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ATM networks and cash usage

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Heli Snellman – Matti Virén

ATM networks and cash usage

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ATM networks and cash usage

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

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ATM networks and cash usage

Bank of Finland Research Discussion Papers 21/2006

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Abstract

This paper deals with the issue of how the market structure in banking affects the choice of means of payment. In particular, the demand for cash is analysed from this point of view. The analysis is based on a simple spatial transactions model in which the banks' optimization problem is solved. The solution quite clearly shows that monopoly banks have an incentive to restrict the number of ATMs to a minimum. In general, the number of ATMs depends on competitiveness in the banking sector. The predictions of the theoretical analysis are tested using panel data from 20 OECD countries for the period 1988–2003. Empirical analysis reveals that there is a strong and robust relationship between the number of ATM networks and the number of ATMs (in relation to population). It also reveals that the demand for cash depends both on the number of ATMs and ATM networks and on the popularity of other means of payment. Thus, the use of cash can be fairly well explained in a transaction demand framework, assuming proper controls for market structure and technical environment.

Key words: automated teller machine, demand for cash, banking, means of payment

JEL classification numbers: E41, E51

Pankkiautomaattien verkot ja käteisrahan käyttö

Suomen Pankin tutkimus
Keskustelualoitteita 21/2006

Heli Snellman – Matti Virén
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tutkimuksessa selvitetään, miten pankkien markkinarakenne vaikuttaa maksuvälineiden valintaan. Erityisesti käteisrahan kysyntää tarkastellaan tästä näkökulmasta. Analyysit perustuvat yksinkertaiseen spatiaaliseen transaktiomalliin, jonka puitteissa pankkien optimointiongelma ratkaistaan. Ratkaisu osoittaa selvästi, että monopolipankilla on houkutus rajoittaa pankkiautomaattien määrä minimiin. Yleisesti ottaen pankkiautomaattien lukumäärä riippuu pankkisektorin kilpailullisuudesta. Teoreettisen mallin ennakoimia tuloksia testataan käyttämällä paneeliaineistoa 20 OECD-maasta ajanjaksolta 1988–2003. Empiiriset analyysit osoittavat, että pankkiautomaattiverkkojen ja pankkiautomaattien lukumäärän (suhteessa väestöön) välillä on voimakas ja pysyvä riippuvuus. Ilmenee myös, että käteisrahan kysyntä riippuu pankkiautomaattien sekä pankkiautomaattiverkkojen lukumäärästä ja muiden maksuvälineiden käytön yleisyydestä. Siten käteisrahan käyttö voidaan kohtuullisen hyvin selittää transaktiokysyntäkehikossa olettaen, että markkinarakenne ja tekninen ympäristö tulevat kunnolla otetuksi huomioon.

Avainsanat: pankkiautomaatti, käteisrahan kysyntä, pankkitoiminta, maksuvälineet

JEL-luokittelu: E41, E51

Contents

Abstract 3
Tiivistelmä (abstract in Finnish) 4

1 Introduction 7

2 Theoretical model 9

3 Empirical results 16

4 Concluding remarks 23

References 25

Appendix 1 27
Appendix 2 28

1 Introduction

Until the early 1980s, payment systems were relatively simply consisting of cash, cheques and bank and postal giros. With the introduction of debit and credit cards, the whole thing has changed. This also shows up in the way cash is used. Earlier, cash was distributed via banks (ie bank offices) but in 1980s automated teller machines and cash dispensers largely replaced banks offices in (cash) liquidity services. The number of ATMs has increased more or less steadily after the early 1980s (and the number of banks offices has correspondingly decreased). In several countries, eg in Finland, the growth of the number of ATMs has, however, turned to a downward trend which is somewhat puzzling because the (real) amount of cash still continues to increase.

One has to take into account that banks, not the Central Bank, are responsible to distribution of cash and they are also running the ATMs. Banks' role is somewhat odd because they do not directly benefit from cash (seigniorage goes to the Central Bank). By contrast, distribution of cash creates considerable costs to banks. Although banks can cover part of the costs by different fees and tariffs, the net 'return' from cash is quite obviously negative. Moreover, the use of cash decreases deposits and thus lowers banks' interest income.

But banks cannot simply stop providing cash because a considerable part of their clients use cash and if a bank had no facilities for cash services it simply would loose these clients. Only banks could collude and form a single cartel which would be responsible for distribution of cash banks could effectively control the number of ATMs. If banks (or the cash distribution cartel of banks) reduced the number of ATMs, the use of cash would become less convenient and the general public would instead turn to use of debit cards which, as pointed out above, would be a better deal for banks. Alternatively, banks could impose some fees for the use of ATMs which would basically produce the same result. In practice, fees are not common. They are mainly collected from other banks' customers (for using an ATM not owned by the cardholders bank).[1]

Recent developments in developed countries seem to be consistent with above expressed concerns. Thus, in several countries banks have formed common networks for ATMs thus do not compete with cash distribution services. Take for instance Finland. There the system started with bank-specific ATMs which could not be used by other banks' clients. After a while commercial banks created a common network for their own clients. Now it covers practically all banks. In fact, banks have formed a joint company, Automatia, which is responsible for the whole cash distribution activity. Needless to say, it has a monopoly position: the only way (except for bank offices) one can get cash is to use Automatia's ATMs.

[1] The use of ATM fees is analyzed eg in McAndrews (2001).

It is interesting to see how things develop in the future. Do similar tendencies take place in all countries and does also happen that the number of ATMs (as well as the number of bank offices) decreases. And if so, how does it affect the use of cash. If it becomes very difficult to get cash the use (demand) for cash would probably diminish. Although this is the probable outcome, it is no all clear because increased transaction costs may also lead to larger cash withdrawals and thereby larger cash balances. Thus, empirical evidence is crucially needed, both to project the relationship between banking sector concentration and supply of ATMs and the demand for cash and the availability of cash services (ATMs) and alternative means of payment.

Based on the earlier literature, there has been little discussion on the influence of ATM network market structure on cash withdrawal services and on the demand for cash. Important exceptions are McAndrews and Rob (1996) who have investigated the effects of various ATM network structures on profits and quantities supplied. The network sharing problem is analyzed by Matutes and Padilla (1994). Furthermore, the literature includes some political economy discussion about the effects of ATM network mergers, like Balto (1995), Baker (1995) and Carlton and Frankel (1995). However, their discussion is not based on any theoretical framework or empirical estimation results. In this paper, we analyse the effects of market structure on ATM density both theoretically and empirically. We construct the ATM equation and use a unique set of data in estimating this ATM equation. The ATM equation is indeed the novelty of this paper.

Even though the market structure of ATM network has not been thoroughly researched, the role of ATMs has been discussed in other connections in the earlier literature. For instance, technology adoption has been studied with ATM data, and the influence of ATMs on the value of cash in circulation has been discussed in many papers. Some examples of the papers analysing the effects of ATMs on the value of currency in circulation are Boeschoten (1992, 1998), Virén (1992), Snellman et al (2000), Drehmann and Goodhart (2000), Drehmann et al (2002) and Stix (2003). The results of these studies are somewhat mixed: The increase in the number of ATMs either decreases or increases the value of cash in circulation. One contribution of our paper is to analyse how ATMs affect the demand for cash. First of all, we construct a theoretical model and suppose that a consumer minimises costs of using a payment instrument and a bank maximises profits. Using this model, we examine the implications in terms of demand for cash. The empirical analyses are based on cross-country data for 20 OECD countries over 1984–2003.

The study is organized in the following way. First we present the theoretical model in section 2, derive the basic results and assess its implications for supply of ATMs and demand for cash. Empirical analysis using pooled cross-country

data from 20 OECD countries for the period 1984–2003 is carried out in section 3. Finally, some concluding remarks follow in section 4.

2 Theoretical model

We assume here that the number of ATMs is one of bank's decision variables. In the case of monopoly bank that is quite clear but also in more competitive banking markets that may be true. It is only in the in the latter case banks may form various sort of cartels (ATM networks) in which the ATM services are either excluded from outsiders or they are only available with extra cost.[2]

Although banks choose the number of ATMs (and other technical details) they are constrained from the part of the general public. First of all, the general public decides which bank to use. Obviously this choice depends on the relevant prices and the amount of services a bank can provide. If, for instance, a bank had zero ATMs and the bank's customers had to use other banks' (more costly) ATMs that would reduce the bank's market share and thereby profits. Thus it is well-founded to focus on the relationship between banks' competitive environment and the ATM structure as well as the demand for cash. First we analyse the case of a monopoly bank which can 'freely' decide the optimal number of ATMs and then turn to more competitive market structures.

In choosing the optimal number of ATMs, the bank has obviously to consider the relevant revenues and expenditures. To make things simply, we assume the interest margin is constant depending on the interest rate which is paid to deposits. Cash holdings reduce deposits and thereby reduce the bank's revenues. Cash holdings also generate costs because of the maintenance costs of ATMs (and to some degree also of bank offices). Debit cards do also create costs although they are probably mainly of fixed cost type. On the other hand, some fee can be charged from debit card transactions while the use of ATM is assumed to be free of charge.

As for the consumer (here we ignore firms and other market participants), they have basically the following choices to be made:

- which bank to choose
- to use cash or debit card
- how much cash to hold

[2] Whitesell (1992) is perhaps the first who has analyzed banks' role if payment system choices. His key variable is the size/frequency of transactions which, as we see later, makes it different from our model.

The first choice, which is a trivial in the monopoly case, is discussed more thoroughly in the context of the derivation of the theoretical model. The basic assumption is anyway that the choice of the bank depends on the service menu which in this case translates to the number of ATMs. The two last choices obviously depend on the cost of getting cash. When the payment media is chosen, the relevant relative cost is the ratio of this transaction cost to the cost (fee) of using the debit cards. The second choice, in turn, depends on the ratio of transaction cost to interest expenses. To illustrate the choice we use a Baumol -type transaction model which is presented in a spatial setting where the ATMs are distributed evenly along a line. Now the transaction costs correspond simply to the distance between the ATM and the customer. Customers are assumed to be evenly distributed long a line.

Although there are numerous analyses which focus on the relationship between transaction technology and the demand for money there is no exact match for our purposes. Perhaps Whitesell (1989) comes to the closest with model where the size of transaction determines the payment media (cash for the small transactions).[3] This model makes much sense but it suffers from the artificial constraint that the size limit is absolutely binding: one cannot use cash for large transactions and debit card for small transactions.[4] Thus, the choice of payment media is dictated by the size distribution of transactions and the transactions costs of the payment instruments. Although the size distribution of transactions is definitely important from the point of view of payment media it is not that crucial for our purposes and in fact we assume a very simply structure of transactions: for each period there is just one transaction of the size one. The only things which matter for the consumer are the travelling costs to the ATM, the cost of using a debit card and the interest rates on deposits.

Denote the number of ATMs by A. The (inconvenience) cost of using the ATM b depends inversely on A so that $b = b(A)$ and $b'(A) < 0$. Assume that if the consumer pays with debit card, she has to pay percentage fee, v, per transaction.[5] Now, according to the Baumol model, and given the market share of cash, reducing ATMs leads to increased costs, which leads to decreased cash withdrawals and thus larger money (cash) demand. If there is an alternative payment instrument available, the results does not necessary hold. If the 'unit' cost of using debit card is less than the cost of using cash, the consumer chooses

[3] See Snellman (2006) for a survey of different models of payment media choice.

[4] Empirical studies give support to the idea that cash dominates in small transactions but one cannot find a cleat cut-off point in terms of the size of the transaction such that the use of money would simply die out after that point. See Virén (1993, 1994) and more recently Bounie and Francois for details. As for firms, which are not handled here, see Hirvonen and Virén (1996a,b) and Virén (1996).

[5] In practice, this kind of fee is not usually changed from the customer but from the seller. Even if this is the case, the incidence of the fee could be quite the same as in the customer charge case.

card payments instead of cash and thus cash demand decreases. Thus, a priori, the net effect of increased/decreased A is ambiguous.

As for consumer, let us assume that there are N consumers who are evenly distributed along the line of length 1 and who are homogenous otherwise but the distance to the ATM varies across consumers. ATMs are assumed to be the only cash distribution channel in the economy. Furthermore, ATMs are assumed to be evenly distributed along the line of length 1 such that the maximum distance to the nearest ATM is constant, 1/(2A).[6] For simplicity, let's suppose that the representative consumer makes one transaction of value 1 every period. Inconvenience cost, ie the distance to the nearest ATM, determines whether the representative consumer pays with cash or with card. The total value of cash and card transactions depend on the total consumption and on the relative prices of payment technologies.

In the Baumol model, the total costs for the consumer of using cash are COST = bT/C + iC/2 where b is the cost from each cash withdrawal, T is the total value of payment transactions made within a relevant time interval, C is the size of cash withdrawal (thus T/C cash withdrawals are made within the time interval) and r is the nominal interest rate which is the relevant opportunity cost of hold cash balances. Now the first order condition for the liquidity cost problem yields the following optimal cash withdrawal

$$C^* = \sqrt{\frac{2bT}{i}} \tag{2.1}$$

The corresponding cash (money) demand is

$$M^* = C^*/2 = \sqrt{\frac{bT}{2i}} \tag{2.1'}$$

The minimum of total costs is obtained by substituting (2.1) into the total costs

$$COST^* = \frac{bT}{C^*} + \frac{iC^*}{2} = \frac{bT}{\sqrt{\frac{2bT}{i}}} + \frac{i\sqrt{\frac{2bT}{i}}}{2} = \sqrt{2bTi} \tag{2.2}$$

Next we introduce another payment instrument, the debit card. As mentioned above, the cost of using cards is v, which is the same for all consumers. Thus consumers select the payment instrument on the basis of their location (not

[6] In a (Salop) circle case, basically the same result would emerge, only that we would have $b_{max} = 1/\pi A$.

according to the size of transaction as in Whiteshell (1989)). If they happen to be close to the ATM, they use cash while people far from the ATM use the debit card. For an indifferent consumer the costs of cash payments equal the costs of card payments

$$\sqrt{2bTi} = vT \tag{2.3}$$

From which can solve a break-even value

$$b^{\circ} = \frac{v^2T}{2i} \tag{2.4}$$

Figure 1. **Choice of the payment instrument**

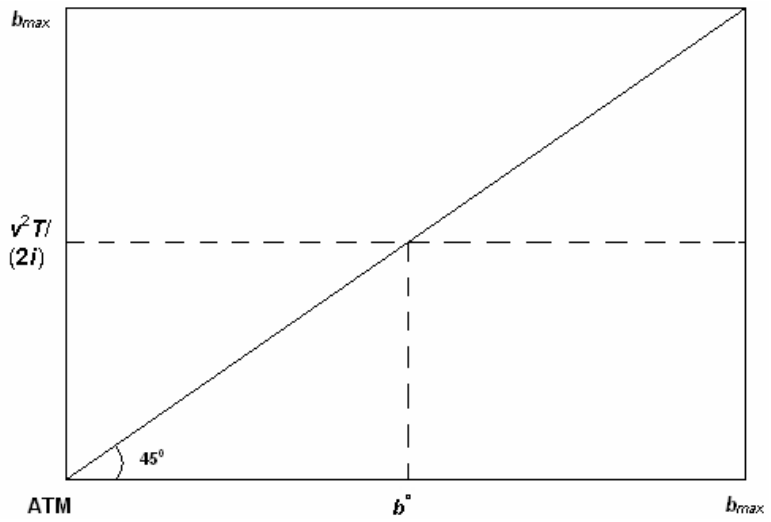


Figure 1 illustrates the choice of payment instruments. If the ATM is located in the origin, b_{max} indicates the maximum distance between the consumer and the ATM. When b equals the cost from card payment, the consumer is indifferent between cash and card usage. Consumers on the left hand side of b° pay for transactions with cash, whereas consumers on the right hand side of b° pay all transactions with debit card.

As stated above, the maximum value of b, denoted by b_{max} is scaled to be 1/(2A). In other words, $0 < b^{\circ} < 1/(2A)$. The ratio of cash payments to the total transactions is

$$\frac{b^{\circ}}{b_{max}} = \frac{b^{\circ}}{\frac{1}{2A}} = \frac{\frac{v^2T}{2i} - 0}{\frac{1}{2A}} = \frac{Av^2T}{i} \tag{2.5}$$

And the ratio of card payments to the total transactions is

$$1-\frac{Av^2T}{i} \tag{2.6}$$

where $0 < Av^2T/i < 1$.

As the value of the total transactions of one consumer is T, and there are N consumers, the total value of card payments is

$$Card_N = NT\left(1-\frac{Av^2T}{i}\right) \tag{2.7}$$

The total stock of average cash holdings is calculated by multiplying the average cash holdings of households that use cash by the share of cash users of all households and the number of households (?).

$$M_N = N^* Av^2T/i^* \int_0^{\frac{v^2T}{2i}} 2A\sqrt{\frac{bT}{2i}}db \tag{2.8}$$

The value of this quantity is $NA^2v^5T^3/3i^3$. Quite clearly an increase in the number of ATMs increases the use of cash. That is because an increase in the number of ATMs lowers travel costs b and thus a part of card users turn to cash users. The outcome is quite different if v is so high that there is no interior solution (or, all or as fraction of households that have no access to debit cards). In the 'cash only' economy the value of M_N would simply be $N\sqrt{\frac{T}{iA}}/3$ which gives the opposite result: increase in the number of ATMs would lower total cash balances. That is because an increase in the number of ATMs would only decrease the average cash withdrawals; the number of cash users would not change, or course.

After these prerequisites we can analyse the profit maximisation problem of the bank. The bank receives revenues from interest rate margin (from deposits) and from debit card payments. Two types of payment media costs are also acknowledged. First of all there are costs for money (cash) supply that is here denoted by Az. In addition, there are costs for maintaining the debit card payment network. These costs, denotes by CCard, are assumed to be fixed.

Consumers' assets W are assumed to consist of cash holdings and deposits: $W_N = M_N + D_N$ from which $D_N = W_N - M_N$. Income from card payments is $Card_N$ (2.7). Thus, in the case of an interior solution for payment media choice profits can be derived from the following equation

$$\pi(A,v) = (r-i)\left(W_N - \frac{NA^2v^5T^3}{3i^3}\right) + v\left(1 - \frac{Av^2T}{i}\right)NT - Az - CCard \qquad (2.9)$$

Scrutinizing equation (2.9) one can readily conclude that for a monopoly bank it is optimal to decrease the number of ATMs to zero. The reason is simple: cash and the ATMs represent only costs to the bank. Hence profit maximization trivially implies minimization of the number of ATMs. As for the debit card transaction fee, it is not necessarily optimal to set it to zero. In that case, $\pi(0,0)$ would simply be $(r - i)WN - Ccard$ which is necessarily not larger than (2.9) because the use of cash is very sensitive to v; thus the bank can reduce the demand for cash sufficiently without giving up of all debit card transaction fees.

In order not to get the corner solution we have to introduce some form of monopolistic competition in the banking market. One possible to way to do that is suppose that the market share of the bank depends among other things on the number of its ATMs. The more the banks spend in cash services the higher is their market share. To put it simply, the market share of the bank i is $s(A_i)$ where $s' > 0$.[7] Quite clearly we would now face a trade-off between the positive *market share effect* and the negative overall *cost effect* from cash services.[8] The nature of the trade-off with some reasonable parameter values is illustrated in Figure 2 below. Although we can see that an interior solution is possible we cannot derive a closed form solution to A from the model.[9] We can only see that there is positive relationship between A, on the one hand, and N and T, on the other hand. Moreover, the corner-solution argument implies that there is also a positive relationship between A and the number of banks (or more precisely banks' ATM networks).[10]

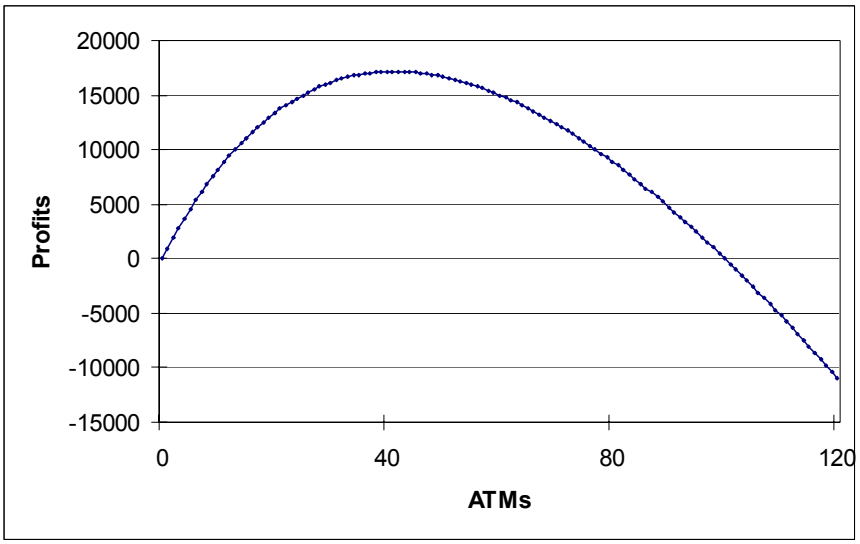
[7] Obviously, $s_i(\ )$ would also depend on all relevant price parameters. The role of v, in particular, could be important not only in generating revenues but selecting customers. Having low values of A and v would possibly attract customers with large deposits and small amount of transaction services.

[8] The nature of trade-off can be seen by multiplying the first two terms on the right-hand side of (2.9) by s(A).

[9] The exact formulas are available upon request from the authors.

[10] The derivation of the figure is based on the following parameter values: v = 0,001, z = 1000, T = 10, r = 0,03, i = 0,01, w = 10000, N = 1000.

Figure 2. **The relationship between profits and number of ATMs**



These considerations clearly indicate that there is a positive relationship between the number of ATMs and the number of banks, or banks' cash distribution networks. The purpose of the empirical analysis is just to test this proposition. In addition we test the role of ATMs in the cash demand equation. Following equation (2.8) we expect that the demand for cash also depends on number of ATMs (density of ATMs). Possibly also the number of ATM networks affect the demand for cash – if there is just one network that presumably make the use of ATMs more convenient (given the number of ATMs). Finally, we expect the demand for cash to depend on the volume of transactions and the rate of interest in the 'usual way' ie according to (2.1').

3 Empirical results

Now turn to the results of empirical analyses. The analysis makes use of pooled cross-country data from 20 OECD countries.[11] The data cover the period 1988–2003 and we have altogether 242 observations.

The data correspond to the number of ATMs and ATM networks, value of cash in circulation, value of debit and credit card transactions, deposit interest rate, population, Gross Domestic Product (GDP), and private consumption expenditures, both in current and constant prices (and the corresponding implicit deflators). Main data sources are the statistics published by the ECB, the BIS, the Finnish Bankers' Association, the Central Bank of Norway, and the Eurostat.[12]

The number of ATM networks differs across countries. In some countries, there is only one network, whereas in some countries there are dozens of networks. Overall, the number of ATM networks is very low in the European countries, with the exception of Greece. For example, in the UK the number of ATM networks reduced to one at the end of the 1990s and in Spain there are three networks. In contrast, the number of ATM networks is high in Canada and in the USA. There are tens of ATM networks in both countries. The development of ATM networks has differed to some extent between countries. Moreover, the ATM network seems to be somewhat difficult to define. There may be one joint ATM network maintained by one company, which all banks own together. On the other hand, there may be two brands that are in common use, ie customers of both brands can withdraw cash at all ATMs independent of its brand, and this is free for customers. Some countries define such structure as one ATM network. Furthermore, some countries have such networks that provide special services only for the bank's own customers whereas some countries do not report such networks at all.[13] The problem with ATM networks is that the number of open and limited access ATMs has not been separated for all countries during 1988–1995.

[11] Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK, the USA.

[12] A detailed account of data and data sources is available from the authors upon request.

[13] In our estimations, we used the data on ATM networks that are available in the ECB and BIS statistics. However, there are some exceptions. The number of ATM networks is one in Germany because it has been changed from four to one backwards in the statistics of the year 2004. According to the central bank of Germany, this has been done because the interpretation of ATM network has changed. So, there have not been any changes in the real number of ATM networks. Italy seems to be quite similar case because they have changed the number of ATM networks backwards from one to four (four networks since 1996 or 1999, depending on the data source). We used four networks for Italy since 1996, and before that n.a. For Japan, we used the data for the period 1988–1999 because there have been changes in the method of data collection, and the post 2000 data are not consistent with the earlier data. For Finland, the number of ATM networks reported in the statistics has been one since 1994. However, there have been two other, small networks that were closed down in 2004. Because networks have been interoperable, we have not changed the reported values.

Also the numbers of nation-wide and regional ATM networks have not been reported for all countries and for all years.

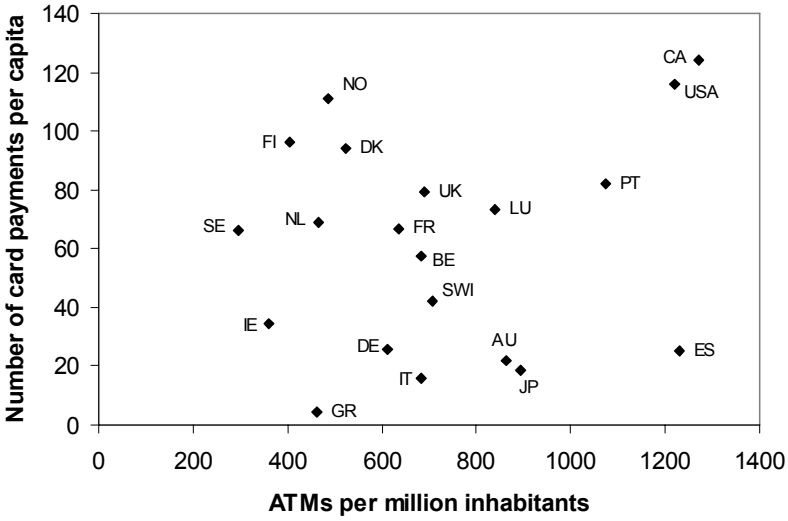
The first cash withdrawal ATMs were installed already in the 1960s in the USA, the UK, Canada, Japan and Sweden. Typically, the first ATM networks were not compatible and banks provided services only to their own customers. Later, the compatibility of ATM networks increased and nowadays there are nation-wide ATM networks that provide services to all banks' consumers. The number of ATMs has been increasing in most of the countries discussed in this study. Finland is the only country where the number of ATMs has considerably decreased during the observation period.

In order to compare the number of ATMs in various countries, we have scaled the number of ATMs by million inhabitants. The number of ATM withdrawals and the value of average ATM withdrawal indicate the usage of ATMs. The number of ATM withdrawals per capita has been increasing in most of the countries during the observation period. Contrary to the number of ATM withdrawals, the average value of ATM withdrawals has been quite stable in most countries. In other words, the growth in the number of ATM withdrawals has been about as rapid as the growth in the value of withdrawals in most countries.

The value of cash in circulation is the other relevant variable in our study. To be able to compare the value of cash in circulation in various countries, we have expressed the nominal values in Euros and scaled the constant price measures by be population. The value of cash in circulation per GDP or private consumption stayed quite stable in most countries in 1988–2001 decreased clearly in the Euro area 2000–2001 because of the Euro conversion to recover again after that.

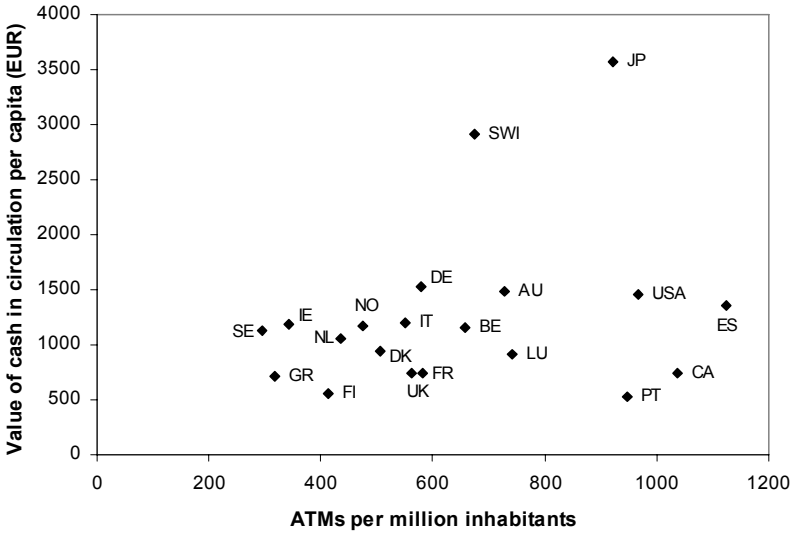
Frequency and value of card payments are relevant explanatory variables for cash balances because card payments are obvious substitutes for cash payments and they serve as instruments for the market share of debit cards in our model. To illustrate the level of electronification we may compare the number of ATMs to the number of card payments (Figure 3).

Figure 3. **The number of ATMs and card payments**



Sources: ECB, BIS, Finnish Bankers' Association and Central Bank of Norway The data are derived from year 2002.

Figure 4. **The number of ATMs and the value of cash in circulation**



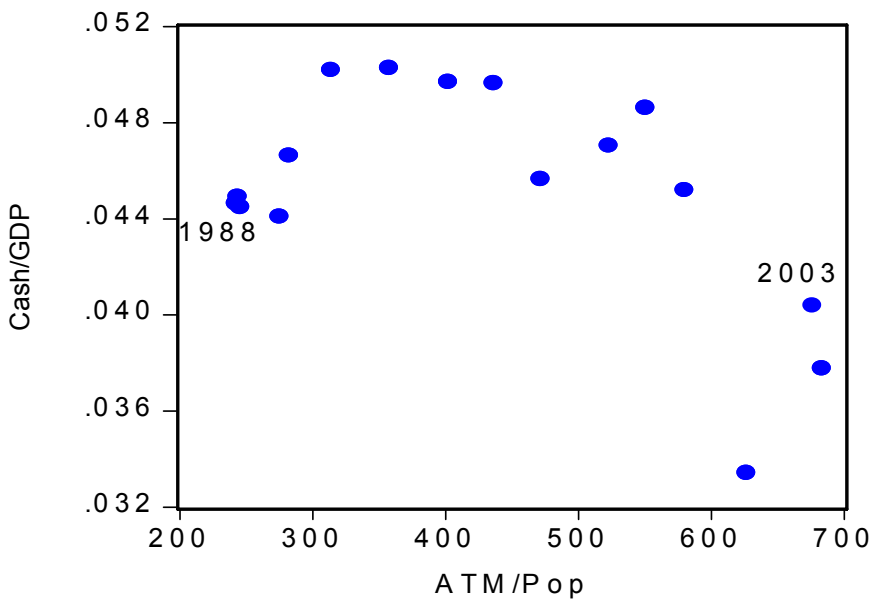
Sources: ECB, BIS, Finnish Bankers' Association and central bank of Norway. The data are derived from year 2000.

Figure 4 in turn compares the value of cash in circulation to the number of ATMs. The relationship is somewhat unclear especially if one excludes Japan and Switzerland which represent some sort of outliers. No surprise, also our estimation results suffer the same ambiguity.

In addition to payment systems data, the data on deposit interest rates are relevant from the point of view of our models (2.8). The deposit interest rate has been decreasing in many countries during the 1990s. In most countries, this rate has been under 10% during the whole observation period. The deposit interest rate has been highest in Greece and Portugal (even 20% in Greece at the beginning of the 1990s) but has decreased during the past years to the level of 2%–3%.

Finally, to illustrate the time series view of the data we show the median values of the currency ratio (Cash/GDP) and the ATM density (ATM/Pop) numbers. Quite clearly the shape of the empirical relationship is an inverted U which reflects the fact that relationship between these two variables is somewhat complicated possibly corresponding to different phases of technical development. The complicated nature of in this relationship also shows up in the subsequent estimation results.

Figure 5. **Median values of ATM/pop and Cash/GDP ratios**



Estimated equations are based on our theoretical model. It is only that we do not have data on the debit card transaction fees v. This would not make much difference if the fees were constant over time and countries but that may not be true. The cash demand equation is basically the Baumol's money demand function. Thus, the transaction variable, the deposit rate and the cost variable are the key determinants. As for the ATM equation, the key determinant is the

number of networks in the economy. The role of this variable is controlled by GDP per capita, the size of population, and the cash/GDP-ratio.

From time series analysis' point of view the data creates problems because most of data are non-stationary. This can be seen from the panel data unit root test statistics reported in Appendix 1.

Obviously, that would give rise analysis of co-integration and specification of an error-correction model. Although we have also looked at the specification from this point of view we have, after all, used a more traditional estimation approach. This is mainly motivated by the relative short sample periods and the panel data set-up. Thus, we have derived the estimating equations from the theoretical model and estimated these long-run relationships with a fixed-effects specification. Both the level and first difference forms are used to see the robustness of results especially in terms of observed non-stationarities. In addition to these standard fixed (or random) effects specifications we estimate some dynamic specifications with the GMM (Arellano-Bond) technique.

A big issue in this context is the simultaneous relationship between cash and the ATMs which needs appropriate instrumenting. In practice that is not easy because we do not have data on (all) relevant exogenous background variables. The role of outliers is also worth acknowledging. To take this problem into account, we use the Huber estimator.

The basic estimating equations are the following two for the number of ATMs and cash

$$a_{jt} = a_{0j} + a_1 net_{jt} + a_2 pop_{jt} + a_3 cy_{jt} + a_4 gdp_{jt} + \varepsilon_{jt}$$

$$cash_{ij} = b_{0j} + b_1 a_{jt} + b_2 gdp_{jt} + b_3 r_{jt} + b_4 card_{jt} + b_5 net_{jt} + b_5 euro_{jt} + \mu_{jt}$$

where
Δ = first difference operator
a_{jt} = number of ATMs per million inhabitants in country j and period t
$card_{jt}$ = value of debit and credit card payments in relation to Gross Domestic Product
cardpc = per capita value of card
$cash_{jt}$ = real value of cash in circulation per capita
cy_{jt} = value of cash in circulation in relation to Gross Domestic Product (GDP)
$euro_{jt}$ = euro conversion dummy
$gdppc_{jt}$ = GDP per capita
net_{jt} = number of ATM networks
pop_{ij} = end-of-year population
r_{ij} = interest rate
ε_{jt}, μ_{jt} = error terms

All (lower case) variables (except for card and euro) are expressed in logs. If not otherwise indicated, all current price variables are expressed in euros.

As a first step we present a set of estimates with these basic equations using the standard panel econometrics estimators (that is, simple pooled data GLS estimator, the fixed-effects GLS estimator (FE) and the random effects GLS estimator (RE)).[14] In addition we use robust (Huber) estimator to assess the impact of outliers. Finally one set of cross-section estimates is included. The corresponding results are tabulated in Tables 1 and 2.

Table 1. **Estimates of the basic ATM equation**

	1	2	3	4	5	6	7
net	.101	.111	.176	.266	.063	.088	.045
	(4.65)	(1.59)	(2.80)	(5.86)	(4.52)	(3.52)	(2.78)
pop	.082	2.574	.179	8.598	.133	.070	.067
	(4.60)	(4.00)	(2.71)	(19.23)	(0.38)	(2.79)	(5.22)
cy	-.149	.043	-.210	-.051	.040	.969	.093
	(2.64)	(0.77)	(1.45)	(0.57)	(1.43)	(0.64)	(1.93)
gdppc	.872	.171	1.891	1.149	.039	.679	.379
	(15.39)	(0.85)	(8.76)	(4.88)	(3.55)	(8.1)	(5.64)
lagged					.836		
dependent					(37.67)		
R^2	.534	.085	.406	.919	.990	..	.239
SEE	.492	.118	.353	.277	.094	..	.342
DW	.113	1.200	.176	.354	1.517	..	..
Panel	no	Dif	RE	FE	FE	no	cross-s
Estimator	GLS	GLS	GLS	GLS	GLS	Huber	OLS
N of obs	242	222	242	242	226	242	20

The dependent variable is log(ATM/Pop). Corrected t-values are inside parentheses. no corresponds to model with no fixed (FE) or random (RE) effects. Dif denotes a first differenced model (without the fixed and random effects). Estimates in the last column are based on sample-averages.

[14] The Hausman tests for correlation of random effects with the RHS variables indicated that the null hypothesis of zero correlation can be rejected – not very decisively but anyway with test statistics that exceed the 5 per cent critical level. Thus, from this point of view the fixed effects specification is slightly preferred in interpreting the results.

Table 2. **Estimates of the basic demand for cash equation**

	1	2	3	4	5	6	7
a	.142	-.020	-.026	-.038	-.005	.242	.363
	(3.84)	(0.95)	(0.74)	(2.01)	(0.50)	(5.75)	(17.33)
gdp	.953	.813	.670	.451	.037	.246	.809
	(23.78)	(5.06)	(5.12)	(4.14)	(0.54)	(15.73)	(20.17)
R	-.128	-.045	-.093	-.075	-.037	-.057	.049
	(9.14)	(4.70)	(4.89)	(6.64)	(5.16)	(2.40)	(5.99)
Euro	-.345	-.327	-.393	-.379	-.352	-.420	-1.820
	(7.61)	(6.68)	(4.87)	(4.60)	(7.62)	(4.13)	(8.59)
card	-.057	.773	-.971	-.050	.029	-.063	-.101
	(21.02)	(1.56)	(2.25)	(0.14)	(0.17)	(14.48)	(8.72)
net	.086	.002	-.034	-.085	-.017	062	.082
	(10.41)	(0.12)	(1.47)	(4.21)	(1.34)	(4.16)	(8.59)
lagged dependent					.870		
					(23.01)		
R^2	.919	.514	.441	.985	.993	..	.844
SEE	.304	.075	.131	.116	.070	..	.207
DW	.171	1.450	.387	.600	1.833	..	..
Panel	no	Dif	RE	FE	FE	no	cross-s
Estimator	GLS	GLS	GLS	GLS	GLS	Huber	OLS
N of obs	231	206	231	231	218	231	20

Dependent variable is log(Cash/P*Pop). Corrected t-values are inside parentheses.
Estimates in the last column are based on sample average.

Also more advances dynamic specification are estimated both in the system form and in a dynamic panel GMM setting (see Appendix 2).

A brief scrutiny of these suggests that, first of all, there is a strong and robust positive relationship between the number of ATM networks and the number of ATMs. According to our interpretation this means that monopolization will reduce the number of ATMs and that in turn will lower the overall use of cash. The number of ATMs seems to follow a quite stable relationship vis a vis the size of the country (measured by population) and the income level (GDP or consumption). By contrast there seem not to be systematic relationship between the currency ratio (Cash/GDP) and the number (density) of ATMs. One might assume that there are more ATMs in countries where cash is used more but that is not necessarily true. One reason to this a bit puzzling result is the fact that the number of ATMs has not been in equilibrium. Then countries which are more advanced in terms payment technology and payment systems might have reached the optimal level earlier than the others which presumably can be characterized with high currency ratios.

As for the results for the demand for cash we find the estimates of the elasticities of the scale variable and the interest rate quite sensible from the point of a standard transaction model of money demand. With the payment system

variables, some ambiguity arises, however. That mainly concerns the role ATMs and ATM networks. Instead the role of card payments seems quite clear and intuitively meaningful: various payment cards crowd out cash payments. With the density of ATMs and the number of ATMs, there seems to be some conflict between cross-section and time series evidence. If fixed effects are not allowed, both variables have a positive effect on cash balances. If, however, fixed effects are introduced, the sign of the effect turns out to be negative (although not very precise). The problem is that with ATM networks we cannot really predict the effect on cash holdings. From consumers' point of view a single network would probably be the best alternative if the number of ATMs would be the same. Thus ceteris paribus, a decrease in the number of networks (given the number of ATMs) would affect cash balances negatively as it in fact turns out in the fixed effects model.[15]

Finally some comments on the system estimation and dynamic panel GMM estimates (Appendix 2) merit note. In general, they follow quite closely the same pattern as the above reported/discussed results. Thus, again, the positive relationship between ATM networks and ATM density can be detected. Also otherwise the results for the ATMS seem to be relatively robust in terms of different estimation methods. As for the cash equation, the results are more sensitive and again we have some ambiguity in terms of the impact of ATMs on cash holding reflecting a bit different time-series and cross-section effects.

4 Concluding remarks

This study has shown that the market structure of the payment system can take quite different forms and differences can have important implications in terms of the use of payment media. The implications can be quite dramatic in terms of cash. In the current system, cash just generates cost to banks while other payment instruments do not lower banks' deposits which still represent the major source of revenue to them. The situation is quite schizophrenic in the sense that banks are responsible for 'selling' central banks products without getting direct revenue or premium. This paper shows that under these circumstances it may well happen that in the future banks organize the distribution of cash in such a way that it becomes too costly for customers and they may switch to other means of payment (in the first place, to various payment cards). This may not be socially optimal.

[15] The development of the demand for cash represents some sort of puzzle because cash balances keep increasing in spite of all technical innovations. The best explanation for this phenomenon is probably an increase in money hoarding for various tax, social security and grey economy reasons (see eg Boeschoten, W. (1992)). To model these factors, is a challenging but an almost compulsory task.

But it does mean that a large number of networks is a good thing; various network sharing solutions might instead a better alternative. An interesting issue is also the question: what will happen to seigniorage revenues and to the money aggregates? Thus, does this possible course of development have any macroeconomic implications? Here we cannot answer to these questions but they surely deserve further analysis.

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Appendix 1

Panel unit root tests

In levels

	Breitung	ADF	PP
ATM network; log(nw)	0,18	15,78	26,96
ATMs per inhabitant; log(apop)	0,3	**59,1**	***183,8***
Cash per GDP; log(cash/gdp)	-0,18	29,1	23,7
Card payments per GDP; log(card/gdp)	1,76	16,37	***82,56***
GDP in real prices per inhabitant; log(gdp/(p*pop))	2,93	11,24	18,42
Population; log(pop)	1,21	***69,36***	***76,88***
Interest rate; log(r)	**-2,05**	20,62	11,23

In first differences

	Breitung	ADF	PP
ATM network; log(nw)	***-4,48***	**38,24**	***77,57***
ATMs per inhabitant; log(apop)	***-2,7***	**60,96**	***152,77***
Cash per GDP; log(cash/gdp)	-1,2	***76,29***	***76,8***
Card payments per GDP; log(card/gdp)	***-3,16***	***68,68***	***155,18***
GDP in real prices per inhabitant; log(gdp/(p*pop))	***-2,82***	***64,75***	***78,16***
Population; log(pop)	**-2,29**	***84,39***	***89,45***
Interest rate; log(r)	***-4,26***	***88,46***	***126,37***

Bold and italic bold test statistics denote significance at 5% and 1% level, respectively. Breitung denotes the Breitung common unit toot t-test, ADF and PP the Augmented Dickey-Fuller and Phillips-Perron individual unit roots Fisher tests, respectively.

Individual country results are available from the authors upon request.

Appendix 2

Further estimation results

	ATM equation				Cash demand equation		
Equation	8	9	10		8	9	10
constant	0.649			constant	0.348		
	(5.24)				(1.42)		
net	0.200	0.167	0.147	a	0.026	-0.020	-0.033
	(3.98	(4.20)	(1.01)		(1.83)	(0.23)	(0.43)
cash	0.024	0.058	0.414	gdppc	-0.005	-.026	0.445
	(1.59)	(0.13)	(1.68)		(0.15)	(0.55)	(0.92)
cardpc	-0.008	0.040	0.059	r	-0.008	-0.015	-0.016
	(0.94)	(0.73)	(0.82)		(3.46)	(3.09)	(3.71)
euro	0.028	0.026	0.181	cardpc	-0.012	0.034	0.026
	(0.77)	(0.15)	(1.98)		(1.22)	(0.72)	(0.53)
lagged dependent	0.884	0.790	0.706	euro	-0.355	-0.315	-0.357
	(46.61)	(6.48)	(3.35)		(13.30)	(7.76)	(5.36)
				lagged dependent	0.953	0.470	0.152
					(51.79)	(1.33	(0.55)
R^2	0.96	0.07	0.15	R^2	0.96	0.48	0.22
J-statistic (34)			29.11	J-statistic (35)			39.5
SEE	0.10	0.11	0.11	SEE	0.10	0.08	0.08
DW	1.32	2.85		DW	1.32	2.06	
Panel	no	Dif	Dif	Panel	no	Dif	Dif
Estimator	TSLS	TSLS	GMM	Estimator	TSLS	TSLS	GMM
N of obs	194	172	173	N of obs	194	172	197

t-values are in parentheses. GMM denotes the dynamic Arellano-Bond GMM estimator. The instrument set used in the dynamic panel data GMM estimation of the ATM equation is the following: $\Delta\ln(m_{jt})$, $\Delta\ln(m_{jt-1})$, $\Delta\ln(x_{jt-1})$, $\Delta\ln(x_{jt-2})$, $\Delta\ln(z_{jt})$, $\Delta\ln(z_{jt-1})$, $\Delta\ln(a_{jt-2})$, $\Delta\ln(a_{jt-3})$, Δi_{jt} and Δd_{jt}. Furthermore, the instrument set used in the dynamic panel data GMM estimation of the cash equation is the following: $\Delta\ln(a_{jt-1})$, $\Delta\ln(a_{jt-1})$, $\Delta\ln(y_{jt})$, $\Delta\ln(y_{jt-1})$, $\Delta\ln(z_{jt})$, $\Delta\ln(z_{jt-1})$, $\Delta\ln(x_{jt-2})$, $\Delta\ln(x_{jt-3})$, Δi_{jt}, Δi_{jt-1} and Δd_{jt}. Neither of the J-statistic is significant standard levels of significance of the $\chi 2$ distribution.

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