ of depositors are locked into the banks competing in the market. Each bank has a share of $(1-\alpha)/3$ locked-in depositors. We assume, for simplicity, that these depositors are located at their banks' branch. We first analyze interest rate competition under each compatibility regime. To conclude, we will prove that (i) full compatibility is not an equilibrium outcome for all α, and (ii) partial compatibility is easier to achieve for large α, that is, when there are few locked-in depositors.

(a) *Partial Compatibility*: Without loss of generality, take A and B compatible. Banks' profits are

$$\pi_A = (R-r_A)\left\{\frac{1-\alpha}{3} + \right.$$
$$\left. + \alpha\left[\frac{r_A-r_B+t}{2t} + \frac{r_A-r_C+1+K}{2}\right]/3\right\}$$
$$\pi_C = (R-r_C)\left\{\frac{1-\alpha}{3} + \right. \qquad \text{(C1)}$$
$$+ \alpha\left[\frac{r_C-r_A+1-K}{2} + \right.$$
$$\left.\left.\frac{r_C-r_A+1-K}{2}\right]/3\right\}$$

(π_B as π_A with r_A and r_B changing places). Solving the associated first order conditions with respect to r_A, r_B and r_C, we obtain [32].

$$r_A = r_B = R - \frac{t(5+\alpha K)}{\alpha(2+3t)}$$
$$r_C = R - \frac{(4t+1)-\alpha K(1+t)}{\alpha(2+3t)} \qquad \text{(C2)}$$

Hence, the profits of a compatible bank, $\pi(2, 1)$ are equal to $\frac{(5+\alpha K)^2}{6\alpha(2+3t)^2}t(1+t)$.

(b) *Incompatibility and full compatibility*: Let θ be 1 when all banks are incompatible, and t when they all share their ATMs. Bank A's profits can be written as

$$\pi_A = (R-r_A)\left\{\frac{1-\alpha}{3} + \right.$$
$$\left. + \alpha\left[\frac{r_A-r_B+\theta}{2\,\theta} + \frac{r_A-r_C+\theta}{2\,\theta}\right]/e\right\} \qquad \text{(C3)}$$

(Similarly, for π_B and π_C). Profit maximization yields $r_A = r_B = r_C = R - \theta/\alpha$. Therefore, bank's profits under incompatibility equal $\pi(1, 1, 1) = 1/3\alpha$, and under full compatibility $\pi(3, 0) = t/3\alpha$.

(c) *Full compatibility is not a P.C.N.E. for all* α: To prove this result, we simply have to show that equation (5) in the text holds for all α, which can be easily seen from direct comparison of $\pi(1, 1, 1)$, $\pi(2, 1)$ and $\pi(3, 0)$ above.

(d) *Switching costs make partial compatibility more difficult*: Let $\psi_\alpha(K, t) = \pi(2, 1) - \pi(1, 1, 1) = \left[\frac{(5+\alpha K)^2}{6\alpha(2+3t)^2}t(1+t) - 1/3\alpha\right]$. Let $t^*(K, \alpha)$ be such that $\psi_\alpha(K, t^*) = 0$, that is, $t^*(K, \alpha)$ solves $\frac{t(1+t)}{(2+3t)^2} - \frac{2}{(5+\alpha K)^2} = 0$. Hence, $dt^*/d\alpha < 0$.

[32] It can be easily shown that there exist values of R and $k(n_i)$ such that existence of a rate equilibrium is guaranteed. Exact conditions are derived in the Working Paper verion of this paper.

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