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## Technological transformation and nonbank competition in a model of retail banking oligopoly

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# BANK OF FINLAND DISCUSSION PAPERS

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8/98

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Research Department  
11.5.1998

## Technological Transformation and Nonbank Competition in a Model of Retail Banking Oligopoly

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# Technological Transformation and Nonbank Competition in a Model of Retail Banking Oligopoly

The views expressed are those of the author and do not necessarily reflect the views of the Bank of Finland.

I thank Pekka Ilmakunnas, David Mayes, Juha Tarkka and Jouko Vilmunen for very helpful comments. Remaining errors are mine. Mailing address: Bank of Finland, Research Department, P.O. Box 160, FIN-00101 Helsinki, Finland. e-mail: [jukka.vesala@bof.fi](mailto:jukka.vesala@bof.fi)

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# Technological Transformation and Nonbank Competition in a Model of Retail Banking Oligopoly

Bank of Finland Discussion Papers 8/98

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## Abstract

A model of banking competition is developed, in which diffusion of electronic banking (eg pc and phone banking) and nonbank competition (eg mutual funds, retail stores and insurance firms) are studied as factors that diminish the benefits of branch and ATM networks in terms of enhanced demand and pricing power. A structural increase in price competition, a decrease in the variation of loan and deposit rates across banks and a decline in the optimal numbers of branches and ATMs is shown to result. Competition increases permanently unless banks are able to redifferentiate from rivals through novel innovation that compensates for the reduced value of network differentiation. Capacity collusion is shown to reduce the sizes of branch and ATM networks as well as banks' markups of loan and deposit rates over the money market rate and respective marginal operating costs. ATM compatibility reduces the total number of machines and under certain conditions raises deposit rates.

Under strategic complementarity technological transformation and nonbank expansion enhance the transmission of monetary policy into lending rates, as well as into deposit rates, because banks' incentives to change their rates and the sizes of optimal responses increase with respect to changes in the money market rate. If these trends continue to be more pronounced on the deposit side, loan rates will become more insulated from deposit market events and the volatility of banks' netinterest income will increase.

Keywords: retail banking, price competition, nonprice competition, technological transformation, monetary policy transmission

# Tekninen kehitys ja toimialaliikumukset oligopolistisessa pankkikilpailumallissa

Suomen Pankin keskustelualoitteita 8/98

Jukka Vesala  
Tutkimusosasto

## Tiivistelmä

Keskustelualoitteessa kehitetään oligopolistista vähittäispankkikilpailua kuvaava malli, jonka avulla tutkitaan uusien elektronisten jakelutapojen (esim. pc- ja puhelinpankkitoiminta) ja pankkisektorin ulkopuolisen kilpailun (mm. rahastot, vähittäiskauppa, vakuutuslaitokset) vaikutuksia pankkien luotto- ja talletuskorkoihin sekä konttori- ja pankkiautomaattiverkostopäätöksiin. Konttori- ja pankkiautomaattiverkostolla pankit voivat perinteisesti lisätä tarjoamiensa luotto- ja talletuspalvelujen kysyntää (markkinaosuutta) ja kasvattaa hinnoitteluvoimaansa suhteessa kilpailijoihin. Uudet elektroniset jakelutekniikat ja kilpailijat kuitenkin vähentävät 'fyysisestä' jakeluverkostosta saatavaa kysyntä- tai hinnoitteluhyötyä, pankeille optimaalinen konttori- ja automaattiverkosto supistuu ja kilpailu luotto- ja talletuskoroilla kiristyy pysyvästi, elleivät pankit onnistu uusilla innovatiivisilla tavoilla differentioitumaan kilpailijoistaan. Työssä osoitetaan myös, että pankkien kollektio konttoreiden ja pankkiautomaattien asetannassa alentaa verkostojen kokoa ja alentaa pankkien marginaaleja luotoissa ja talletuksissa. Pankkiautomaattien yhteiskäyttöisyys vähentää laitteiden kokonaismäärää ja tietyin ehdoin nostaa talletuskorkoja.

Mallin avulla saadaan tulokseksi, että tekninen kehitys ja kilpailun laajentuminen parantavat rahapolitiikan tehokkuutta, koska pankkien kannustimet muuttaa luotto- ja talletuskorkojaan suhteessa markkinakorkojen muutoksiin kasvavat ja pankeille optimaaliset korkomuutokset kasvavat. Työssä osoitetaan, että luotto- ja talletuskorkojen muutosherkkyys suhteessa talletuskorkojen muutoksiin pienenee ja pankkien korkokatteen vaihtelevuus kasvaa, jos teknisen kehityksen ja toimialaliukumien vaikutukset ovat tulevaisuudessakin talletuspalveluissa luottopuolta suuremmat.

Asiasanat: vähittäispankkitoiminta, hintakilpailu, jakeluverkostokilpailu, tekninen kehitys, rahapolitiikan transmissio

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# 1 Introduction

Traditionally, branching has clearly been the most important 'nonprice' feature of retail banking competition for private customers and small and medium sized companies. Banks have generally attracted customers by either topping rivals' deposit rates, undercutting their loan rates, or expanding their own branch networks. Branching has also been the primary source of banks' market power, since providing less costly access to services has been their most important means of differentiating themselves from rivals, while the actual services and products have been quite homogeneous. In addition, the sunk costs related to established branch networks have created an effective barrier to entry.

The emergence and diffusion of electronic remote banking technologies for banking services, particularly phone and PC banking, fundamentally revolutionise these underpinnings of retail banking competition.<sup>1</sup> By offering a relatively inexpensive alternative delivery channel to branching, and to some extent to ATMs, remote banking reduces the strategic value of these 'physical' delivery outlets. For small banks and nonbank competitors that have emerged in many traditionally bank-dominated activities remote banking offers a way to extend the customer base aggressively. Banks with extensive branch networks could also have defensive motives for protecting future market share in addition to apparently strong cost-based incentives to invest in remote banking.

As a result, competitive positions change *within the banking industry* across banks with different branch and ATM network sizes, as does banks' competitive position *against nonbank suppliers* of contesting services. The purpose of this paper is to analyse and distinguish between these two effects and address some of the key policy issues involved.

I do not examine incentives to invest in remote banking.<sup>2</sup> I rather take the emergence of alternative service access possibilities and new competition outside the traditional banking industry as exogenous shocks or trends and study their implications for banks' interest rate setting and branch and ATM network choices in a combined network and price competition model of retail banking. The number of market participants is given in the model, ie I do not analyse entry issues. The model is in two stages: the first stage is concerned with capacity (ie branch and ATM network) choices, and the second with short-term oligopolistic competition in loan and deposit rates with fixed capacity. In the model, nonbank suppliers are distinguished from banks in the following ways: Banks operate in both loan and deposit markets while nonbanks are specialized; nonbanks do not have branch or ATM networks, or access to them; nonbanks' services may differ in quality from banks' services; and nonbanks cannot engage in cooperative arrangements with banks.

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<sup>1</sup> In most EU countries remote banking has been established or is expected to be established in the near future (section 3). Kalakota and Frei (1996) report on a rush in the US to invest in electronic banking.

<sup>2</sup> It is not necessary that all market participants offer remote banking to produce the results in the paper (although all seem to have strong incentives to do so). It suffices that customers have in principle access to these technologies.

There are relatively few papers that deal with combined network and price competition in retail banking. This paper contributes by incorporating outside competition, both loan and deposit markets and detailed treatment of customer 'utility parameters', which are affected by the availability and nature of access to banking services.

In the model, the size of branch and ATM networks increases the demand facing individual banks, and generates differentiation benefits against other banks and nonbank competitors. The extent of these benefits depends on the rates at which customers' utility declines when their accessibility to services provided at branches and ATMs worsens, as well as on their marginal utilities related to these outlets. Both of these effects depend on the availability and costliness of alternative service access options.

The key conclusion is that the diffusion of alternative access technologies results in a structural increase in price competition. An increase in the market share of nonbank suppliers has the same effect, or an improvement in their service quality vs banks. Branches and ATMs lose their significance as a source of pricing advantage, as customers can more readily use the services of more distant suppliers and transact with a greater number of suppliers in search of the best offers in the market. Perceived demands for banking services become more elastic, and a price cut has a bigger impact on market shares than before. Naturally, the widespread lifting of controls on interest rates has paved the way for the increase in price competition in banking.

The greater the pricing benefit banks get from expanding their branch and ATM networks, the stronger their incentives to do so. Hence equilibrium numbers of branches and ATMs fall with a structural increase in price competition. When banks share their ATM networks, ie when the machines are compatible, the extent to which banks are differentiated from each other diminishes, but banks' competitive position against nonbanks without access to the ATM network is strengthened. I also study possible cooperative arrangements and find that semi-collusion in interest rates with competitive capacity setting produces the greatest and semi-collusion in capacities with competitive pricing the smallest numbers of branches and ATMs. Consequently, capacity collusion has the effect of lowering banks' markups in loan and deposit markets. Banks' markups in deposits taking fall alternatively as a result of ATM compatibility arrangements under certain conditions.

The model is also intended for use in studying implications for policy questions that relate to competitive conditions in loan and deposit markets. In the paper, I examine (i) the efficiency of the transmission of money market rate changes into the loan (and deposit) rates, ie the efficiency of monetary policy transmission, (ii) the effects of further deregulation of deposit rates on banks' lending rates, and (iii) some competition policy questions.

The first two issues are quite topical in the context of the shift to EMU in Europe. First, the paper shows how competitive conditions and the development stage of banking technologies determine the efficiency of monetary policy transmission into lending rates. Notably, country-specific differences in these regards would produce varying effects of the single monetary policy on output and investment in different countries within the euro area. Secondly, enhancing integration of the European banking markets will very likely force further

harmonization of banking regulations and tax rules that still differ across European countries.

So far, technological development has had a bigger impact on the delivery of deposit-related services than on lending activities, and this situation is likely to persist in the near future. Changes in the processing and delivery of standardized low-risk consumer credits and mortgages are however gaining pace in contrast to commercial lending that requires close credit risk evaluation and monitoring. This asymmetric development has a bearing on the short- to medium-term policy conclusions, and has a particularly adverse effect on banks income development.

The next section describes the relation of this study to the literature. Section 3 presents some background notions on the diffusion of remote banking and nonbank competition, and provides evidence that these trends have already produced tangible effects on the delivery of services and firms' conduct in the banking industry and have strong potential to produce further such effects. Section 4 presents the modelling of deposit supply and loan demand. As usual, the analysis proceeds first to the price setting stage (section 5), and then to the capacity setting stage (section 6). Sections 7 and 8 report the analysis of the policy issues, and section 9 concludes.

## 2 Relation to the literature

Many recent industrial organization-type studies emphasise the nonprice aspects of retail banking competition.<sup>3</sup> In the existing spatial (horizontal locational differentiation) models of banking competition<sup>4</sup>, which usually apply Salop's (1979) model of monopolistic competition ('circular city'), branching coincides with new entry, and competition between multi-branch banks is not analysed at all. In these models competitive conditions change only after entry and exit and not because of delivery network decisions, outside competition or technological change, which are at focus here.

There are only a few studies that explicitly address branching as a part of the strategic behaviour of banks. Cerasi (1995) studies banks' branching decisions in order to find the equilibrium conditions for unit banking and branch banking, and hence the industry structure.<sup>5</sup> Gherig (1990) and Matutes and Vives (1996) explain with positive externalities related to the size of banks' total branch network the possibility of the emergence of asymmetric industry configurations.<sup>6</sup>

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<sup>3</sup> For example, Degryse (1996), Matutes and Vives (1996), Bouckaert and Degryse (1995), Matutes and Padilla (1994), and dePalma and Uctum (1992), to mention only a few.

<sup>4</sup> Eg Chiappori et al (1995), Schmid (1994), and Besanko and Thakor (1992).

<sup>5</sup> According to her results, unit banking obtains when the market size is small. Nakamura and Parigi (1992) explain the coexistence of unit and branch banks with heterogeneous preferences: distance plays a role only for a fraction of banks' customers.

<sup>6</sup> Literature on the effect of branching on banks' pricing is also quite scant. Calem and Nakamura (1995) develop a model which suggest more diverse pricing across banks with branch rather than with unit banking. Mester (1987) and Gale (1992) argue that branching increases competition to the extent that rivals compete at multiple locations.

This and Cerasi's paper are more general than the applications of the spatial models, since (in equilibrium) competition among all market participants is allowed, rather than just between neighbouring firms in the horizontal dimension (section 4). However, apart from different research topics, our modelling of differentiation is different. Cerasi applies Shaked and Sutton's (1990) model of demand for a single output (deposit services) of multi-product firms (branches represent the different products or variations), whereas I adopt a variant of a multi-dimensional product differentiation model developed by Feenstra and Levinsohn (1995), which is a generalization of the one-dimensional differentiation model of the Hotelling-type. In contrast to Cerasi's analysis, I also include the loan market.

Another difference compared to the literature is that I incorporate ATMs as another 'physical' delivery channel for the deposit market. This is justified, since cash-dispensing and multi-purpose ATMs provide many of the most often demanded deposit-related payment and account transfer services. Matutes and Padilla (1994) study the impact of ATM compatibility on banking competition with a three-bank spatial model. They study the effect on competition within the banking industry but do not analyse the competitive position of the banking industry vs outside competitors, which constitutes a sort of network externality for the participants of the compatibility agreement.

Bouckaert and Degryse (1995) and Degryse (1996) study banks' incentives and conditions in offering remote banking. One of their main results is that the incentives increase with price competition. In their papers there is a negative interaction between different differentiation characteristics (service quality and location).

### 3 Notions on remote banking and nonbank competition

*Remote banking* refers to acquisition of banking services without face-to-face contact with the supplier's personnel (at a branch office). The primary means of remote banking are *phone banking* (sometimes called *direct-banking*) where voice communication with the supplier of services is done over the telephone, and *PC banking* where data-messages are sent to the supplier via the telephone network with the help of some, usually supplier-specific, software or via the Internet with the help of the software available in the Internet. *Multi-purpose payment ATMs* that can be used for account transfers and other transactions, and not just for cash withdrawals as is the case with *cash-dispensing ATMs*, are often classified within remote banking as well. However, payment and cash-dispensing ATMs constitute a proprietary delivery channel for banks, as branches, which makes them different from the telephone networks and Internet, which are not owned by banks, and generally open to all firms that wish to enter the market. Hence it is sensible to regard phone- and PC-banking technologies as alternatives to branches and ATMs in the way that is done in this paper: The latter channels are 'physical' and proprietary to banks and the former 'electronic' and open to all market participants.

Remote banking options already exist for a wide range of retail banking services in many countries.<sup>7</sup> Based on the literature and market information, it seems safe to conclude that remote banking possibilities are more advanced and more frequently used for deposit-related saving and payment management services than lending activities, though eg phone-banks currently also offer consumer and mortgage credits quite extensively.<sup>8</sup>

The significance of branches has already decreased considerably for depositors due to the use of ATMs and remote banking. Companies have used computers for making payments much longer than private customers. In Finland this development has proceeded quite far, and branches have already lost much of their importance for deposit customers, since based on the Finnish Bankers' Association data, the most frequent banking transactions are mostly effected without visiting branches. As regards future development, some observers stress the comparative advantage of telephones, while others expect that the Internet will become the main channel for private customers. At least in part, the growth in phone- and PC-banking will reduce the use of payment ATMs, since they substitute for the services offered through them.

The development of credit scoring techniques can in the future significantly increase the remote supply of standardized, low risk loans such as consumer credits and mortgages (eg Avery et al 1997). Loans that involve extensive credit risk, notably commercial lending, will probably continue to require close customer contacts and proximity for credit risk evaluation and monitoring. Processing of private information about borrowers is after all, according to recent theoretical contributions (following eg Diamond 1984), the most important aspect of financial intermediation. However, even in this field the new techniques for assessing credit risk (eg neural networks) can substitute for close physical presence and increase competition, though competition in this segment of the credit market seems to be already quite keen in many countries.

There are a number of factors *on the demand side* that support the rapid diffusion of remote banking or its breakthrough as a banking method for the 'masses'. Consumers increasingly demand more convenient and 24-hour services for effecting transactions. ATMs deliver that, but remote banking transactions can be carried out wherever there is access to a phone or the Internet. Perhaps more importantly, consumers are increasingly computer-literate, and the younger generation is much more apt to change banking habits. Kennickell and Kwast (1997) find in their study that household heads below 35 in the US are considerably more likely than the older ones to use PCs for payments. Finally, there should already exist a 'critical mass' for growth in terms of both the number

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<sup>7</sup> Anderton (1995), Crane and Bodie (1996) and Kalakota and Frei (1996) present descriptions and categorizations of the products that are available in the market.

<sup>8</sup> According to data collected by the BIS the market share of phone banking currently varies between 11 per cent and 3 per cent in the European G-10 countries. In Finland all major banks offer phone- and PC-banking possibilities, and roughly 30 per cent of their private customers have made either phone or PC-banking contracts to effect transactions. This figure might overestimate the share of remote banking, since some contracts may remain unused. Phone and PC-banking have similar shares in Finland at the moment, but PC-banking is growing significantly faster according to the data collected by the Finnish Bankers' Association.

of customers who have tried new electronic banking means and the number of PC-using households.<sup>9</sup>

*On the supply side*, there are, firstly, cost-based incentives to invest in remote banking. Deregulation and opening up of markets forces banks to cut costs, and there is evidence that remote banking is significantly cheaper to supply than branch-based banking.<sup>10</sup> Moreover, electronically handled transactions exhibit apparently stronger economies of scale than manual transactions, since the fixed cost component is much more significant than the variable cost component (eg McAndrews 1992 and Humphrey 1994). Widespread cooperation of banks in many European countries in the field of electronic payments supports the existence of significant scale economies (Vesala 1995). Secondly, remote banking offers new possibilities for those seeking ways to expand. A competitive advantage of the newcomers is that they do not have the cost burden associated with the old banking infrastructure. In this environment, in which there is also increasing customer demand for remote banking, banks that do not make such investments face the possibility of losing market share in the future.

Remote banking technologies can also be used by the nonbank entrants for an aggressive expansion in the market. In the field of payment management, money market funds already offer payment services eg in the US and France, and 'niche' banks that have won market shares especially in the UK and Sweden offer deposit-related services to often quite narrowly defined customer groups. However, telecom firms and software houses are often mentioned as the strongest outside competitors for banks in the payments area.

Remote banking provides new opportunities for credit card companies and other providers of consumer credit and probably also for specialized mortgage banks. In commercial lending, the most likely area for increasing competition outside the traditional banking industry is in low-credit-risk collateralized short-term credits (financing companies). Securitization of loans and capital market funding, which is expected in Europe to catch up with developments in the US, also creates an important threat to banks' position in the credit market. Corporate loans are much more difficult to securitize than mortgages, because they are heterogeneous and require credit risk evaluation and monitoring. However, in the US the securitization of even small business loans is already occurring (Crane and Bodie 1996).

In asset management services (niche banks, mutual funds, brokerage and insurance firms), close physical contacts are likely to remain important for many customers, and branch-banks should maintain some of their current advantages in this area, but remote supply (eg foreign banks and mutual funds) and abundant information of competing offers through phone and the Internet put strong discipline on banks that sell these products through their branch network.

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<sup>9</sup> Kalakota and Frei (1996) state that home banking with PCs failed to grow in earlier times in the US due to the absence of a 'critical mass' of PCs and PC-friendly population.

<sup>10</sup> Anderton et al (1995) estimate cost savings of up to 80 per cent of overhead. Robinson and Flaatraker (1995) find that in Norway the cost of branch-based transactions is around three times that of automated transactions. Frei et al (1997) (their Table 4) cite survey information for the USA that indicates the following costs per transaction: teller (USD 1.40), telephone with human operator (USD 1.00), automated telephone (USD 0.15), and ATM (USD 0.40).

Finally, retail corporations have already become significant lenders eg in auto sales and have engaged in deposit-related services although their operations have not usually been based on remote banking options. Retail firms can use their own outlets in competition against banks.

To obtain cash, customers still must rely very much on cash dispensing ATMs, which gives a competitive advantage to banks that possess the cash-dispenser networks, though there are some signs that retail firms might start distributing cash. However, the ongoing overall decline in the use of cash (Humphrey et al, 1996a) is reducing the significance of this advantage. Most importantly, the widespread establishment of electronic funds transfer (EFT-POS) terminals in retail stores and other outlets has significantly increased the use of debit and credit cards for making retail payments and hence reduced the use of cash.<sup>11</sup> Moreover, there is potential for diffusion of the use of electronic cash (e-cash, stored on chip-cards or electronic purses for purchases in the Internet) in the future.

Having access to central banks' payment and settlement services would very likely give a big boost to nonbanks' activities in the field of payment management. However, discussion of the pros and cons of this policy choice falls beyond the scope of this paper. Regulatory and supervisory treatment of nonbank providers of financial services is also currently unclear (eg regulation of e-cash issuers), but I tend to think that for large-scale activities the necessary licencing and regulatory compliance should not constitute a major barrier to entry.

To summarize, it seems clear that technological transformation and nonbank competition will have an increasingly important effect on the nature and extent of banking competition. Let us turn next to the modelling issues as set out in the introduction.

## 4 Demand for banking services

In the model, there are  $N$  banks that have entered the market to collect deposits and provide the associated payment services and to supply loans. In stage one of the game, they have established  $b_1$  branches and  $b_2$  ATMs ( $\mathbf{b}_i = (b_{i1}, b_{i2})$ ,  $i=1, \dots, N$ ). These decisions are sunk when deposit supply and loan demand are realized. ATMs are relevant for the deposit customers only. Addition of a  $(N+1)$ th competitor in both the deposit and loan markets captures the nonbank competition outside the traditional banking sector. The nonbank competitors have one branch but no ATMs or access to the ATM network ( $\mathbf{b}_{N+1} = (1,0)$ ) and are specialized in either lending or deposit taking and the related activities.

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<sup>11</sup> Humphrey et al (1996b) report that across 14 developed countries for 1993 there was a statistically significant negative relationship between the availability of EFT-POS terminals and the ratio of cash holdings to GDP.



## 4.1 Supply of deposits

Depositors each have one unit of cash that they can deposit with some bank or use the nonbank option to obtain interest at rate  $r$  as well as payment and account keeping services.<sup>12</sup> The nonbank competitor can be thought of eg as a money market mutual fund offering payment management services. A fixed number of depositors is continuously and uniformly distributed within a certain geographical area ( $\Delta$ ).<sup>13</sup>

I allow depositors' preferences for branch and ATM network densities to vary across *representative* groups of depositors that could be defined eg as different age groups of private customers, different propensities to use remote access, or groups with different numbers of regular transactions to make. Each of these groups is characterized by  $\mathbf{b}^* = (b_1^*, b_2^*) \in \Delta$  which represents the ideal network density for them.<sup>14</sup> Branches and ATMs are not necessarily substitutes, and depositors can have a positive valuation of both.

In this setting, the utility of a *representative* depositor with certain  $\mathbf{b}^*$  depends on the deposit rate and the numbers of the branches and ATMs of the institution with which she has deposited her funds; not the exact location of its branches and ATMs. I use a quadratic formulation for the part of the utility function that depends on the observable differentiation characteristics as in Feenstra and Levinsohn's (1995) model<sup>15</sup>:

$$\begin{aligned} U(\mathbf{b}_i, \mathbf{b}^*, r_i) &= u(\mathbf{b}_i, \mathbf{b}^*) + r_i \equiv \gamma_0 + \gamma_1' \mathbf{b}_i - (\mathbf{b}^* - \mathbf{b}_i)' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_i) + r_i, \quad i=1, \dots, N \\ U(\mathbf{b}_{N+1}, \mathbf{b}^*, r_{N+1}) &= u(\mathbf{b}_{N+1}, \mathbf{b}^*) + r_{N+1} \equiv \gamma_1' \mathbf{b}_{N+1} - (\mathbf{b}^* - \mathbf{b}_{N+1})' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_{N+1}) + r_{N+1}, \end{aligned} \quad (1)$$

where  $\gamma_1 = (\gamma_{11}, \gamma_{12}) > 0$  represent depositors' constant marginal utilities of branches and ATMs. These utilities should approach zero when there is free, unconstrained and easy access to alternative delivery channels.  $\gamma_0$  captures a service quality difference between banks and the nonbank supplier that is not related to service accessibility. The quality of the nonbank provider is normalized

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<sup>12</sup> There is no explicit price for payment and other ancillary services in the model. Banks' explicit service charges have been quite negligible in many countries (Humphrey et al 1996a), especially when compared to banks' net interest income. Robinson and Flaatraker (1995) provide evidence from Norway that payment service prices have been much lower than their production costs, ie they have been heavily cross-subsidized. However, banks seem to have recently set higher prices for manual than automated transactions to direct demand toward automated services and to save labour costs. Determination of deposit rates and service fees and reasons for cross-subsidization are studied extensively by Tarkka (1995).

<sup>13</sup> The size of the overall deposit market ( $\Delta$  times one unit of cash) is determined by the number of depositors but can be alternatively thought of as expanding due to growth in income or wealth. Then, deposit supply increases to all market participants, and market shares remain unaffected.

<sup>14</sup> The taste distribution is such that  $\mathbf{b}^*$  ranges from zero to maximum  $\mathbf{b}^*$  such that the market space is saturated with outlets.

<sup>15</sup> The total number of banks' outlets does not add to utility (like in Cerasi 1995 and Matutes and Vives 1996) unless there is a compatibility agreement (see section 6), and depositors can use also other than his own banks' outlets.

to zero.  $\gamma_0 > 0$  when greater acceptance of bank-provided payment means, easier use or a richer assortment of banks' services generates a quality difference that favours banks.

The quadratic term captures the negative effect on utility when branch and ATM network densities are less than is preferred.  $\tau_1$  and  $\tau_2$  are constant and positive diagonal elements of the matrix  $\mathbf{T}$ . They represent the rates at which utility declines when there is less than the preferred service availability through branches and ATMs. The sizes of these parameters depend on depositors' transport costs or search and transaction costs associated with the alternative delivery technologies. There is no utility loss if actual proximity of branches and ATMs exceeds the preferred proximity ( $\mathbf{b}^* \leq \mathbf{b}_i$ ) or the rates  $\tau_1$  and  $\tau_2$  equal zero, which obtains when there is less costly and easier access to the alternative delivery channels than to branches and ATMs.

Let  $\Delta_i$  be the set of depositors with  $\mathbf{b}^*$  who choose bank  $i$ . It is defined by the following utility comparisons against other banks and the nonbank:

$$\Delta_i \equiv \{\mathbf{b}^* \in \Delta \mid \gamma_1' \mathbf{b}_i - (\mathbf{b}^* - \mathbf{b}_i)' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_i) + r_i \geq \gamma_1' \mathbf{b}_j - (\mathbf{b}^* - \mathbf{b}_j)' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_j) + r_j, \quad i, j = 1, \dots, N, \quad i \neq j, \text{ or} \quad (2)$$

$$\Delta_i \equiv \{\mathbf{b}^* \in \Delta \mid \gamma_0 + \gamma_1' \mathbf{b}_i - (\mathbf{b}^* - \mathbf{b}_i)' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_i) + r_i \geq \gamma_1' \mathbf{b}_{N+1} - (\mathbf{b}^* - \mathbf{b}_{N+1})' \mathbf{T} (\mathbf{b}^* - \mathbf{b}_{N+1}) + r_{N+1}\}, \quad i = 1, \dots, N$$

In order to evaluate each supplier's  $\Delta_i$ , the inequalities in (2) can be written as

$$\Delta_i = \{\mathbf{b}^* \in \Delta \mid \gamma_1' \mathbf{b}_i - \gamma_1' \mathbf{b}_j + (\mathbf{b}_i' \mathbf{T} \mathbf{b}_i - \mathbf{b}_j' \mathbf{T} \mathbf{b}_j) - 2\mathbf{b}^* \mathbf{T} (\mathbf{b}_j - \mathbf{b}_i) \geq r_j - r_i\}, \quad i, j = 1, \dots, N, \quad i \neq j, \text{ or} \quad (3)$$

$$\Delta_i = \{\mathbf{b}^* \in \Delta \mid \gamma_0 + \gamma_1' \mathbf{b}_i - \gamma_1' \mathbf{b}_{N+1} + (\mathbf{b}_i' \mathbf{T} \mathbf{b}_i - \mathbf{b}_{N+1}' \mathbf{T} \mathbf{b}_{N+1}) - 2\mathbf{b}^* \mathbf{T} (\mathbf{b}_{N+1} - \mathbf{b}_i) \geq r_{N+1} - r_i\}, \quad i = 1, \dots, N$$

We see that bank  $i$  can increase its deposit base ( $\Delta_i$  times one unit of cash) and market share ( $\Delta_i/\Delta$ ) by either increasing its deposit rate or increasing the size of its branch and ATM networks relative to its rivals in the first stage of the game. This tradeoff depends on the utility parameters  $(\gamma_1, \mathbf{T})$  (*competition among banks*) or  $(\gamma_0, \gamma_1, \mathbf{T})$  (*competition against the nonbank supplier*). Notice that when all banks increase or reduce their networks in the same proportion market shares remain

unaffected across banks, but when banks reduce their networks their competitive position against the nonbank rival weakens.<sup>16</sup>

The quantities  $(r_j - r_i)$  and  $(r_{N+1} - r_i)$  in (3) give us the sizes of the competitive advantages of a bank  $i$  with extensive branch and ATM networks against bank competitors with smaller networks, which are increasing in  $(\mathbf{b}_i - \mathbf{b}_j, j = 1, \dots, N+1)$ ,  $\gamma_1$ ,  $T$  and  $\gamma_0$  (against the nonbank rival only). Alternatively, these quantities measure the *imperfectness of the substitutability of bank  $i$ 's services* with respect of those provided by its rivals, ie the degree of insulation of bank  $i$  from price competition due to branch and ATM networks. Bank  $i$  can win depositors with given  $\mathbf{b}^*$  as long as its deposit rate does not fall below its competitors' rates by more than these amounts.

Derivation of the perceived deposit supply functions,  $D_i$ , requires integration over each  $\Delta_i$  ( $i = 1, \dots, N+1$ ):

$$D_i = \int_{\Delta_i} \mu d\mathbf{b}^*, \quad (4)$$

where  $\mu$  is the density of depositors over  $\Delta$ . (4) does not have a closed form solution, but Feenstra and Levinsohn's (1995) theory proposes a first-order approximation for quadratic utility functions such as the one in (1). Their Proposition 1 proves the existence of the following first derivatives<sup>17</sup> of a firm-specific demand function with respect to own ( $p_i$ ) and rivals' prices ( $p_j$ ):

$$\begin{aligned} (a) \quad \frac{\partial D_i}{\partial p_i D_i} &= -\sum_{j \neq i} \frac{M \delta_{ij}}{(h_{ij} + \omega_j - \omega_i)}, \\ (b) \quad \frac{\partial D_i}{\partial p_j D_i} &= \frac{M \delta_{ij}}{(h_{ij} + \omega_j - \omega_i)}, \\ (c) \quad \sum \delta_{ij} &= 1. \end{aligned} \quad (5)$$

Here these semi-elasticities are needed to characterize the perceived deposit supply curves and consequently in section 5 the oligopoly pricing equilibrium. In applying (5),  $M$  equals the number of differentiation parameters,  $h_{ij}$  is the distance (differentiation) in terms of the characteristics between suppliers  $i$  and  $j$ , and the  $\delta_{ij}$ 's are firm-specific weights, each equal the share of  $i$ 's market space that is exposed to competition against  $j$ .  $\omega_i$  is the price after adjusting for the marginal utilities of the characteristics.

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<sup>16</sup> The set of depositors who choose the nonbank supplier ( $\Delta_{N+1}$ ) is obtained by reversing the direction of the latter inequalities in (2) and (3). Notice that the nonbank competitor can attract deposits only by raising its interest rate offer as long as  $\gamma_0 > 0$ .

<sup>17</sup> It is not possible to derive a closed form deposit supply function even in the case of uniform densities  $\mu$ . Anderson et al (1989) show that a solution exists only when the total number of firms minus one does not exceed the number of differentiation parameters.

In applying Feenstra and Levinsohn's theory,<sup>18</sup> I first denote the 'utility adjusted' deposit rates as

$$\begin{aligned}\xi_i &\equiv r_i + \gamma_1 \mathbf{b}_i, & i = 1, \dots, N+1, \text{ and} \\ \omega_i &\equiv \xi_i + \gamma_0, & i = 1, \dots, N, \\ \omega_{N+1} &\equiv \xi_{N+1}\end{aligned}\tag{6}$$

Since depositors always prefer a wider network, or are indifferent, bank  $i$  has a competitive advantage over its rivals only if its network is larger, and therefore the decreasing part of the quadratic function,  $h_{ij}$ , on  $b_1$ ,  $b_2$  and  $\mathbf{T}$  must be ruled out:

$$\begin{aligned}h_{ij} &\equiv (\mathbf{b}_i - \mathbf{b}_j)^T \mathbf{T} (\mathbf{b}_i - \mathbf{b}_j) \quad \text{if } \mathbf{b}_i > \mathbf{b}_j \\ &\equiv (\mathbf{b}_{ki} - \mathbf{b}_{kj})^2 \tau_k \quad \text{if } \mathbf{b}_{ki} > \mathbf{b}_{kj} \text{ and } \mathbf{b}_{li} < \mathbf{b}_{lj}, \quad k, l = 1, 2, \quad k \neq l \\ &\equiv 0 \quad \text{if } \mathbf{b}_i \leq \mathbf{b}_j, \quad i, j = 1, \dots, N+1, \quad i \neq j\end{aligned}\tag{7}$$

I assume that all market participants are in competition against each other. This is not unrealistic with increasingly mobile customers, and it simplifies the weights. In this case, the weights correspond to the endogenously determined market shares, which are normalized so that the condition (c) is satisfied. This also has intuitive appeal since the bigger the supplier in relative terms, the larger its impact on the semi-elasticities.

$$\sum_{j \neq i}^N \delta_j + \delta_{N+1} \equiv \delta_{-i} + \delta_{N+1} = 1, \quad j = 1, \dots, N,\tag{8}$$

where  $\delta_{-i}$  is the joint market share of bank  $i$ 's rival banks, and  $\delta_{N+1}$  that of the nonbank competitor.

### Result 1.

*The elasticity of bank  $i$ 's perceived deposit supply curve ( $D_i$ ) with respect to own deposit rates ( $> 0$ ) can be written as*

$$\epsilon_i^D \equiv \frac{\partial D_i}{\partial r_i} \frac{r_i}{D_i} = \sum_{j \neq i}^N \frac{2r_i \delta_j}{(h_{ij} + \xi_i - \xi_j)} + \frac{2r_i \delta_{N+1}}{(h_{iN+1} + \xi_i - \xi_{N+1} + \gamma_0)},$$

or (9)

$$\epsilon_i^D = 2r_i \left[ \frac{\delta_{-i}}{h_i^B} + \frac{\delta_{N+1}}{h_i^{NB}} \right] = \frac{2r_i}{H_i}, \quad i, j = 1, \dots, N$$

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<sup>18</sup> The necessary condition of continuous differentiability to apply the first-order approximation requires that  $\Delta_i$  is assumed convex.

PROOF. (9) results after applying (5), (6) and (8). The second expression is obtained by multiplying the first term of the first expression by  $\sum \delta_j / \sum \delta_j$  ( $j \neq i$ ), and defining  $h_i^B$ ,  $h_i^{NB}$  and  $H_i$  as

$$\begin{aligned} h_i^B &\equiv \left[ \sum_{j \neq i}^N \frac{\delta_j / \sum_{j \neq i}^N \delta_j}{(h_{ij} + \xi_i - \xi_j)} \right]^{-1}, \\ h_i^{NB} &\equiv \left[ \frac{1}{(h_{iN+1} + \xi_i - \xi_{N+1} + \gamma_0)} \right]^{-1}, \\ H_i &\equiv \left[ \frac{\delta_{-i}}{h_i^B} + \frac{\delta_{N+1}}{h_i^{NB}} \right]^{-1}, \quad i = 1, \dots, N, \end{aligned} \tag{10}$$

where  $h_i^B$  is a summary measure of bank  $i$ 's differentiation *against rival banks* as regards branch and ATM networks and corresponds to a weighted harmonic mean of the price-adjusted  $h_{ij}$ 's ( $i, j = 1, \dots, N$ ), since rival banks' weights  $\delta_j$  are normalized by their sum.  $h_i^{NB}$  represents a price-adjusted measure of the differentiation *against the nonbank rival*. Finally, the overall differentiation measure<sup>19</sup>,  $H_i$ , is a combination (weighed harmonic mean) of the measures  $h_i^B$  and  $h_i^{NB}$ , and is increasing in both measures. Appendix 1 reports the first-order approximations for the perceived deposit supply functions.

Bank  $i$ 's perceived deposit supply curve ( $D_i$ ) is, first, the more inelastic (ie the greater bank  $i$ 's market power), the more it is differentiated from its rivals in terms of its branches and ATMs, ie the bigger the  $h_i^B$  and  $h_i^{NB}$ . These measures are in turn increasing in the numbers of branches and ATMs ( $\mathbf{b}_i$ ) and in utility parameters  $T$ ,  $\gamma_1$  and  $\gamma_0$  (only  $h_i^{NB}$ ). The impact of  $h_i^{NB}$  on the deposit supply elasticity is the larger, the smaller the value of  $\mathbf{b}_i$ . By (7), the elasticity is fully determined by  $h_i^{NB}$  for the bank with the smallest  $\mathbf{b}_i$  among the banks. Secondly, the supply elasticities are decreasing in the differences in utility-adjusted deposit rates ( $\xi_i - \xi_j$ ), ie they are *not* constant but decreasing in  $r_i$ , given rivals' deposit rates. Thirdly, the elasticities are increasing in rivals' market shares ( $\delta_{-i}$  and  $\delta_{N+1}$ ). Hence a bank's market power is the greater, the bigger its market share, and we have indirectly come to the usual result that market power increases with concentration. Moreover,  $\delta_{-i}$  is likely to be positively correlated with the number of firms in the market.<sup>20</sup>

Under symmetric banking industry configurations ( $\mathbf{b}_i = \mathbf{b}$  and  $\delta_i = \delta$ ,  $i = 1, \dots, N$ ) each bank's  $1/H$  is the same, and equals  $(\delta_{N+1}/h^{NB})$ . Hence the deposit supply elasticity faced by all banks depends only on the standing *against the nonbank rival*, and the *within-banking-industry* effects cancel out. The elasticity

<sup>19</sup> These kinds of index measures of differentiation are developed by Feenstra and Levinsohn (1995).

<sup>20</sup> It can be easily shown that the perceived 'own rate' elasticity of deposit supply faced by the nonbank supplier falls (market power rises) with  $\delta_{N+1}$  and rises with  $\gamma_{11}$ ,  $\gamma_0$  and the size of banks' delivery networks.

falls with the size of banks' branch and ATM networks and with the utility parameters  $T$ ,  $\gamma_1$ ,  $\gamma_0$ , and rises with  $\delta_{N+1}$ .<sup>21</sup>

**Result 2.**

*The cross-elasticities of bank i's perceived deposit supply curve with respect to rivals' rates ( $< 0$ ) are:*

$$\begin{aligned} \epsilon_{ij}^D &\equiv \frac{\partial D_i}{\partial r_j} \frac{r_j}{D_i} = -\frac{2r_j \delta_j}{(h_{ij} + \xi_i - \xi_j)}, \quad i, j = 1, \dots, N, i \neq j, \\ \epsilon_{iN+1}^D &= -\frac{2r_{N+1} \delta_{N+1}}{h_i^{NB}}. \end{aligned} \tag{11}$$

PROOF. (11) is obtained after applying (5), (6), (8), (9) and (10).

We see that increasing differentiation in terms of branches and ATMs makes the deposit supply faced by banks more insulated from rivals' interest rate offers. The bigger the market share of the rival, the bigger the impact of its deposit rate on the deposit supply to bank i.

The present model de facto classifies banks in a quality dimension depending on their numbers of branches and ATMs (ie offered service availability). Thus, a type of vertical differentiation modelling is applied. The model does not have an *explicit* spatial structure, as the exact location of branches and ATMs is irrelevant. However, the spatial interpretation of the model is that branches and ATMs are uniformly distributed in the market area. The more branches and ATMs a bank has, the denser its distribution of the respective outlets and the closer the bank gets to the *representative* depositor in geographic terms. Banks' competitive position weakens when they do not offer 'geographic' proximity but must instead offer higher deposit rates in order to attract customers.

Nevertheless, the key predictions of Salop's (1979) model of spatial competition and its banking applications are also produced here. The 'own rate' elasticity falls with a bank's market share (which in Salop's model is represented by the segment of the circle occupied by the firm), and the elasticity decreases with depositors' transport costs (here in  $T$ ). However, the present model is more general than the applications of Salop's 'circular city' where banks in equilibrium compete only with their geographic neighbours. In the model developed here all market participants compete with each other. Since customers can bank with numerous branches and ATMs and have become increasingly mobile and less loyal to single banks, this approach is justified.<sup>22</sup>

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<sup>21</sup> A uniform increase in banks' deposit rates leads to a rise in the deposit supply to the banking sector by an amount  $[2\delta_{N+1}/h^{NB}]$ , which characterizes the elasticity of the aggregate banking industry deposit supply curve in the symmetric case.

<sup>22</sup> The model is especially suited to characterizing competition in banking systems where there are a few nationally operating universal banks in competition with each other. Nordic countries and many other European countries exhibit such banking systems, in contrast to the dispersed US system.

## 4.2 Demand for loans

The basic assumptions are the same for the loan and deposit markets. Fixed number of borrowers is uniformly and continuously distributed over a market space ( $P$ ), and each borrower needs to borrow one unit of funds from some bank or a nonbank supplier. The nonbank competitor can be thought of as eg a credit card company in case of household loans, or a financing company or even the capital market in case of corporate loans.

The representative borrower's utility is expressed as

$$U(b_{1i}, b^*, t_i) = u(b_{1i}, b^*) - t_i = \eta_0 + \eta_1 b_{1i} - (b^* - b_{1i})^2 v - t_i, \quad i = 1, \dots, N$$

$$U(b_{1N+1}, b^*, t_{N+1}) = u(b_{1N+1}, b^*) - t_{N+1} = \eta_1 b_{1N+1} - (b^* - b_{1N+1})^2 v - t_{N+1},$$
(12)

where  $b_1^*$  is the preferred branch network density,  $t$  the loan rate,  $\eta_1$  the borrowers' constant marginal utility of branches, and  $v$  the constant rate at which utility declines when accessibility to branches is less than preferred. Lenders with fewer branches, who are more costly to reach and inform for purposes of credit risk evaluation and monitoring, need to compensate the borrower with a lower rate. The cost of informing the lender are important especially in the case of small firms. According to the literature, for example, the information-related costs are the main reason why small firms resort to bank lending and not to capital market finance. The information-related benefits that borrowers obtain through bank branches are captured here in parameters  $\eta_1$  and  $v$ . New information technologies can reduce these benefits, in particular at the low-risk end of the spectrum (consumer credits and mortgages, short-term collateralized commercial credits).<sup>23</sup>

$\eta_0$  represents the quality difference between banks' and the nonbank's credit-related services which is not related to the service accessibility. This difference captures the greater utility borrowers could get from the closer credit risk evaluation and project selection consultation, or personal financial consultation, offered by banks than the nonbank lender, which saves borrowers' costs and increases the expected return of the projects for which financing is obtained. The prerequisite for these benefits for borrowers is that banks have superior information on the borrower and his environment.

The set of borrowers,  $P_i$ , who choose the bank  $i$  is defined in a similar fashion as the set  $\Delta_i$ . Bank  $i$  can increase its share of the loan market ( $P_i/P$ ) by increasing the number of branches or lowering its loan rate, given the rates and networks of its rivals. The tradeoff depends on the utility parameters ( $\eta_1, v$ ) (*competition among banks*) or ( $\eta_0, \eta_1, v$ ) (*competition against the nonbank supplier*). Similarly as for the deposit market, it can be shown that the *substitutability of bank  $i$ 's credit services* is decreasing in  $(b_{1i} - b_{1j}, j = 1, \dots, N+1)$ ,  $\eta_1, v$ , and  $\eta_0$ .

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<sup>23</sup> From the banks' viewpoint, branching means ability to get closer to the customer and to better evaluate and monitor credit risk. Therefore, banks get a pricing advantage through branching, because they can more accurately price the credit risk. This benefits the borrower as well as the bank.

Applying again Feenstra and Levinsohn's (1995) theory,<sup>24</sup> I denote first the 'utility adjusted' loan rates as:

$$\begin{aligned}\zeta_i &\equiv t_i - \eta_1 b_{1i}, & i=1, \dots, N+1, \text{ and} \\ \omega_i &\equiv \zeta_i - \eta_0, & i=1, \dots, N, \\ \omega_{N+1} &= \zeta_{N+1}\end{aligned}\tag{13}$$

The normalized weights for the semi-elasticities based on rivals' market shares satisfy

$$\sum_{j \neq i}^N \rho_j + \rho_{N+1} \equiv \rho_{-i} + \rho_{N+1} = 1, \quad i=1, \dots, N,\tag{14}$$

where  $\rho_{-i}$  is the joint market share of the rival banks to bank  $i$ , and  $\rho_{N+1}$  that of the nonbank competitor.

### Result 3.

Analogously to Result 1, the elasticity of bank  $i$ 's perceived loan demand curve ( $L_i$ ) with respect to own lending rates ( $< 0$ ) can be written as

$$\epsilon_i^L \equiv \frac{\partial L_i}{\partial t_i} \frac{t_i}{L_i} = - \sum_{j \neq i}^N \frac{t_j \rho_j}{(k_{ij} + \zeta_j - \zeta_i)} - \frac{t_{N+1} \rho_{N+1}}{(k_{iN+1} + \zeta_{N+1} - \zeta_i + \eta_0)}, \quad i, j=1, \dots, N, \quad i \neq j,$$

or (15)

$$\epsilon_i^L = -t_i \left[ \frac{\rho_{-i}}{k_i^B} + \frac{\rho_{N+1}}{k_i^{NB}} \right] = -\frac{t_i}{K_i} \quad i=1, \dots, N,$$

where

$k_{ij} \equiv (b_{1i} - b_{1j})^2 v$  if  $b_{1i} > b_{1j}$ , and  $k_{ij} \equiv 0$  otherwise,  $i, j=1, \dots, N+1, \quad i \neq j$  and

$$\begin{aligned}k_i^B &\equiv \left[ \sum_{j \neq i}^N \frac{\rho_j / \sum_{j \neq i}^N \rho_j}{(k_{ij} + \zeta_j - \zeta_i)} \right]^{-1}, & k_i^{NB} &\equiv \left[ \frac{1}{k_{iN+1} + \zeta_{N+1} - \zeta_i + \eta_0} \right]^{-1}, \\ K_i &\equiv \left[ \frac{\rho_{-i}}{k_i^B} + \frac{\rho_{N+1}}{k_i^{NB}} \right]^{-1}, & i &= 1, \dots, N.\end{aligned}\tag{16}$$

<sup>24</sup> The condition of continuous differentiability requires that  $P_i$  be convex.



$k_i^B$  represents the summary measure of bank  $i$ 's differentiation in terms of branches *against rival banks*, and corresponds to a weighted harmonic mean of the price adjusted distances.  $k_i^{NB}$  is the price-adjusted measure of the differentiation *against the nonbank rival*. Finally,  $K_i$ , the overall measure of differentiation, is a combination (weighted harmonic mean) of  $k_i^B$  and  $k_i^{NB}$ , and is increasing in both. Appendix 1 contains the first-order approximations for the bank-specific loan demand functions.

Bank  $i$ 's perceived loan demand curve ( $L_i$ ) is, firstly, the more inelastic (the greater its market power), the larger the values of  $k_i^B$  (and  $k_i^{NB}$ ), which are increasing in  $b_{1i}$ ,  $v$ ,  $\eta_1$  (and  $\eta_0$ ). The elasticity for the bank with the smallest  $b_{1i}$  of the banks is entirely determined by  $k_i^{NB}$ . Secondly, the elasticity is decreasing in absolute value of the differences in utility-adjusted loan rates ( $\zeta_j - \zeta_i$ ), ie increasing in  $t_i$ . Thirdly, the elasticity is increasing in absolute value in rivals' market shares ( $\rho_{-i}$  and  $\rho_{N+1}$ ).<sup>25</sup> Under symmetric industry configurations, the *within* banking industry effects of branch networks cancel out, and each bank's  $1/K$  equals  $\rho_{N+1}/k^{NB}$ .<sup>26</sup>

#### Result 4.

*Analogously to Result 2, the cross-elasticities of bank  $i$ 's perceived loan demand curve ( $> 0$ ) with respect to rivals' loan rates can be written as*

$$\epsilon_{ij}^L \equiv \frac{\partial L_i}{\partial t_j} \frac{t_j}{L_i} = \frac{t_j \rho_j}{(k_{ij} + \zeta_j - \zeta_i)}, \quad i, j = 1, \dots, N, \quad i \neq j, \quad \epsilon_{iN+1}^L = \frac{t_{N+1} \rho_{N+1}}{k_i^{NB}}. \quad (17)$$

Differentiation in terms of branches insulates the loan demand for bank  $i$  from rivals' rates, as does a positive quality advantage vs the nonbank competitor.

The predictions are again in line with the core results from spatial models of banking competition, though the treatment is more general here. There are signs of increasing mobility and decreasing customer loyalty on the part of borrowers as well as depositors, which reduces the significance of the spatial aspect and supports the viewing of competition more broadly among all market participants.

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<sup>25</sup> The perceived loan demand elasticity for the nonbank supplier is decreasing (market power increasing) in absolute value in  $\rho_{N+1}$  and increasing in  $\eta_1$ ,  $\eta_0$  and the size of banks' branch networks.

<sup>26</sup> The elasticity of the aggregate loan demand curve for the banking industry is characterized by  $-[\rho_{N+1}/k^{NB}]$  in the symmetric cases.

## 5 Short-term oligopolistic competition in loan and deposit rates

In the price competition phase (stage two) banks choose the lending and deposit rates to maximize profits, given the delivery capacity from stage one and the number of banks (from stage zero):

$$\begin{aligned} \max_{(t_i, r_i)} \pi_i(i, t_i, t_j, r_i, r_j, \mathbf{b}_i, \mathbf{b}_j, N) = & t_i L_i(t_i, t_j, b_{1i}, b_{1j}, N) + i S_i(L_i, D_i) \\ & - r_i D_i(r_i, r_j, \mathbf{b}_i, \mathbf{b}_j, N) - C_i(L_i, D_i, \mathbf{b}_i) \end{aligned} \quad (18)$$

$$\text{s.t. } S_i \equiv D_i - L_i, \quad i, j = 1, \dots, N, \quad i \neq j.$$

The balance restriction  $S_i$  equals the amount of excess deposits invested in securities that earn a market rate of interest ( $D_i > L_i$ ), or the amount of market funding for excess loans ( $D_i < L_i$ ).

Following the Klein-Monti model (eg Freixas and Rochet, 1997), I assume that banks can exercise market power when setting loan and deposit rates but are too small to influence the money market rate ( $i$ ). In order to keep things tractable in the later stages, I assume that the short-term operating (noninterest) costs ( $C_i(L_i, D_i, \mathbf{b}_i)$ ) are separable by activity (ie  $\partial^2 C / \partial L \partial D = 0$ ) and that the second partial derivatives of the cost function with respect to its arguments are zero. The first assumption implies that economies or diseconomies of scope do not exist and the second that (short-run) marginal operating costs are constant with respect to lending and deposit-taking volumes. Since revenues are concave under the adopted deposit supply and loan demand specifications, there exists a point that maximizes profits for the above cost specifications. The cost functions may be bank-specific.<sup>27</sup>

I first employ the assumption of noncooperative Bertrand conduct in the setting of loan and deposit rates but relax this restriction later on.

### Result 5.

*If banks act as Bertrand competitors treating the loan and deposit rates of other banks as fixed, the Nash equilibrium (unregulated) loan ( $t_i^*$ ) and deposit rates ( $r_i^*$ ) are equal to*

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<sup>27</sup> The marginal operating cost of granting loans ( $c^L$ ) includes an average expected credit risk per unit of incremental loans granted. The marginal operating cost of security investments is assumed to be zero and the reserve requirement is excluded for simplicity.

$$\begin{aligned}
t_i^*(i, c_i^L, \mathbf{b}_i, N+1) &= i + c_i^L + \left[ \frac{\rho_{-i}}{k_i^B} + \frac{\rho_{N+1}}{k_i^{NB}} \right]^{-1} = i + c_i^L + K_i \\
r_i^*(i, c_i^D, \mathbf{b}_i, N+1) &= i - c_i^D - \left[ \frac{\delta_{-i}}{h_i^B} + \frac{\delta_{N+1}}{h_i^{NB}} \right]^{-1} = i - c_i^D - \frac{H_i}{2},
\end{aligned} \tag{19}$$

where

$$c_i^L \equiv \frac{\partial C_i}{\partial L_i} = c_i^L(\mathbf{b}_i), \text{ and } c_i^D \equiv \frac{\partial C_i}{\partial D_i} = c_i^D(\mathbf{b}_i), \quad i, j = 1, \dots, N.$$

PROOF. In Appendix 2. The second order conditions are analysed in section 7.

We see that banks' markups in the loan and deposit markets, over  $(i + c_i^L)$  and  $(i - c_i^D)$ , respectively are the wider, the higher the values of the differentiation measures against other banks and the nonbank rival.<sup>28</sup> Result 5 is in line with vertical differentiation models, in which firms with higher quality can set higher prices.

The *relative markups* or *Lerner indices* of price competition intensity  $((p - C)/p)$ , equal for each bank the inverse of the absolute value of the perceived loan demand or deposit supply elasticities, ie  $K_i/t_i$  or  $H_i/2r_i$ . Therefore, the analysis of markups coincides with the analysis of the perceived elasticities in section 4, and the factors that grant pricing power against other banks can be separated from those that grant pricing power for the banking industry as a whole. When the respective elasticities are infinite, markups vanish and banks act as price takers in the loan and deposit markets. The markups go to zero when  $k_i^B$  and  $k_i^{NB}$ , or  $h_i^B$  and  $h_i^{NB}$ , go to zero.

Table 1 summarizes the key properties of the equilibrium loan and deposit markups in absolute terms.

Table 1. **Effects on equilibrium markups**

|                                      | $(t_i^* - i - c_i^L) = K_i$ | $(i - r_i^* - c_i^D) = H_i/2$ |
|--------------------------------------|-----------------------------|-------------------------------|
| $K_i, k_i^B, k_i^{NB}$               | +, +, +                     | 0, 0, 0                       |
| $H_i, h_i^B, h_i^{NB}$               | 0, 0, 0                     | +, +, +                       |
| $\eta_{11}, \eta_0$                  | +, +                        | 0, 0                          |
| $\gamma_{11}, \gamma_{12}, \gamma_0$ | 0, 0, 0                     | +, +, +                       |
| $v$                                  | +                           | 0                             |
| $\tau_1, \tau_2$                     | 0, 0                        | +, +                          |
| $\rho_{-i}, \rho_{N+1}$              | -, -                        | 0, 0                          |
| $\delta_{-i}, \delta_{N+1}$          | 0, 0                        | -, -                          |
| $N^{1)}$                             | -                           | -                             |

1) If  $\partial \rho_{-i} / \partial N > 0$  or  $\partial \delta_{-i} / \partial N > 0$

<sup>28</sup> When  $L_i > D_i$   $i$  equals banks' marginal cost of funds. When  $L_i < D_i$  banks' marginal cost of funds  $(r_i + c_i^D)$  can be lower than  $i$ , but then  $i$  represents the opportunity return on investment and  $i$  plus  $c_i^L$  is the floor that should be earned from incremental lending.

Banks' loan (deposit) markups go to zero when  $\eta_1$ ,  $\eta_0$  and  $v$  ( $\gamma_{11}$ ,  $\gamma_{12}$ ,  $\gamma_0$ , and  $\tau_1$ ,  $\tau_2$ ) go to zero *simultaneously*. Thus positive marginal utilities derived from 'physical' banking outlets, ie the transport, search or transaction cost savings associated with these outlets, or a positive service quality gap vs nonbanks can alone maintain some pricing power for banks. However, the diffusion of the new delivery technologies likely reduces all these parameters, which generates a permanent structural increase in competition. Expansion in the nonbank's activities has the same effect, as the markups are decreasing in  $\rho_{N+1}$  and  $\delta_{N+1}$  respectively.

**Result 6.**

*Under general cooperative oligopolistic competition, the Nash equilibrium (unregulated) loan ( $t_i^*$ ) and deposit rates ( $r_i^*$ ) are equal to:*

$$t_i^*(i, c_i^L, \mathbf{b}_i, N) = i + c_i^L + \left[ \frac{\rho_{-i}(1-\theta_L)}{k_i^B} + \frac{\rho_{N+1}}{k_i^{NB}} - \theta_L \sum_{j \neq i}^N \frac{\rho_j L_j}{K_j} \right]^{-1} \tag{20a}$$

$$r_i^*(i, c_i^D, \mathbf{b}_i, N) = i - c_i^D - \left[ \frac{\delta_{-i}(1-\theta_D)}{h_i^B} + \frac{\delta_{N+1}}{h_i^{NB}} - \theta_D \sum_{j \neq i}^N \frac{\delta_j D_j}{H_j} \right]^{-1},$$

where<sup>29</sup>

$$\theta_L \equiv \frac{\partial t_j}{\partial t_i}, \theta_D \equiv \frac{\partial r_j}{\partial r_i}, \quad i, j = 1, \dots, N, \quad i \neq j, \quad 0 \leq \theta_L \leq 1, \quad 0 \leq \theta_D \leq 1, \quad \text{and} \tag{20b}$$

$$\frac{\partial t_{N+1}}{\partial t_i}, \quad \frac{\partial r_{N+1}}{\partial r_i} = 0.$$

PROOF. In Appendix 2. The final terms in (20a) stem from the conjectured changes in rivals banks' market shares.

Parameters  $\theta_L$  and  $\theta_D$  identify the full range of different cooperative oligopolistic conduct.  $\theta_L$  and  $\theta_D$  equal to zero is consistent with noncooperative Bertrand-Nash competition in prices (a special case of 20a), when (20a) reduces to the familiar 'elasticity relationship'. In this case any pricing power is due to differentiation which is here captured by the indices  $K$  and  $H$ . Collusive conduct is consistent with  $\theta_L, \theta_D > 0$ , and joint profit maximization, ie monopoly or perfect cartel pricing is associated with  $\theta_L$  and  $\theta_D$  equal to one. In the latter case banks' markups are the widest.<sup>30</sup> Notice that the oligopolistic price conjectures act as if reducing

<sup>29</sup> Oligopolistic price conjectures (strategic coordination terms) are defined equal across all banks following Waterson (1984), and represent thus average conjectures. (20a) is not fully in reduced form as own market shares appear on the right hand side of the equations.

<sup>30</sup> The degree of collusion is given here for the given period of time, and its sustainability to withstand entry, or price changes, is not explicitly analysed. A mere existence of a nonbank rival may prevent banks from engaging in collusion.

the elasticity of the perceived loan demand and deposit supply curves and further widen banks' markups. In the symmetric banking industry configurations ( $\mathbf{b}_i = \mathbf{b}$ ,  $\rho_i = \rho$  and  $\delta_i = \delta$ ,  $i = 1, \dots, N$ ), collusion can widen banks' markups from those defined by  $\rho_{N+1}/k^{NB}$  or  $\delta_{N+1}/h^{NB}$ . We know from oligopoly theory that collusion is the more likely, the more symmetric the firms are.

Since the numbers of branches and ATMs are exogeneous in this second stage of the game, I can state the following proposition given the network decisions from the stage one.

**Proposition 1.a**

*The more asymmetric banks are as regards their branch (branch and ATM) networks, market shares and marginal operating costs, the greater the variance of loan (deposit) rates across banks.*

**Proposition 1.b**

*The greater the utility parameters  $\eta$  and  $v$  ( $\gamma_{11}$ ,  $\gamma_{12}$  and  $\tau_1$ ,  $\tau_2$ ), the greater the variance of loan (deposit) rates across banks under asymmetric industry configurations.*

PROOF. (1.a) In the extreme cases of symmetric banking industry configurations ( $\mathbf{b}_i = \mathbf{b}$ ,  $\rho_i = \rho$  and  $\delta_i = \delta$ ,  $i = 1, \dots, N$ ), all banks have equal markups and the variance of the loan and deposit rates reflects the variance of the marginal operating costs only (which in the model can be due to the differences in credit risk on the lending side). If marginal costs are also the same, the variance of the rates is zero under symmetric configurations. (1.b) holds because the utility parameters produce differences in banks' markups that are increasing in the value of the parameters.

In Finland the average loan and deposit rates have been significantly negatively correlated with branch network sizes, which supports the results given in Table 1. During the periods of deregulation of banks' deposit rates (1989–1991) and loan rates (1986–1990), the variabilities of average deposit rates (Figure 1) and lending rates (Figure 2) naturally increased. Afterwards the variability of the average loan rates has fallen much less visibly (and the variability is higher) than on the deposit side. This suggests that the significance of banks' 'physical' delivery outlets has remained higher on the lending side. Further discussion on the Finnish evidence is left for more careful empirical work.

## 6 Branch and ATM network choices

In stage one banks choose their branch and ATM network size (the number of  $b_1$  and  $b_2$ ) expecting to receive the profits implied by the Nash equilibrium of the price subgame. These capacity choices represent more lasting decisions than the pricing decisions, and affect the loan demands and deposit supplies faced by banks, as well as the intensity of price competition among market participants.

Bank  $i$  chooses  $b_{1i}$  and  $b_{2i}$  to maximize its reduced form profit function:

$$\max_{(b_{1i}, b_{2i})} \pi_i^R(t_i^*(b_{1i}, b_{1j}, N), r_i^*(b_i, b_j, N), b_i, b_j, N) \equiv \pi_i^R(b_i, b_j, N) = \quad (21)$$

$$t_i^*(b_{1i}, b_{1j}, N)L_i + iS_i - r_i^*(b_i, b_j, N)D_i - C_i(L_i, D_i, b_i) - f_i' b_i, \quad i, j = 1, \dots, N, \quad i \neq j,$$

where

$$L_i = L_i(t_i, t_j, b_{1i}, b_{1j}, N)$$

$$D_i = D_i(r_i, r_j, b_i, b_j, N)$$

$$S_i \equiv D_i - L_i.$$

The vector  $f_i = (f_{1i}, f_{2i})$  represents bank-specific sunk costs associated with branch and ATM establishment. Long-run operating costs are thus equal to  $C_i + f_i' b_i$ .

### Result 7.

*The conditions for (unregulated) subgame perfect equilibrium numbers of branches ( $b_{1i}^*$ ) and ATMs ( $b_{2i}^*$ ) reduce to*

$$\begin{aligned} \frac{\partial \pi_i^R}{\partial b_{1i}} = & (1 - \theta_{B1})(t_i^* - i - c_i^L) \frac{\partial L_i}{\partial b_{1i}} \Big|_{k_i^B} + (t_i^* - i - c_i^L) \frac{\partial L_i}{\partial b_{1i}} \Big|_{k_i^{NB}} \\ & + (1 - \theta_{B1})(i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{1i}} \Big|_{h_i^B} + (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{1i}} \Big|_{h_i^{NB}} - \frac{\partial C_i}{\partial b_{1i}} - f_{1i} = 0 \end{aligned} \quad (22a)$$

$$\frac{\partial \pi_i^R}{\partial b_{2i}} = (1 - \theta_{B2})(i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{2i}} \Big|_{h_i^B} + (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{2i}} \Big|_{h_i^{NB}} - \frac{\partial C_i}{\partial b_{2i}} - f_{2i} = 0.$$

*That is, outlets are established up to the point where the above conditions are satisfied. In (22a):*

$$\theta_{B1} \equiv \frac{\partial b_{1j}}{\partial b_{1i}}, \quad \theta_{B2} \equiv \frac{\partial b_{2j}}{\partial b_{2i}}, \quad \forall i, j = 1, \dots, N, \quad i \neq j, \quad 0 \leq \theta_{B1} \leq 1, \quad 0 \leq \theta_{B2} \leq 1, \quad \text{and} \quad (22b)$$

$$\frac{\partial b_{1N+1}}{\partial b_{1i}}, \quad \frac{\partial b_{2N+1}}{\partial b_{2i}} = 0$$

*and the partial derivatives are conditioned on the effects on loan demand and deposit supply through  $k_i^B$  and  $h_i^B$  (competitive effects within the banking sector) and  $k_i^{NB}$  and  $h_i^{NB}$  (competitive effects against the nonbank rivals).*

PROOF. In Appendix 3.<sup>31</sup>

<sup>31</sup> To obtain Result 7, I assume in contrast to Cerasi (1995) that there is no 'cannibalism', ie opening up branches does not steal business from a bank's existing branches. There is a sort of cannibalism however, since setting up ATMs can reduce depositors' valuation of branches ( $\gamma_{11}, \tau_1$ ). The cost benefits of ATMs then need to exceed this loss.

The possibility of oligopolistic coordination in capacity setting is parameterized similarly as for price coordination.  $\theta_{B1}$  or  $\theta_{B2}$  equal to zero signifies perfectly competitive capacity setting, and  $\theta_{B1}$  or  $\theta_{B2}$  equal to one signifies perfect coordination.

I do not analyse why some banks might adopt a branching strategy with less aggressive pricing and some the opposite strategies. Since here all customers have equal 'utility parameters', asymmetric configurations can hence arise only due to differences in the operating cost functions and sunk branch and ATM establishment costs across banks. The lower the marginal effect of outlets on the operating costs or the smaller the associated sunk costs, the more branches or ATMs a bank establishes. As a result of this notion, I can establish a counterpart for Proposition 1.a:

**Proposition 2.**

*The more asymmetric banks are with respect to the marginal cost effects of branch ( $\partial C_i/\partial b_{1i}$ ) or ATM establishment ( $\partial C_i/\partial b_{2i}$ ) or sunk costs of branches ( $f_{1i}$ ) or ATMs ( $f_{2i}$ ), the greater the variance of loan and deposit markups results in the second stage of the game.*

PROOF. Follows from Results 5 or 6 and 7, since asymmetries across banks with respect to numbers of branches and ATMs would generate differences in banks' markups in the loan and deposit markets.

The differences in the cost effects can be due to different output levels, differences in factor prices or internal management efficiency, eg in payment processing.

We see from (22a) that the wider the envisaged markups in the second stage of the game, the more branches or ATMs are established, ie the more pricing power can be realized via branches and ATMs. This is true since,  $\partial L_i/\partial b_{1i}$ ,  $\partial D_i/\partial b_{1i}$ , and  $\partial D_i/\partial b_{2i}$  are always nonnegative.<sup>32</sup> They are also increasing in the underlying utility parameters ( $\eta_1$ ,  $\gamma_{11}$ ,  $v$ ,  $\tau_1$ ) and ( $\gamma_{12}$ ,  $\tau_2$ ) respectively.

We also see that loan or deposit rate regulation, when effective (eg deposit rate ceiling above the free equilibrium rates), widens banks' markups and encourages the setting up of more branches and ATMs as the marginal benefit of capturing new clients is higher than under effective price competition. In fact, a history of extensive regulation of deposit rates has been regarded as the main reason for extensive branch networks in many European countries (Neven 1989, Chiappori et al 1995).

In sum, increasing price competition lowers the optimal numbers of branches and ATMs. This trend is already now observable in many countries eg from the data collected by the BIS on the numbers of branches and in some cases also on the numbers of ATMs, as competition in the banking systems has intensified.

Analysis of the comparative static effects of the underlying utility parameters on the subgame perfect equilibrium numbers of branches and ATMs is quite complex in the general oligopoly case with  $N+1$  firms, asymmetric costs and two capacity variables. Instead, I study the case of a monopoly bank (or perfect capacity collusion) for which the comparative static effects of the model

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<sup>32</sup> The derivatives are zero when establishing outlets does not add to differentiation vs other banks as given by (7).

parameters on the equilibrium capacities can be quantified. These are collected in Table 2, given the cost assumptions reported in section 5. Note that only the stance of the monopoly bank vs the nonbank rivals matters for the comparative static analysis. As shown in Appendix 3, I am able to derive the comparative static expressions in terms of the second differentials of the reduced form profit functions. Thus I am able to sign the expressions with the help of the second order conditions for profit maximum, and I do not need to make any assumptions about the competitive conditions in the second stage of the game.

The monopoly case is illustrative, since we see that whether ATMs raise or reduce the marginal profitability of branches or vice versa determines the cross-effects of the utility parameters. For example, if ATMs reduce the marginal profitability of branches ( $\partial^2 \pi_i / \partial b_1 \partial b_2 < 0$ ), an increase in borrowers' valuations of branches via higher values of  $\eta_1$  or  $v$  would reduce the optimal number of ATMs. As a result of two capacity variables on the deposit side, the comparative static impacts of depositors' utility parameters are generally ambiguous under negative cross effects on marginal profitability, but the impacts will be similar to those on the loan side as long as the direct effects on marginal profitability ( $\partial^2 \pi_i / \partial b_k^2$ ) ( $k = 1, 2$ ) exceed the cross effects on marginal profitability (Appendix 3). When this holds, the comparative static effect of  $\tau_1$  on  $b_1^*$  is always positive, for example. Hence, a structural decline in the utility parameters related to branches ( $\eta_1, \gamma_{11}, v, \tau_1$ ) and ATMs ( $\gamma_{12}, \tau_2$ ) would reduce the optimal numbers of branches and ATMs via increasing price competition.

A note of caution is in place when generalizing these results, since in the general oligopoly case we might encounter ambiguities that do not show up in the comparative static analysis for the monopoly.

Table 2. **Signs of comparative static effects on subgame perfect equilibrium  $b_1^*$  and  $b_2^*$  of a monopoly bank (or perfect capacity collusion)**

|                            | $b_1^*$  |  | $b_2^*$  |  |
|----------------------------|--|--|--|--|
|                            | $\partial^2 \pi_i / \partial b_1 \partial b_2 < 0$ | $\partial^2 \pi_i / \partial b_1 \partial b_2 > 0$ | $\partial^2 \pi_i / \partial b_1 \partial b_2 < 0$ | $\partial^2 \pi_i / \partial b_1 \partial b_2 > 0$ |
| $\eta_1, v$                | +, +   | +, +   | -, -   | +, +   |
| $\gamma_{11}, \gamma_{12}$ | ?, ?   | +, +   | ?, ?   | +, +   |
| $\tau_1, \tau_2$           | ?, ?   | +, +   | ?, ?   | +, +   |
| $\eta_0$                   | +  | +  | -  | +  |
| $\gamma_0$                 | ?  | +  | ?  | +  |

Let me next turn to the analysis of various cooperative arrangements.

### Proposition 3.a

*Noncooperative capacity decisions ( $\theta_{B1}$  or  $\theta_{B2} = 0$ ) leads to the highest numbers of branches or ATMs and capacity collusion ( $\theta_{B1}$  or  $\theta_{B2} > 0$ ) always reduces the scope of banks' branch or ATM networks, ceteris paribus.*



### 3.b

*Of the various collusive arrangements, semi-collusion in interest rates only ( $\theta_L$  or  $\theta_D > 0$  and  $\theta_{B1}$  or  $\theta_{B2} = 0$ ) generates the largest branch and ATM networks; double-collusion in both rates and delivery capacities ( $\theta_L$  or  $\theta_D > 0$  and  $\theta_{B1}$  or  $\theta_{B2} > 0$ ) produces an intermediate result; and semi-collusion in capacities only ( $\theta_L$  or  $\theta_D = 0$ , and  $\theta_{B1}$  or  $\theta_{B2} > 0$ ) generates the smallest branch and ATM networks.<sup>33</sup>*

PROOF. Follows from Results 6 and 7.

Establishment of branches and ATMs by one bank reduces the profits of the others, given their prices. In cooperative capacity setting, this effect is internalized or banks expect their rivals to match their establishment decisions, and a bank cannot gain market power. The branch and ATM networks of each bank are therefore smaller than under effective capacity competition.<sup>34</sup> Proposition 3.b reflects the general result that effective price competition reduces the optimal numbers of branches and ATMs, and collusion in prices intensifies competition in nonprice terms.

In Finland, banks set up a joint firm to manage a fully compatible cash dispenser network in 1994. This led to a reduction in the overall number of ATMs by 15 per cent in the first year and by an additional 5 per cent in the second year after the agreement, which is in line with Proposition 3.a.

### Proposition 4.

*Capacity collusion leads to a decrease in banks' markups in lending and deposit taking over the money market rate and the respective marginal operating costs in the price setting subgame, ceteris paribus.*

PROOF. If there is perfect capacity collusion ( $\theta_{B1}$  or  $\theta_{B2} = 1$ ), branches or ATMs are extended by the Result 7 up to the point where the marginal benefit due to increasing competitive advantage *vs nonbank rivals*,  $(\partial k_i^{NB}/\partial b_{ii})$  or  $(\partial h_i^{NB}/\partial b_i)$ , equals the respective net increase in costs,  $\partial C_i/\partial b_i + f_i$ . If capacity collusion is imperfect ( $0 \leq \theta_{B1}$  or  $\theta_{B2} < 1$ ), more branches and ATMs will be established than stipulated by the above conditions, since banks would strive to realize differentiation benefits *vs other banks* through  $(\partial k_i^B/\partial b_i)$  or  $(\partial h_i^B/\partial b_i)$  and loan and deposit markups would rise by Results 5 or 6, since  $k_i^B$  or  $h_i^B$  and also  $k_i^{NB}$  or  $h_i^{NB}$  would increase.

Note that  $\partial C_i/\partial b_i$  contains the direct marginal cost effect of branches,  $\partial C_i/\partial b_i$ , and indirect effects through the impact on marginal operating costs of loans and deposit services. Hence possible reductions in the marginal operating costs of

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<sup>33</sup> Semi-and double collusion in prices and capacities has been studied in general terms by Fershtman and Gandal (1994), and propositions 3.a and 3.b reflect their general results. Also Matsui (1989) shows how cartel pricing may lead to larger capital investments.

<sup>34</sup> One can also conclude that capacity reductions are realized the more rapidly, the more widespread and common across the banking industry a reduction in underlying profitability and ensuing overcapacity problem. This corresponds to the situation in Finland in the mid-1990s. When some banks expand and some face rationalization pressure, collusion is less likely and capacity reductions are more sluggish.

loans ( $\partial c_i^L / \partial b_{ii}$ ) or deposit services ( $\partial c_i^D / \partial b_i$ ) through branch and ATM establishment add to the benefits of the outlets on the revenue side. Branches could lower the average cost of loans due to more careful credit risk evaluation and monitoring possibilities, while ATMs should reduce the average cost of deposit services due to the savings in labour costs and greater potential for scale economies in electronic processing of payments. Moreover, capacity collusion lowers loan rates and increases deposit rates if the reductions in banks' pricing power through lower  $k$ 's and  $h$ 's exceed the (possible) reductions in the respective marginal operating costs.

Compatibility of ATM networks lowers banks  $h_i^B$ 's, as they cannot appropriate the benefits of their own proprietary ATM networks *vs other banks* (Matutes and Padilla 1994). In the case of full compatibility, the part in  $h_i^B$  generated by the  $b_{2i}$ 's vanishes.<sup>35</sup> However, there is an increase in the competitive advantage *vs the external competitor* (which is increasing in  $\tau_2$  and  $\gamma_{12}$ ), which could be substantial, especially for small banks. These benefits plus the associated cost savings from overlapping functions and realization of the scale economies of automated transactions (lower average costs) should be large enough to compensate for the loss in the pricing advantage against other banks. After a competitive start, ATM compatibility arrangements have become quite typical in Europe (Vesala 1995), which suggests that the benefits have outweighed the competitive losses.

**Proposition 5.**

*Full compatibility of all banks' ATMs has the same effect on ATM establishment as perfect capacity collusion in ATMs ( $\theta_{B2} = 1$ ), since competition among banks in ATMs disappears. The resulting number of ATMs is higher under full compatibility in the case there is no compatibility in the collusive case.*

PROOF. Full compatibility means that  $\partial D_i / \partial b_{2i} | h_i^B = 0$ ,  $i = 1, \dots, N$  (within banking sector effects vanish), which has the same effect on the equilibrium conditions (22a) as  $\theta_{B2} = 1$ . The latter part of 5 holds, because  $\partial D_i / \partial b_{2i} | h_i^{NB}$  increases under compatibility agreements.

Under full compatibility, ATMs are set up to the point that the marginal benefit due to the enhanced competitive standing *vs the nonbank rival* is offset by the marginal (net) effect on the operating cost of deposit services plus the sunk ATM establishment cost. Section 8 discusses the impact of ATM compatibility on banks' pricing and the related competition policy issues.<sup>36</sup>

Small banks can, under compatibility arrangements, compete on a more equal footing with larger ones that are themselves able to provide a wide network and realize the related competitive and cost benefits. Hence the benefits from ATM compatibility are asymmetric across banks of different sizes, and large banks are

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<sup>35</sup> In the case of full ATM compatibility,  $b_{2i} = \sum_j^N b_{2j} \forall i$ . In this case all banks' ATMs are interconnected. Partial compatibility could also be parameterized in the model. I do not analyse possible free riding effects on ATM establishment under compatibility arrangements.

<sup>36</sup> In Finland the compatibility agreements effected in the late 1980s had a visible effect of slowing down the growth in the total number of cash dispensing ATMs.

less apt to enter into compatibility arrangements. Of course, the appropriation of benefits is an 'internal' pricing issue, but satisfying solutions for large banks might be hard to obtain. In Finland the largest bank recently decided to disconnect its payment transfer ATMs from the common network.

## 7 Policy issues (I): monetary policy transmission and deregulation of deposit rates

I approach the two policy issues of this section by analysing the short run equilibrium conditions of the model that appear in section 5. Decisions on the numbers of branches and ATMs are thus exogenous in this analysis.

### 7.1 Transmission of money market rates into loan and deposit rates

Rotemberg and Saloner (1987) offer an explanation for the often observed phenomenon of greater price rigidity in a monopoly than an oligopoly with respect to changes in marginal production cost. Their explanation is partly based on the proposition that firms' incentives to alter prices in response to changes in marginal cost increase with the price elasticity of their perceived demand curves.

This issue is analogous to the question of banks changing their rates on new lending and deposits in response to changes in the money market rate, ie the efficiency of monetary policy transmission, as the stance of monetary policy is reflected in the money market rate. Hannan and Berger (1989 and 1991) apply Rotemberg and Saloner's methodology in an empirical study of the pass-through of changes in the money market rate into banks' deposit rates. Their analysis is based on linear deposit supply functions and does not include the loan market. Neither do they examine explicitly oligopoly equilibria, which are driven by the *strategic substitutability* or *complementarity* of oligopolists' products, as shown by Bulow et al (1985).

I summarize the reaction functions of the rivals of bank  $i$ , as in Dixit (1986), as a single aggregate reaction function which defines the optimal reaction of the rivals to a change in bank  $i$ 's loan and deposit rates.<sup>37</sup> Otherwise, full solution of the following problems would require solving a system of  $(N+1)(N+1)$  equations, which is not manageable with product heterogeneity. As detailed in Bulow et al (1985), the slopes of the aggregate reaction functions are determined by  $(g_{-i}^L \equiv \partial^2 \pi_{-i} / \partial t_{-i} \partial t_i)$  and  $(g_{-i}^D \equiv \partial^2 \pi_{-i} / \partial r_{-i} \partial r_i)$  for the loan and deposit rates respectively. The slopes of bank  $i$ 's reaction functions are in turn determined by  $(g_i^L \equiv \partial^2 \pi_i / \partial t_i \partial t_{-i})$  and  $(g_i^D \equiv \partial^2 \pi_i / \partial r_i \partial r_{-i})$ . When these quantities are positive, strategic complements are in question, and the reaction curves are upward sloping.

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<sup>37</sup> Dixit uses this procedure to obtain comparative static results for a general oligopoly model that is capable of handling all the usual equilibrium concepts.

The usual presumption for price competition is that oligopolists regard their products as *strategic complements*: when an oligopolist lowers or raises its prices, its competitors match these decisions in adjusting their own prices. Strategic complementarity *always* obtains under my demand and cost specifications, since Bulow et al (1985) show that with constant marginal cost (with respect to the strategic variable in question) this holds if an increase in rivals' prices lowers the elasticity of firms' perceived demand curves. We see from Result 3 that the absolute value of the perceived loan demand elasticity of bank  $i$  falls with an increase in rivals' loan rates and, from Result 1, that the value of the perceived deposit supply elasticity decreases with a reduction in rivals' deposit rates.

Following Rotemberg and Saloner (1987) and Berger and Hannan (1989, 1991) incentives of bank  $i$  to change loan and deposit rates in response to a change in the money market rate depend on the gross profit gain that results from these decisions.<sup>38</sup> Changing loan or deposit rates always involves some costs, and banks compare the gross gains to these costs. Then, the actual changing of the loan or deposit rates is the more likely, the greater the gross gains, which are equal to the amounts by which overall profit would deviate from the new optimum if the rates remained unchanged. The costs of changing loan and deposit rates include the costs associated with customer information (menu costs) and with the possible violation of the implicit or explicit contracts between banks and their customers (Hannan and Berger 1991). Moreover, the sustainability of the new level of the money market rate may be uncertain, which would cause banks to be hesitant in changing their loan rates in order to avoid negative customer reactions (hysteresis phenomenon).

The loss in profits of bank  $i$  if it does not change its loan and deposit rates after an unexpected change in the money market rate can be roughly approximated by a Taylor series approximation at the old optimum ( $t_i^*$  and  $r_i^*$ ):

$$\begin{aligned} \pi_i(t_i) - \pi_i(t_i^*) &\approx \left( \frac{d\pi(t_i^*)}{dt_i} \right) (\Delta t_i) + \frac{1}{2} \left( \frac{d^2\pi_i(t_i^*)}{dt_i^2} \right) (\Delta t_i)^2, \quad \Delta t_i = t_i - t_i^* \\ \pi_i(r_i) - \pi_i(r_i^*) &\approx \left( \frac{d\pi(r_i^*)}{dr_i} \right) (\Delta r_i) + \frac{1}{2} \left( \frac{d^2\pi_i(r_i^*)}{dr_i^2} \right) (\Delta r_i)^2, \quad \Delta r_i = r_i - r_i^*. \end{aligned} \quad (23)$$

The first terms in the series are zero due to profit maximization (envelope theorem). The gross gains from changing the loan and deposit rates are equal to the negatives of the foregone profits, which are positive by the second order conditions for profit maximization:

$$G_i^t \approx -\frac{1}{2} \left( \frac{d^2\pi_i(t_i^*)}{dt_i^2} \right) (\Delta t_i)^2 > 0, \quad G_i^r \approx -\frac{1}{2} \left( \frac{d^2\pi_i(r_i^*)}{dr_i^2} \right) (\Delta r_i)^2 > 0. \quad (24)$$

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<sup>38</sup> When Rotemberg and Saloner contrast monopoly with duopoly, they find basically that price changes are more attractive to a duopolist because some of the benefits thereof are derived at the expense of the competitor, which enhances the positive profit effect.

Expressing the gross gains in terms of the money market rate change produces the following expression:

$$G_i^t \approx -\frac{1}{2} \left( \frac{dt_i}{di} \right)^2 \left( \frac{d^2 \pi_i(t_i^*)}{dt_i^2} \right) (\Delta i)^2, \quad (25)$$

$$G_i^r \approx -\frac{1}{2} \left( \frac{dr_i}{di} \right)^2 \left( \frac{d^2 \pi_i(r_i^*)}{dr_i^2} \right) (\Delta i)^2, \quad i=1, \dots, N+1.$$

Analysis of the second stage oligopoly equilibrium produces the ensuing results:

**Result 8.a**

*The following holds for the sizes of the reactions of the equilibrium loan ( $dt/di$ ) and deposit rates ( $dr/di$ ) with respect to a change in the money market rate:*

$$\frac{dt_i}{di} = \frac{\frac{d^2 \pi_i}{dt_i di} \left[ -\Omega_1 + \frac{g_i^L \Omega_2}{d^2 \pi_i} \right]}{\frac{d^2 \pi_i}{dt_i^2} \left[ \Omega_1 + \frac{g_i^L \Omega_3}{d^2 \pi_i} \right]}, \quad \frac{dr_i}{di} = \frac{\frac{d^2 \pi_i}{dr_i di} \left[ -\Omega_4 + \frac{g_i^D \Omega_5}{d^2 \pi_i} \right]}{\frac{d^2 \pi_i}{dr_i^2} \left[ \Omega_4 + \frac{g_i^D \Omega_6}{d^2 \pi_i} \right]}, \quad i=1, \dots, N+1, \quad i \neq j \quad (26)$$

**8.b**

*The following approximate expressions result for the gross gains of changing loan rates ( $G^t$ ) and deposit rates ( $G^r$ ):*

$$\begin{aligned}
G_i^t &\approx \frac{1}{2} \frac{\left( \frac{d^2\pi_i}{dt_i di} \right)^2 \left[ -\Omega_1 + \frac{g_i^L \Omega_2}{\frac{d^2\pi_i}{dt_i di}} \right]^2}{\left( \frac{d^2\pi_i}{dt_i^2} \right) \left[ \Omega_1 + \frac{g_i^L \Omega_3}{\frac{d^2\pi_i}{dt_i^2}} \right]^2} (\Delta i)^2 > 0, \\
G_i^r &\approx \frac{1}{2} \frac{\left( \frac{d^2\pi_i}{dr_i di} \right)^2 \left[ -\Omega_4 + \frac{g_i^D \Omega_5}{\frac{d^2\pi_i}{dr_i di}} \right]^2}{\left( \frac{d^2\pi_i}{dr_i^2} \right) \left[ \Omega_4 + \frac{g_i^D \Omega_6}{\frac{d^2\pi_i}{dr_i^2}} \right]^2} (\Delta i)^2 > 0,
\end{aligned} \tag{27}$$

where  $\Omega_1, \Omega_2, \Omega_3, \Omega_4, \Omega_5$  and  $\Omega_6 < 0$ .

PROOF. 8.a: in Appendix 4. 8.b results from 8.a after applying (25).

In Results 8.a and b, the quantities  $\Omega_1 - \Omega_6$  are negative under strategic complementarity because of the second order conditions for profit maximum and stability conditions for the loan and deposit market equilibria (see Appendix 4).

### Result 9.

*Given the assumptions for the operating cost function, the following holds for the quantities that determine the sizes of the reactions of the loan and deposit rates, and the respective gross profit gains, with respect to an increase in the money market rate.*

$$\begin{aligned}
\frac{d^2\pi_i}{dt_i di} &= -\frac{dL_i}{dt_i} = -(1-\theta_L) \frac{\partial L_i}{\partial t_i}, \\
\frac{d^2\pi_i}{dr_i di} &= \frac{dD_i}{dr_i} = (1-\theta_D) \frac{\partial D_i}{\partial r_i}, \\
\frac{d^2\pi_i}{dt_i^2} &= 2 \frac{dL_i}{dt_i} + (t_i^* - i - c_i^L) \frac{d^2L_i}{dt_i^2} = 2(1-\theta_L) \frac{\partial L_i}{\partial t_i} + (1-\theta_L)^2 (t_i^* - i - c_i^L) \frac{\partial^2 L_i}{\partial t_i^2}, \\
\frac{d^2\pi_i}{dr_i^2} &= -2 \frac{dD_i}{dr_i} + (i - r_i^* - c_i^D) \frac{d^2D_i}{dr_i^2} = -2(1-\theta_D) \frac{\partial D_i}{\partial r_i} + (1-\theta_D)^2 (i - r_i^* - c_i^D) \frac{\partial^2 D_i}{\partial r_i^2}.
\end{aligned} \tag{28}$$

PROOF. In Appendix 4.

These are also the only quantities that depend on bank  $i$ 's differentiation measures. A fully closed form solution for the above differentials and hence for the gross profit gains exists only for symmetric banking industry configurations, where the within banking industry effects cancel out:

**Result 10.**

*The following holds for symmetric banking industry configurations ( $b_i = b$ ,  $\rho_i = \rho$  and  $\delta_i = \delta$ ,  $i = 1, \dots, N$ ):*

$$(G_i^L)^{1/2} \approx (\Omega_0^L)^{1/2} \left( \frac{L_i}{k_i^{NB}} \right)^{1/2} \left[ \frac{-\Omega_1 + \frac{g_i^L \Omega_2}{(1-\theta_L) \frac{L_i}{k_i^{NB}} \rho_{N+1}}}{\Omega_1 - \frac{g_i^L \Omega_3}{(1-\theta_L)^2 \frac{L_i}{k_i^{NB}} \rho_{N+1} \left( \frac{2}{1-\theta_L} + \frac{1}{\rho_{N+1}} - 1 \right)}} \right] (\Delta i), \quad (29a)$$

$$(G_i^D)^{1/2} \approx (\Omega_0^D)^{1/2} \left( \frac{2D_i}{h_i^{NB}} \right)^{1/2} \left[ \frac{-\Omega_4 + \frac{g_i^D \Omega_5}{(1-\theta_D) \frac{2D_i}{h_i^{NB}} \delta_{N+1}}}{\Omega_4 - \frac{g_i^D \Omega_6}{(1-\theta_D)^2 \frac{2D_i}{h_i^{NB}} \delta_{N+1} \left( \frac{2}{1-\theta_D} + \frac{1}{2\delta_{N+1}} - 1 \right)}} \right] (\Delta i),$$

where  $\Omega_1, \Omega_2, \Omega_3, \Omega_4, \Omega_5$  and  $\Omega_6 < 0$ ,  $i = 1, \dots, N$ .

*The multipliers take the following forms:*

$$\Omega_0^L \equiv \frac{1}{2} \left( \frac{\rho_{N+1}}{\frac{2}{1-\theta_L} + \frac{1}{\rho_{N+1}} - 1} \right) \quad \text{and} \quad \Omega_0^D \equiv \frac{1}{2} \left( \frac{\delta_{N+1}}{\frac{2}{1-\theta_D} + \frac{1}{2\delta_{N+1}} - 1} \right) \quad (29b)$$

PROOF. Follows from Results 8.b and 9 after calculating the partial derivatives given in Result 9 (see Appendix 4). The noncooperative Bertrand case can be obtained by setting  $\theta_L$  and  $\theta_D$  equal to zero.<sup>39</sup>

Table 3 collects the effects of the model variables and parameters on the gross profit gains under strategic complementarity and symmetric banking industry configurations, given the assumptions for the operating cost function (section 5).

<sup>39</sup> Note that the cases of perfect collusion in loan and deposit markets are not nicely behaved in the above formulations and so must be studied separately.

Table 3.

**Effects on the incentives to change loan and deposit rates (gross profit gains) under strategic complementarity and symmetric banking industry configurations**

|                                      | $G_i^l$   | $G_i^d$   |
|--------------------------------------|-----------|-----------|
| $k_i^{NB}, h_i^{NB}$                 | $-, 0$    | $0, -$    |
| $\eta_1, \eta_0$                     | $-, -$    | $0, 0$    |
| $\gamma_{11}, \gamma_{12}, \gamma_0$ | $0, 0, 0$ | $-, -, -$ |
| $v, \tau_1, \tau_2$                  | $-, 0, 0$ | $0, -, -$ |
| $\rho_{N+1}, \delta_{N+1}$           | $+, 0$    | $0, +$    |
| $\theta_L, \theta_D$                 | $-, 0$    | $0, -$    |
| $g_i^L, g_i^D$                       | $-, 0$    | $0, -$    |

Given strategic complementarity ( $g_i^L$  and  $g_i^D > 0$ ), Result 10 allows me to conclude definitely that banks' incentives to change loan and deposit rates are always the greater, the smaller their market power since ( $G_i^l$ ) and ( $G_i^d$ ) are always decreasing in  $k_i^{NB}$  and  $h_i^{NB}$ . The gross gains reach their maximum when the differentiation indices approach zero. In addition, collusion in the setting of loan and deposit rates increases the stickiness of banks' loan and deposit rates, while an increase in nonbank market share reduces it.

Although closed form solutions are not obtainable for the second derivatives given under Result 9 in the general cases of asymmetric banking industry configurations, the derivatives behave similarly as regards  $K_i$  and  $H_i$ , as established with respect to  $k_i^{NB}$  and  $h_i^{NB}$ . This is true since

$$\frac{\partial^2 L_i}{\partial t_i^2} = \frac{\frac{L_i}{K_i} + \frac{\partial}{\partial t_i}(K_i)}{K_i^2} \quad \text{and} \quad \frac{\partial^2 D_i}{\partial r_i^2} = \frac{2 \frac{D_i}{H_i} - \frac{\partial}{\partial r_i}(H_i)}{H_i^2}, \quad (30)$$

which are decreasing in  $K_i$  and  $H_i$ . The first derivatives are clear by the Results 1 and 3. Hence, the more banks are differentiated vs rival banks, the less incentive they have to change loan and deposit rates, and thus banks' loan and deposit rates become more sticky with respect to changes in the money market rate.

We see from Results 8.a and b that all factors that increase the loss in profit of not changing the loan and deposit rates also increase the size of the pass-through of a money market rate change to banks' loan and deposit rates. Thus the effects given in Table 3 hold also for  $dt_i/di$  and  $dr_i/di$  (Exhibit 1).

Drawing on the analysis in this section, I can state the following proposition:

**Proposition 6.a** (*Efficiency of monetary policy transmission*)

*The reaction of the lending rates is always the larger and the more likely in response to a change in the money market rate:*

- *the less banks are differentiated in terms of their branch networks from rival banks ( $k_i^B$ ) and the nonbank supplier of credit ( $k_i^{NB}$ ),*



- *the smaller the borrowers' marginal utility of branches ( $\eta_1$ ) and utility loss of imperfect accessibility to branches ( $\nu$ ),*
- *the smaller the quality difference of banks' credit-related services vs those of the nonbank suppliers of credit ( $\eta_0$ )*
- *the greater the market share of the nonbank suppliers of credit ( $\rho_{N+1}$ ),*

## 6.b

*The reaction of the deposit rates is always the larger and the more likely in response to a change in the money market rate:*

- *the less banks are differentiated in terms of their branch and ATM networks from rival banks ( $h_i^B$ ) and the nonbank supplier of deposit-related services ( $h_i^{NB}$ ),*
- *the smaller the depositors' marginal utilities of branches ( $\gamma_{11}$ ) and ATMs ( $\gamma_{12}$ ) and the respective utility losses of imperfect accessibility to branches and ATMs ( $\tau_1$  and  $\tau_2$ ),*
- *the smaller the quality difference of banks' deposit-related services vs those of the nonbank suppliers of deposit services ( $\gamma_0$ )*
- *the greater the market share of nonbank suppliers of deposit-related services ( $\delta_{N+1}$ ),*

PROOF. Follows from Result 8.a, b and 10 and the ensuing analysis.

Rotemberg and Saloner's (1987) observation that the perceived demand elasticities determine the size of the price reaction is essentially established here also. All factors that increase the elasticities of the perceived loan demand and deposit supply schedules also increase the sensitivities of the loan and deposit rates with respect to money market rate changes.<sup>40</sup> Collusion in price setting increases the rigidity of loan and deposit rates, because it acts as if reducing the perceived elasticity of loan demand or deposit supply. Technological change in banking is apt to increase the pass-throughs structurally and hence enhance the

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<sup>40</sup> Hannan and Berger (1991) find that banks in more concentrated local markets exhibit greater deposit rate rigidity. Cottarelli and Kourelis (1994) find evidence that in international comparison weak transmission of monetary policy can be explained by imperfect competition, which they measure by banking concentration and capital market development.

efficiency of the monetary policy transmission, as it reduces the marginal utility of physical banking outlets and the utility losses related to imperfect accessibility.<sup>41</sup>

Differences across banking systems in the future euro area as to how large the pass-throughs of money market rate changes into banks' lending rates will be would produce complications for the conduct of single monetary policy. The effects of monetary policy easing on output and investment, for example, would differ across countries. There is evidence that the pass-throughs are significantly different across European countries (Cottarelli and Kourelis 1994, Dornbusch et al 1998). According to the above results, technological development in banking would enhance the pass-through of monetary policy changes in the lending rates and could produce convergence in the effects of the single monetary policy in different countries. Enhanced integration of European credit markets due to EMU would also have the same consequence to the extent that competition increases in the euro area. Similarly, increased use of the capital market in firms' funding (ie more nonbank competition) would make the monetary policy transmission more effective. The disadvantage is that changing conditions in the credit markets produce new uncertainties for monetary policymaking. Ongoing monitoring of the issue would thus be needed.

The stickiness of the loan and deposit rates means that loan margins should narrow and deposit margins widen when the money market rate rises. Figure 3 depicts the development of Finnish banks' average margins over the money market rate in lending and deposit taking and demonstrates quite clearly the stickiness of their loan and deposit rates.

Allowing for economies or diseconomies of scale would cause intractability in the general oligopoly case. Nevertheless, it can be shown that a monopoly bank would less likely react to a change in a money market rate by changing its loan and deposit rates, under significant economies of scope. Increasing eg the loan rate would lower the marginal profitability of deposit taking, and this would result in a smaller change in the loan rate. This result likely carries over to the oligopoly situation, given the analysis of Bulow et al (1985).<sup>42</sup>

Because the perceived loan demand (deposit supply) curve is downward sloping (upward sloping) ie  $L' < 0$  ( $D' > 0$ ), loan (deposit) rates should be stickier

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<sup>41</sup> To the extent the lending rates follow long-term market rates, incomplete pass-through of the short-term market rates to the long-term rates can also result in incomplete transmission into banks' lending rates. Moreover, fixed rate loans, or discrete adjustment of the variable rate loans causes additional stickiness in the average rates on banks' loan stocks independent of banks' pricing policies. In Finland the use of short-term market rates and banks own prime rates as reference rates in lending has continually increased. This should in principle increase the pass-through of the market rates, but prime rates can still be adjusted imperfectly and banks can absorb changes in money market rates in their margin over the market reference rate, according to the model predictions. Also banks' choices of the reference rates can be thought of resulting from the competitive conditions as described here.

<sup>42</sup> Lending and deposit taking are likely to exhibit scope economies. For example, the information from deposit customers can be reused when granting loans, which results in lower credit risk to the extent depositors are also lenders. Moreover, the same branches and employees can service loan and deposit customers. Empirical evidence also points to the existence of the economies of scope between loans and deposits (eg Humphrey and Pulley 1993). However, the recent emergence of specialized banks and nonbanks, new delivery technologies and unbundling of many financial services could indicate that the economies of scope have lost some of their significance.

upward (downward) than downward (upward), *ceteris paribus*. However, the asymmetric reaction may be due to many other factors that can work in the other direction, and thus the question of asymmetric reactions becomes primarily an empirical issue. For instance, the breakdown of collusive arrangements is more likely in the case of price decreases, which reduce the incentive to lower loan rates or raise deposit rates, while customer reactions would be more negative in the case of rate increases, which increase the costs of raising loan rates or lowering deposit rates.

## 7.2 Implications of further deregulation of deposit rates

The analysis of the past section can be used to yield direct implications for the issue of this section as well:

### Result 11.

*The following holds for the size of the reaction of the equilibrium loan rates to changes in the deposit rates:*

$$\frac{dt_i}{dr_i} = \frac{\frac{dt_i}{di}}{\frac{dr_i}{di}} = \frac{\frac{d^2\pi_i}{dt_i di} \left[ -\Omega_1 + \frac{g_i^L \Omega_2}{\frac{d^2\pi_i}{dt_i di}} \right]}{\frac{d^2\pi_i}{dt_i^2} \left[ \Omega_1 + \frac{g_i^L \Omega_3}{\frac{d^2\pi_i}{dt_i^2}} \right]} \frac{\frac{d^2\pi_i}{dr_i^2} \left[ \Omega_4 + \frac{g_i^D \Omega_6}{\frac{d^2\pi_i}{dr_i^2}} \right]}{\frac{d^2\pi_i}{dr_i di} \left[ -\Omega_4 + \frac{g_i^D \Omega_5}{\frac{d^2\pi_i}{dr_i di}} \right]}, \quad (31)$$

where  $\Omega_1, \Omega_2, \Omega_3, \Omega_4, \Omega_5$  and  $\Omega_6 < 0, i = 1, \dots, N+1, i \neq j$ .

PROOF. Follows from result 8.a.

We see that all factors that increase  $dt_i/di$  increase  $dt_i/dr_i$ , while all factors that increase  $dr_i/di$  reduce  $dt_i/dr_i$ . Hence an increase in price competition in the loan market due to a fall in banks' differentiation as regards their branch networks or due to an increase in nonbank market share, would increase the reaction of the loan rates to changes in the deposit rate. These kind of developments in the deposit market would have opposite effects.

Then, given strategic complementarity the following proposition obtains:

### Proposition 7.a

*If technological transformation proceeds faster in the deposit than loan market, ie  $H_i$  falls faster than  $K_i$  due to reductions in the respective utility parameters, the loan rates turn relatively more sticky than the deposit rates as regards the money market rate changes, and*

## 7.b

*Banks' loan rates become more unresponsive to deposit rate changes, ie  $dt/dr_i$  declines.*

## 7.c

*Faster nonbank expansion in the deposit than loan market has the same effects.*

PROOF. Follows from Results 8.a, b and 10.

This implies that if this trend strengthens or persists, banks' overall interest margins would become more and more variable and money market rate rises would result in an increasingly adverse impact on banks' overall profitability. This is since the loan rates would become relatively more insensitive with respect to money market rate changes than the deposit rates, and any deposit rate increases would have a smaller impact on the optimal loan rates.

If deposit rates are by regulation below what would obtain under free competition, deregulation would reduce banks' deposit margins and thus have an effect analogous to a decrease in the  $H_i$ 's. Thus deregulation by itself would make loan rates more insulated from the changes in deposit rates.

Even though banking deregulation has proceeded far, some controls particularly on demand deposit rates remain in many countries. In Finland there are still limits on the interest rates that can be earned free of tax on interest income, regardless the type of deposit accounts. These limits reduce the interest cost of banks at least by the amount of the tax benefit to customers. Abolition of these allowances would raise banks' deposit rates, because depositors would require compensation for the tax they need to pay. An apparent increase in deposit market competition due to fast expansion of remote banking possibilities and substitutes for traditional bank accounts would thus lower the future impact of the deregulation of tax allowances on bank lending rates. In the case of continuously more extensive technological advances on the deposit than lending side, further deregulation of banks' deposit rate setting would have a smaller and smaller impact on loan rates, and the repercussions on banks' borrowers would become more and more favourable.

As shown by Chiappori et al (1995), loan rates may be cross-subsidized from the deposit margin when deposit rates are regulated, and abolition of this practice after deregulation would result in an increase in the loan rates. When controls on deposit rates are effected through tax exemption allowances, as in Finland, banks' cross-subsidization possibilities would be significantly lower than under definite deposit rate ceilings, since rivals are able to attract depositors with higher, but taxable, deposit rate offerings.<sup>43</sup>

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<sup>43</sup> In Chiappori et al (1995), cross-subsidization emerges in equilibrium when tying-up of borrowers as depositors with the lending bank is allowed in their model. Such tying can only emerge when deposit rates are regulated, because otherwise customers can be attracted with more favourable competing interest rate offerings.

## 8 Policy issues (II): implications for competition policy

Unless banks are able to regain market power through differentiating in some novel service quality aspects, competition will increase considerably due to the emergence of new electronic delivery technologies *even without new entry*. As shown in Table 1, a structural decline in banks' markups in loan (deposit) markets would follow a decline in borrowers' (depositors') marginal utility of branches (branches and ATMs) and the utility loss via imperfect accessibility to branches (branches and ATMs) associated with the technological transformation. The expansion in nonbank competitors' activities has the same adverse effect on banks' markups.

Technological change certainly provides new possibilities for *product innovation* and for obtaining a solid customer base. However, the possibilities for regaining market power seem quite limited, since retail banks seem to be developing their services in quite the same directions, and the competitive threat from outside the traditional banking industry is increasing in importance. Barriers to entry generated by regulation have also significantly receded due to widespread deregulation and opening up of international competition (European single market and EMU). As a result, the possibilities for collusive conduct have diminished. The outlook is that banks will increasingly attract customers through price competition and thus allow customers to participate in cost savings due to technological advancements in banking.

The fact that banks' profits have usually derived mainly from retail banking suggests that they have indeed been able to capture rents in these activities. X-inefficiency is usually found to vary considerably across banks in many countries, which also constitutes a sign of imperfect competition.<sup>44</sup> The pro-competitive effects of technological transformation and nonbank competition are probably strongest in the area of private retail deposit customers in which banks' have traditionally enjoyed the widest margins and from which the bulk of banks' profits have come. The resulting customer benefits are thus likely to be significant, while banks will have to face a structural decline in their revenues.

From the competition policy view point a structural increase in competition and contestability of the banking markets strongly alleviates any concerns about adequacy of competition even though there is ongoing consolidation within banking systems. As regards the more specific issues, the definition of '*relevant markets*' for banking services has to be rethought (eg for merger control purposes). The '*relevant market*' has two components, a *geographic market* and a *product market* (eg Smith and Ryan 1997).

Remote banking technologies allow customers to obtain financial services easily from suppliers that do not have close physical presence. Hence the focus of competition policy should be increasingly on the national rather than the local community level. Possibilities for cross-border acquisition of services or increasing cross-border merger and acquisition activities even reduce the importance of the national level. Technological advances, EMU and the European

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<sup>44</sup> Berger and Humphrey (1995) present an extensive survey of the literature.

single market are likely to create an increasingly homogeneous market for financial services. In particular the euro area could become the relevant geographical market, although some remaining barriers, especially due to persisting customer preferences for domestic service providers, could sustain the relevance of national markets. As regards the product markets, a broader interpretation seems to be required, and the products and services offered by nonbank providers should be included in the definitions of relevant product markets for banking services.

European competition law allows banks to engage in cooperation in payment networks (giro circuits and ATM networks) provided that this cooperation has no adverse impact on price competition (Commission of the EC 1992). Based on Proposition 4, this principle seems sound: capacity collusion in fact supports price competition. However, the effect of capacity collusion on customer utility is ambiguous, since fewer branches and ATMs lower the utility and lower markups increase it. In general, these effects would lose their significance with the diffusion of alternative electronic delivery technologies for banking services.

Full ATM compatibility across the banking industry would improve all banks' competitive position vs nonbank suppliers of deposit-related services ( $h_i^{NB}$  increases), while it would cancel out the effects of differences in ATM networks on the degree of differentiation of banks vis-à-vis other banks ( $h_i^B$  falls). The net effect on banks' markups in the deposit market depends by Results 5 and 6 on the balance of these two effects. If banks are symmetric in terms of their ATM networks, compatibility agreement would lead to an increase in banks' markups, since the former effect would dominate the latter. However, the complete effect on deposit rates also includes a possible effect of compatibility on the marginal operating cost of deposit services. ATM interoperability may well lower the per-transaction cost of ATM transactions (and encourage customers to use more ATMs instead of branches), which could indeed lower the marginal operating cost of deposit services. In sum, the more asymmetric banks are in terms of their ATM networks and the bigger the marginal cost reducing effect of ATM interoperability, the more favourable the impact an ATM compatibility agreement would have on the deposit rates, from the customers' viewpoint.

ATM compatibility probably increases the number of outlets that are available to all banks' customers, which would produce a positive utility effect. This excludes the possibility that the network reducing effect of ATMs (Proposition 5) is so strong that the total number of ATMs would fall below the size of some banks' previous networks.

## 9 Concluding remarks

The model developed in this paper regards branching and ATM network choices of banks as means of enhancing demand for loans and supply of deposits and gaining pricing power via differentiation vis-à-vis other banks and nonbank competitors. The extent of these gains depends fundamentally on customers' valuation of branches and ATMs. Technological transformation in retail banking reduces these gains, and reduces the competitive advantages of banks' with large networks vs small banks and nonbank rivals. If banks are symmetric in terms of

their branch and ATM networks and market shares, banks' pricing power depends only on their competitive standing vs nonbank competitors, if banks' do not act collusively. This in turn hinges on the benefits due to branching and ATM networks (which are enhanced by compatibility arrangements) and on the quality difference between banks' and nonbanks' services. This quality difference seems to be also affected by the technological advances, since an increasingly wide assortment of payment and account maintenance services can be offered by nonbank competitors.

Unless banks are able to retrieve market power through differentiating in some novel service quality aspects or collusion, competition would increase considerably due to the emergence of new electronic delivery technologies and expansion of nonbank supply, even without new entry. However, the possibilities for regaining pricing power seem to be limited and therefore the resulting customer benefits could be considerable. The volatility of loan and deposit rates across banks would also diminish with reductions in bank-specific markups.

Declining markups lower banks' revenues, and as shown in section 7.2 more rapid technological transformation and diffusion of nonbank competition on the deposit side, as seems to be taking place, would put particular pressures on banks' net interest revenues. Banks' net interest revenues and hence profitability would become more volatile and vulnerable with respect to increases in the money market interest rate if banks regard their rivals' products and services as strategic complements. Furthermore, if the situation of more rapid advances in the deposit market vs the loan market persists, further deregulation of banks' deposit rate setting would generate smaller and smaller effects on banks' lending rates.

The numbers of branches and possibly also ATMs is likely to fall in the future, since the equilibrium outcomes depend on the revenue increasing effects of these outlets, which decline with structural increases in price competition due to technological transformation and nonbank competition. This trend is already observable in many countries, though there are many additional country-specific reasons.

The major conclusion for monetary policy is that reducing banks' competitive advantages in the loan market due to extensive branch networks and extending external competition (eg from the capital market) would unambiguously enhance the transmission of money market rate changes into loan rates. That is, the efficiency of monetary policy transmission would increase. By providing a detailed 'micro level' account of the transmission of the money market rates into equilibrium loan and deposit rates, the paper provides hypotheses that can be used for related empirical analyses of the stickiness of banks' loan and deposit rates, which are quite scant. It is shown that asymmetries across banks, the status of delivery technologies, and external competitive pressures play important roles in such transmission.

This paper also presents an application of general product differentiation theory by Feenstra and Levinsohn (1995) that could be fruitfully applied in empirical analyses of banking competition, or loan and deposit markets. The channels through which technological change affects the outcomes of price and capacity competition in banking have been identified, which could prove helpful for empirical work on this issue.

## Appendix 1

### First-order approximations for deposit supply and loan demand

The following first-order approximation can be obtained for banks' deposit supply curves based on Results 1 and 2, as in Feenstra and Levinsohn (1995):

$$\ln D_i = \alpha_0 + 2 \frac{(r_i + \gamma_0 + \gamma_1' \mathbf{b}_i)}{H_i} - 2 \sum_{j \neq i}^N \frac{\delta_j (r_j + \gamma_0 + \gamma_1' \mathbf{b}_j)}{(h_{ij} + \xi_i - \xi_j)} - \frac{\delta_{N+1} (r_{N+1} + \gamma_{11})}{(h_{iN+1} + \xi_i - \xi_{N+1})}, \quad (\text{A1.1})$$

$i = 1, \dots, N$ .

A first-order approximation for banks' loan demand function, based on Results 3 and 4, is

$$\ln L_i = \beta_0 - \frac{(t_i - \eta_1 b_{1i} - \eta_0)}{K_i} + \sum_{j \neq i}^N \frac{\rho_j (t_j - \eta_1 b_{1j} - \eta_0)}{(k_{ij} + \zeta_j - \zeta_i)} + \frac{\rho_{N+1} (t_{N+1} - \eta_1)}{k_{iN+1} + \zeta_{N+1} - \zeta_i}, \quad (\text{A1.2})$$

$i, j = 1, \dots, N$ .

The intercept terms capture the effects on total market size, which increase equally all banks' deposit supply and loan demand.



## Appendix 2

### Derivation of Results 5 and 6

The necessary first-order conditions for profit maximum are

$$\begin{aligned}\frac{d\pi_i}{dt_i} &= L_i + (t_i - i - c_i^L) \frac{\partial L_i}{\partial t_i} + (t_i - i - c_i^L) \sum_{j \neq i}^N \frac{\partial L_i}{\partial t_j} \frac{\partial t_j}{\partial t_i} = 0 \\ \frac{d\pi_i}{dr_i} &= -D_i + (i - r_i - c_i^D) \frac{\partial D_i}{\partial r_i} + (i - r_i - c_i^D) \sum_{j \neq i}^N \frac{\partial D_i}{\partial r_j} \frac{\partial r_j}{\partial r_i} = 0.\end{aligned}\tag{A2.1}$$

The final terms of (A2.1) exist only in the general oligopoly case that allows for price conjectures.

Since

$$\frac{\partial L_i}{\partial t_j} = \frac{L_i \rho_j}{k_{ij} + \zeta_j - \zeta_i} + \frac{\partial L_i}{\partial \rho_j} \frac{\partial \rho_j}{\partial t_j}, \quad \text{and} \quad \frac{\partial D_i}{\partial r_j} = \frac{D_i \delta_j}{h_{ij} + \xi_i - \xi_j} + \frac{\partial D_i}{\partial \delta_j} \frac{\partial \delta_j}{\partial r_j},\tag{A2.2}$$

the first-order conditions can be written as

$$\begin{aligned}1 - (t_i - i - c_i^L) \left( \frac{1}{K_i} \right) + \theta_L (t_i - i - c_i^L) \left( \sum_{j \neq i}^N \frac{\partial L_i}{\partial t_j L_i} - L_i \sum_{j \neq i}^N \frac{\partial \rho_j}{\partial t_j} \right) &= 0 \\ -1 + (i - r_i - c_i^D) \left( \frac{2}{H_i} \right) - \theta_D (i - r_i - c_i^D) \left( \sum_{j \neq i}^N \frac{\partial D_i}{\partial r_j D_i} + D_i \sum_{j \neq i}^N \frac{\partial \delta_j}{\partial r_j} \right) &= 0.\end{aligned}\tag{A2.3}$$

Results 5 and 6 are obtained from (A2.3) by applying the formulas for own and cross rate elasticities of section 4, calculating the respective derivatives of the loan and deposit market shares of rival bank  $j$ , and factoring out  $t_i^*$  and  $r_i^*$ .

## Appendix 3

### Derivation of Result 7 and comparative statics for monopoly

To solve the program (21), I do not need to take the derivatives with respect to  $t^*$  and  $r^*$  due to the envelope theorem, ie  $\partial\pi_i^R/\partial t_i = 0$  and  $\partial\pi_i^R/\partial r_i = 0$  and hence  $\partial t_j^*/\partial b_{1i}$ ,  $\partial r_j^*/\partial b_{1i}$  and  $\partial r_j^*/\partial b_{2i}$  do not appear in the equilibrium conditions. To establish the equilibrium conditions, I need to look instead at the *direct demand effects* of  $b_1$  and  $b_2$  on  $L_i$  and  $D_i$  and the *strategic effects via rivals' capacity decisions*. The condition for  $b_{2i}$  is unaffected by the loan rates or lending volumes.

The *direct demand effects* (conditioned on the competitive effects vis-à-vis other banks and against the nonbank rivals) amount to the following:

$$\begin{aligned} \frac{\partial \pi_i}{\partial b_{1i}} \Big|_{\text{direct demand effect}} &= (t_i^* - i - c_i^L) \frac{\partial L_i}{\partial b_{1i}} \Big|_{k_i^B} + (t_i^* - i - c_i^L) \frac{\partial L_i}{\partial b_{1i}} \Big|_{k_i^{NB}} + \\ &\quad (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{1i}} \Big|_{h_i^B} + (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{1i}} \Big|_{h_i^{NB}} \end{aligned} \quad (\text{A3.1})$$

$$\frac{\partial \pi_i}{\partial b_{2i}} \Big|_{\text{direct demand effect}} = (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{2i}} \Big|_{h_i^B} + (i - r_i^* - c_i^D) \frac{\partial D_i}{\partial b_{2i}} \Big|_{h_i^{NB}}, \quad i = 1, \dots, N.$$

By Result 7 there is a revenue effect of capacity only when in competing pairs of banks  $i$  and  $j$  capacity of bank  $i$  exceeds that of a bank  $j$ . In these pairs, bank  $i$ 's decisions would not have an effect on bank  $j$ 's prices, and *strategic price effects* through rivals' prices would not arise. Ie  $\frac{dL_i}{db_{ki}} > 0$  only if  $b_{ki} > b_{kj}$ ,  $i, j = 1, \dots, N+1$ ,

$k = 1, 2$ . Hence only the *direct demand effects on revenues* need to be considered.

Finally, the *strategic effects through rivals' capacity choices* are

$$\begin{aligned} \frac{\partial \pi_i^R}{\partial b_{1i}} \Big|_{\text{strategic capacity effect}} &= (t_i^* - i - c_i^L) \left( \sum_j^N \frac{\partial L_i}{\partial b_{1j}} \frac{\partial b_{1j}}{\partial b_{1i}} \right) \\ &\quad + (i - r_i^* - c_i^D) \left( \sum_j^N \frac{\partial D_i}{\partial b_{1j}} \frac{\partial b_{1j}}{\partial b_{1i}} \right), \end{aligned} \quad (\text{A3.2})$$

$$\frac{\partial \pi_i^R}{\partial b_{2i}} \Big|_{\text{strategic capacity effect}} = (i - r_i^* - c_i^D) \left( \sum_j^N \frac{\partial D_i}{\partial b_{2j}} \frac{\partial b_{2j}}{\partial b_{2i}} \right), \quad i = 1, \dots, N.$$

Result 7 obtains after combining (A3.1) and (A3.3) and noting that

$$\begin{aligned}
\frac{\partial L_i}{\partial b_{1i}} \Big|_{k_i^B} &= \frac{\partial L_i}{\partial t_i} \frac{\partial t_i}{\partial b_{1i}} \Big|_{k_i^B} = - \sum_{j \neq i}^N \frac{\partial L_i}{\partial t_j} \frac{\partial t_j}{\partial b_{1j}} \Big|_{k_i^B}, \\
\frac{\partial D_i}{\partial b_{1i}} \Big|_{h_i^B} &= \frac{\partial D_i}{\partial r_i} \frac{\partial r_i}{\partial b_{1i}} \Big|_{h_i^B} = - \sum_{j \neq i}^N \frac{\partial D_i}{\partial r_j} \frac{\partial r_j}{\partial b_{1j}} \Big|_{h_i^B}, \text{ and} \\
\frac{\partial D_i}{\partial b_{2i}} \Big|_{h_i^B} &= \frac{\partial D_i}{\partial r_i} \frac{\partial r_i}{\partial b_{2i}} \Big|_{h_i^B} = - \sum_{j \neq i}^N \frac{\partial D_i}{\partial r_j} \frac{\partial r_j}{\partial b_{2j}} \Big|_{h_i^B}, \quad i, j = 1, \dots, N.
\end{aligned} \tag{A3.3}$$

The comparative static results presented in Table 2 for a monopoly bank are derived by totally differentiating the equilibrium conditions under Result 7 with respect to  $b_1$ ,  $b_2$  and the parameter in question, after adjusting the conditions (22a) for the monopoly case and replacing the loan and deposit markups by  $K$  and  $H/2$  respectively. I can now drop the subscript  $i$ . Finally, I do not need to solve simultaneously the problem for the monopoly bank and the nonbank competitors, since nonbank competitors' capacity is predetermined.

For example:

$$\begin{aligned}
\frac{db_1}{d\eta_1} &= \frac{-\frac{\partial K}{\partial \eta_1} \frac{\partial L}{\partial b_1} \left( \frac{d^2 \pi^R}{db_2^2} \right)}{|\Pi|} > 0, \quad \frac{db_2}{d\eta_1} = \frac{\frac{\partial K}{\partial \eta_1} \frac{\partial L}{\partial b_1} \left( \frac{d^2 \pi^R}{db_1 db_2} \right)}{|\Pi|}, \\
\frac{db_1}{d\tau_1} &= \frac{-\frac{1}{2} \frac{\partial H}{\partial \tau_1} \frac{\partial D}{\partial b_1} \left( \frac{d^2 \pi^R}{db_2^2} \right) + \frac{1}{2} \frac{\partial H}{\partial \tau_1} \frac{\partial D}{\partial b_1} \left( \frac{d^2 \pi^R}{db_1 db_2} \right)}{|\Pi|}, \text{ and} \\
\frac{db_2}{d\tau_1} &= \frac{-\frac{1}{2} \frac{\partial H}{\partial \tau_1} \frac{\partial D}{\partial b_2} \left( \frac{d^2 \pi^R}{db_1^2} \right) + \frac{1}{2} \frac{\partial H}{\partial \tau_1} \frac{\partial D}{\partial b_1} \left( \frac{d^2 \pi^R}{db_2 db_1} \right)}{|\Pi|}, \text{ where } |\Pi| > 0.
\end{aligned} \tag{A3.4}$$

Only the competitive standing vs the nonbank rivals matters for the monopoly bank. This standing is in turn determined by the degree of differentiation of the monopolist vis-à-vis the nonbank rivals, ie  $K$  and  $H$  only depend on  $k^{NB}$  and  $h^{NB}$ .

The Cramer determinant ( $|\Pi|$ ) is positive by the second order condition for the stability of the equilibrium. For example, the first comparative static derivative gets the positive sign, since the second-order derivative of profits with respect to  $b_1$  is negative, due to the second order condition for profit maximization, and  $K$  is increasing in  $\eta_1$ . The other comparative static derivatives that appear in Table 2 are obtained similarly to the above ones.

## Appendix 4

### Derivation of Results 8.a and 9

Given the cost assumptions (section 5) and the application of Dixit's (1986) methodology explained in section 7.1, the following first-order conditions determine the oligopoly equilibrium:

$$\begin{aligned} \frac{d\pi_i}{dt_i} = L_i + (t_i^* - i - c_i^L) \frac{dL_i}{dt_i} = 0, \quad \frac{d\pi_i}{dr_i} = -D_i + (i - r_i^* - c_i^L) \frac{dD_i}{dr_i} = 0 \\ \frac{d\pi_{-i}}{dt_{-i}} = L_{-i} + (t_{-i}^* - i - c_{-i}^L) \frac{dL_{-i}}{dt_{-i}} = 0, \quad \frac{d\pi_{-i}}{dr_{-i}} = -D_{-i} + (i - r_{-i}^* - c_{-i}^D) \frac{dD_{-i}}{dr_{-i}} = 0, \end{aligned} \quad (\text{A4.1})$$

$$\text{where } L_{-i} \equiv \sum_{j \neq i}^{N+1} L_j \text{ and } D_{-i} \equiv \sum_{j \neq i}^{N+1} D_j.$$

Result 8.a is obtained by totally differentiating the above system of first-order equilibrium conditions with respect to  $t_i$ ,  $r_i$ ,  $t_{-i}$ ,  $r_{-i}$  (average rates of rivals), and  $i$ . The system of equations takes the following form, given the cost assumptions reported in section 5:

$$\begin{pmatrix} \frac{d^2\pi_i}{dt_i^2} & 0 & \frac{d^2\pi_i}{dt_i dt_{-i}} & 0 \\ 0 & \frac{d^2\pi_i}{dr_i^2} & 0 & \frac{d^2\pi_i}{dr_i dr_{-i}} \\ \frac{d^2\pi_{-i}}{dt_{-i} dt_i} & 0 & \frac{d^2\pi_{-i}}{dt_{-i}^2} & 0 \\ 0 & \frac{d^2\pi_{-i}}{dr_{-i} dr_i} & 0 & \frac{d^2\pi_{-i}}{dr_{-i}^2} \end{pmatrix} \begin{pmatrix} dt_i \\ dr_i \\ dt_{-i} \\ dr_{-i} \end{pmatrix} = \begin{pmatrix} \frac{d^2\pi_i}{dt_i di} \\ \frac{d^2\pi_i}{dr_i di} \\ \frac{d^2\pi_{-i}}{dt_{-i} di} \\ \frac{d^2\pi_{-i}}{dr_{-i} di} \end{pmatrix} di, \quad (\text{A4.2})$$

from which  $dt_i/di$  and  $dr_i/di$  are calculated by applying Cramer's rule.

The  $\Omega$  quantities are the following:

$$\begin{aligned}
\Omega_1 &\equiv \left( \frac{d^2\pi_i}{dt_i^2} \right) (SC^D) < 0, \\
\Omega_2 &\equiv \left( -\frac{d^2\pi_i}{dt_i di} \right) \left( g_i^D g_i^D - g_i^L \left( \frac{d^2\pi_i}{dr_i^2} \right) \right) < 0 \text{ since } -\left( \frac{d^2\pi_i}{dt_i di} \right) < 0, \\
\Omega_3 &\equiv -g_i^L (SC^D) < 0, \quad \Omega_4 \equiv \left( \frac{d^2\pi_i}{dr_i^2} \right) < 0, \\
\Omega_5 &\equiv -g_i^D \left( -\frac{d^2\pi_i}{dr_i di} \right) < 0 \text{ since } \left( -\frac{d^2\pi_i}{dr_i di} \right) > 0, \quad \Omega_6 \equiv -g_i^D g_i^D < 0,
\end{aligned} \tag{A4.3}$$

where  $SC^D \equiv \left( \frac{d^2\pi_i}{dr_i^2} \frac{d^2\pi_i}{dr_i^2} - g_i^D g_i^D \right) > 0$ , and

$$g_i^L = \frac{\partial^2\pi_i}{\partial t_i \partial t_i} > 0, \quad g_i^D = \frac{\partial^2\pi_i}{\partial r_i \partial r_i} > 0, \quad g_i^L = \frac{\partial^2\pi_i}{\partial t_i \partial t_i} > 0, \quad g_i^D = \frac{\partial^2\pi_i}{\partial r_i \partial r_i} > 0.$$

$SC^D > 0$  is the condition for stability of the deposit market equilibrium. Otherwise the negative signs follow from strategic complementarity, second-order conditions for profit maximum, and the above given signs of the cross profit derivatives with respect to  $i$  (which can be easily verified from (A4.1)).

To derive the Result 9, note first that

$$\frac{dL_i}{dt_i} = \frac{\partial L_i}{\partial t_i} + \frac{\partial L_i}{\partial t_i} \frac{\partial t_i}{\partial t_i} \equiv (1 - \theta_L) \frac{\partial L_i}{\partial t_i}, \text{ since } \frac{\partial L_i}{\partial t_i} = -\frac{\partial L_i}{\partial t_i}. \tag{A4.4}$$

Secondly:

$$\frac{d^2L_i}{dt_i^2} = \frac{d}{dt_i} \left[ (1 - \theta_L) \frac{\partial L_i}{\partial t_i} \right] = (1 - \theta_L) \left[ \frac{\partial^2 L_i}{\partial t_i^2} + \frac{\partial^2 L_i}{\partial t_i \partial t_i} \frac{\partial t_i}{\partial t_i} \right] = (1 - \theta_L)^2 \frac{\partial^2 L_i}{\partial t_i^2}, \tag{A4.5}$$

since  $\frac{\partial L_i^2}{\partial t_i^2} = -\frac{\partial^2 L_i}{\partial t_i \partial t_i}$ .

The results for the deposit market under Result 9 obtain after similar calculations.

The above partial derivatives are easily calculated in the case of symmetric banking industry configurations. The results of this exercise show up in Result 10.

Figure 1.

**Difference of highest and lowest average deposit rates among main Finnish banks**

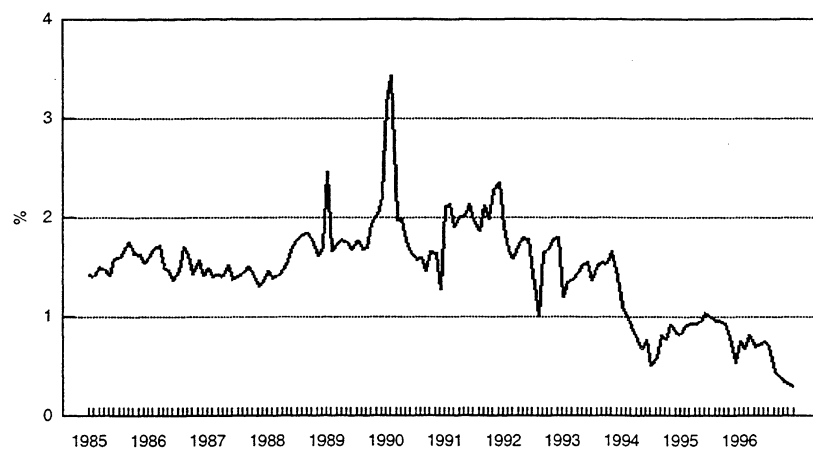


Figure 2.

**Difference between highest and lowest average new lending rates among main Finnish banks**

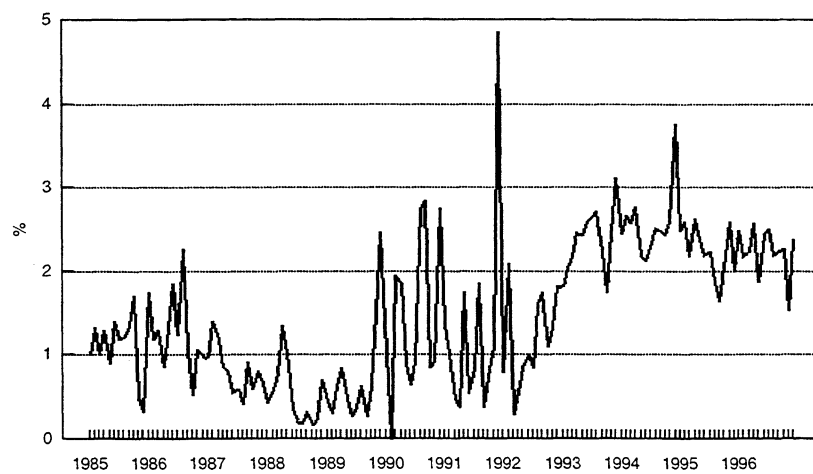


Figure 3.

**Finnish banks' average margins in new lending (3) and deposit taking (2) over the money market rate (3-month HELIBOR) (1)**

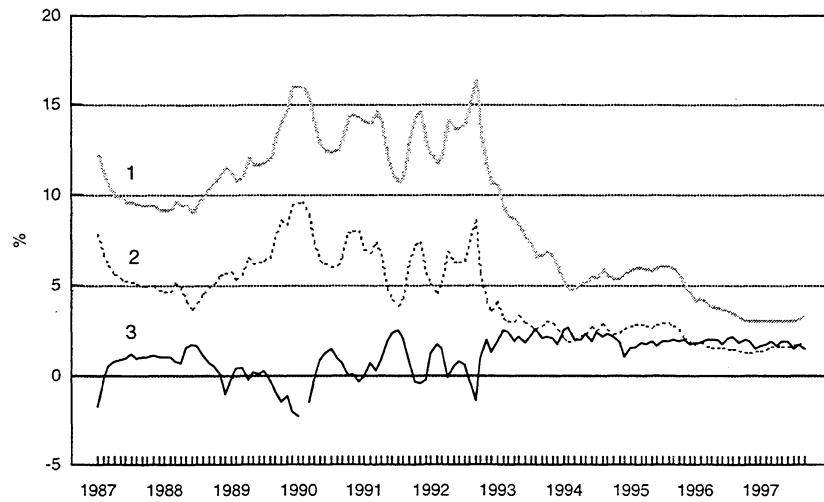
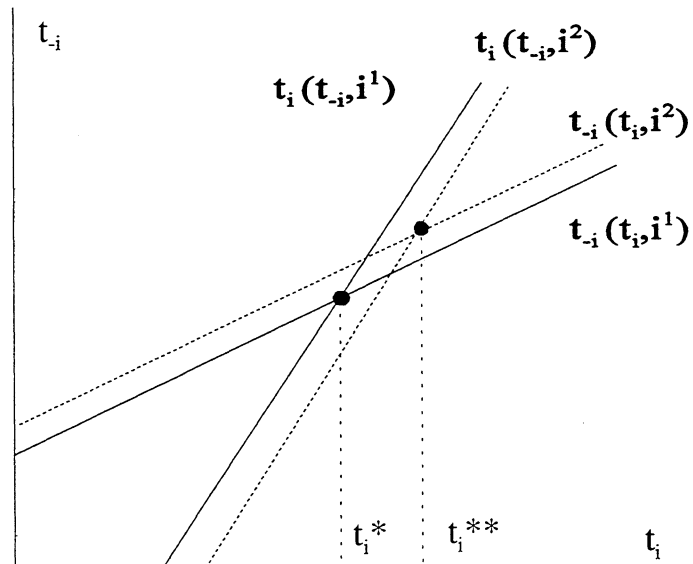


Exhibit 1.

**Old (money market rate  $i^1$ ) and new (money market rate  $i^2 > i^1$ ) reaction curves  $t_i$  (bank  $i$ ) and  $t_{-i}$  (aggregate for bank  $i$ 's rivals) with strategic complements**



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