BANK OF FINLAND
DISCUSSION PAPERS

8/99

Jussi Snellman – Jukka Vesala

Research Department
20.7.1999

Forecasting the Electronification of Payments with Learning Curves: The Case of Finland

SUOMEN PANKIN KESKUSTELUALOITTEITA • FINLANDS BANKS DISKUSSIONSUNDERLAG

Suomen Pankki
Bank of Finland
P.O.Box 160, FIN-00101 HELSINKI, Finland
☎ + 358 9 1831

Jussi Snellman* – Jukka Vesala**

Research Department
20.7.1999

Forecasting the Electronification of Payments with Learning Curves: The Case of Finland

* Bank of Finland, Research Department, P.O.Box 160, FIN-00101 Helsinki, Finland. e-mail: jussi.snellman@bof.fi

** While conducting this research, Jukka Vesala worked at the Bank of Finland, Research Department. e-mail: jukka.vesala@ecb.int

The authors wish to thank Markku Hirvonen (Finnish Bankers' Associastion), David Humphrey, David Mayes, Harry Leinonen, Juha Tarkka, Jouko Vilmunen and Matti Virén for help, comments and suggestions. All errors are, nevertheless, ours.

ISBN 951-686-617-4
ISSN 0785-3572

Suomen Pankin monistuskeskus
Helsinki 1999

Forecasting the Electronification of Payments with Learning Curves: The Case of Finland

Bank of Finland Discussion Papers 8/99

Jussi Snellman – Jukka Vesala
Research Department

Abstract

This paper examines the electronification of noncash payments in Finland and the extent to which noncash payment means are used as substitutes for cash. We model the processes of cash substitution and electronification of payments as 'S' -shaped learning curves and generate forecasts by extrapolating these curves. The 'S'-shaped learning curves fit the data well. Our results indicate that in Finland the cash substitution process as a whole is approaching the saturation point. Although the electronification process is clearly ongoing as regards larger-value bill payments, for small-value point-of-sale payments we seem to have reached saturation. Electronification of payments, having progressed swiftly and extensively in Finland, is already beginning to slow down. We conclude the paper with a discussion of the reasons for this turn of events and of the different factors that affect the speed of diffusion of new means of payment.

Keywords: payments, electronification, learning curves

Suomen maksuliikkeen elektronisoituminen: Oppimiskäyräanalyysi ja ennusteet

Suomen Pankin keskustelualoitteita 8/99

Jussi Snellman – Jukka Vesala
Tutkimusosasto

Tiivistelmä

Tässä keskustelualoitteessa tutkitaan ei-käteismaksujen elektronisoitumista ja käteismaksujen korvautumista muilla maksutavoilla Suomessa. Käteissubstituutio- ja elektronisoitumisprosesseja mallitetaan käyttäen oppimiskäyriä, eli nk. ’S’-käyriä, ja ennusteet prosessien jatkumisesta generoidaan ekstrapoloimalla saatuja käyriä. Mallinnustapa sopii aineistoon hyvin. Saadut tulokset viittaavat siihen, että käteisen korvautuminen olisi Suomessa jo edennyt lähelle pitkän ajan tasapainotasoaan. Korttimaksujen elektronisoitumisprosessi näyttää jo saturoituneen, kun taas laskujen maksaminen elektronisoituu edelleen nopeasti. Kaiken kaikkiaan maksuliikkeen elektronisoituminen on Suomessa ollut poikkeuksellisen nopeaa. Se on edennyt pitkälle ja saavuttanut jo hidastuvan vaiheen. Lopuksi tuodaan esille tekijöitä, jotka ovat todennäköisesti vaikuttaneet elektronisoitumisprosessin nopeuteen.

Asiasanat: maksuliike, elektronisoituminen, oppimiskäyrät

Contents

1 Introduction

During the 1980s and 1990s banks have increasingly replaced paper-based payment methods of their 'front office' operations with electronic systems. This phenomenon has been World-wide, but in some countries, notably Finland, the process has been very rapid. Our paper analyses the electronification of payments in Finland by modelling the electronification processes as 'S'-shaped learning curves (logistic and Gompertz),[1] which have been found to depict well the diffusion of many innovations. This technique has been usefully applied to forecast telephone adoption and use, the adoption of robots in automobile manufacturing, and many other applications, but to our knowledge this is the first time it has been applied to payment patterns, although there are good reasons to think that the acceptance of new payment instruments would conform to the common 'S'-shaped pattern of the diffusion of innovations.[2]

The quality of Finnish data allows us to measure the payment flows and electronification process in a detailed manner, since separating electronic payments by the nature of the customer-bank linkage, ie. whether it is electronic (paperless) or paper-based, is possible. We are also able to use a more accurate classification of payments by 'end use', whether payments are effected to pay small value point-of-sale (POS) purchases, larger value bill payments or disbursements by firms and the government. Different payment instruments substitute each other within but not much between these classes.

The Finnish case indicates that, once the process gets going, the adoption of electronic payments may advance rapidly, in the way predicted by the 'S'-curve models. The transformation of payment patterns can thus be fast in a favourable institutional environment for new payment innovation (concentrated banking system, competition policy and legislation), and diffusion of innovations ('critical' mass of computers and computer-literate clientele on the demand-side, and banks' strategies for boosting electronic payments on the supply-side).

We first describe in section 2 the data on payments in Finland used in this study. Methodological issues of fitting the 'S'-shaped learning curves to the data and generating forecasts are discussed in section 3, and estimation results and forecasts presented in section 4. In section 5 we briefly return to factors (institutional and legislative features, and banks' supply-side actions) supportive to innovation in the payments field. Finally section 6 concludes.

Electronification is increasing the efficiency of the payment system: lowering the total social cost of making payments and increasing the speed of transactions. The volume of payment transactions rather than the face value of payments is decisive for efficiency, since the face value of payments does not bear much relevance for the amount of resources needed to process those payments. A ten markkaa transaction costs approximately the same as a transaction with a thousand-fold value. Moreover, the value approach would distort the analysis of the extent of electronification, since big payments tend to be (at least in Finland) more paper-based than small payments (excluding cash payments). For these reasons, we mostly resort to payment volumes in this paper.

---

[1] 'S'-shaped learning curves are also commonly referred to as growth curves (eg Meade and Islam 1995a).

[2] A working paper by Humphrey et al. (1998) applies learning curves to examine the substitution of cheques with other payment means in the US.

2 Categorisation and description of data

Characterisation of data. The data characterising noncash payments in Finland are collected by the Finnish Bankers' Association, and are described in Appendix 1. The data set consists of yearly observations from 1988 to 1996 covering the payment traffic through the Finnish banking sector, which accounts for the almost entire payment traffic in the Finnish economy. The data are arranged into a panel consisting of nine yearly observations for four main Finnish banks or banking groups, which renders a total of 36 observations.

It is quite common in the literature to have only a few observations to estimate the learning curves, since long time series are seldom available, and many innovations are not that long lived either. Moreover, not so many observations are needed to characterise a 'S'-shaped learning curve.[3] Besides increasing degrees of freedom, the panel approach allows us to control for bank specific differences due to differences in banks' clientele (different demographic groups), or differences in banks' policies, particularly pricing, which affect the use of the various payment instruments by their customers. The data confirm that there are indeed significant differences in clients payment patterns across banks' customers.

Categorisation of data. The various payments effected in an economy should not be regarded as homogeneous transactions, but instead payments should be categorised by their 'end uses'. The Finnish payments data allow us to categorise noncash payments transfers into:[4]

(1) point-of-sale (POS),
(2) bill payment (BP) and
(3) disbursement (DB).

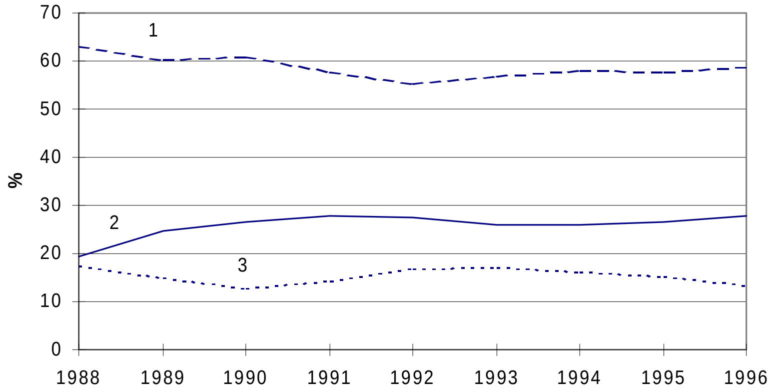
The idea is that distinct payment needs underlie these classes of transactions, and various payment instruments substitute within, but not much across the classes. This notion gets support, when the shares of the three payment classes are graphed over time. Figures 1 and 2 show that over our sample period the shares of the three categories have remained fairly constant with respect to the total number or value of transactions. During the early years of the sample did payments with debit and credit cards substitute for credit transfers to some extent due to the rapid diffusion of payment cards and Electronic Fund Transfer at Point Of Sale (EFT-POS) -terminals, which permit efficient conduct of card payments. In terms of our categorisation this resulted in a fall in the relative share of bill payment transfers and increase in POS-payment transfers. However, by and large the data support the notion that there is a reasonably constant relative need for POS-, BP- and DB-transactions, and only the ways of effecting them change over time. In addition,

[3] For example, Young and Ord (1989) have only 10 observations in analysing the diffusion of phones on electronic switching systems in the US, or 24 observations to examine the diffusion of cable TV among households. Meade and Islam (1995a) use some 10 observations to analyse the diffusion of phones in various countries.

[4] Common practise is to classify payments according to, whether they are credit or debit transactions, but this classification neglects the aspect of actual 'end use' of the various instruments. Our three classes can comprise both credit and debit transactions.

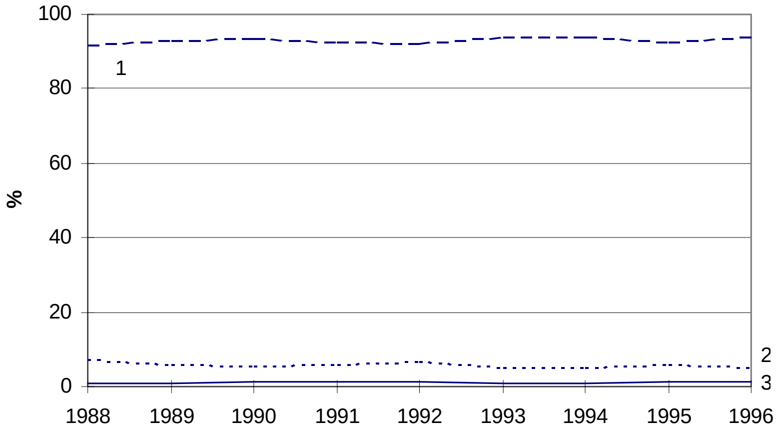
various payment needs explain, why different payment instruments can co-exist despite of the apparent efficiency and cost differences between them.

Figure 1. **Shares of different payment types in total volume of payments**



1 Bill payments
2 POS-payments
3 Disbursements

Figure 2. **Shares of different payment types in total value of payments**



1 Bill payments
2 Disbursements
3 POS-payments

Exhibit 1. **Categorization of the Finnish payment data**

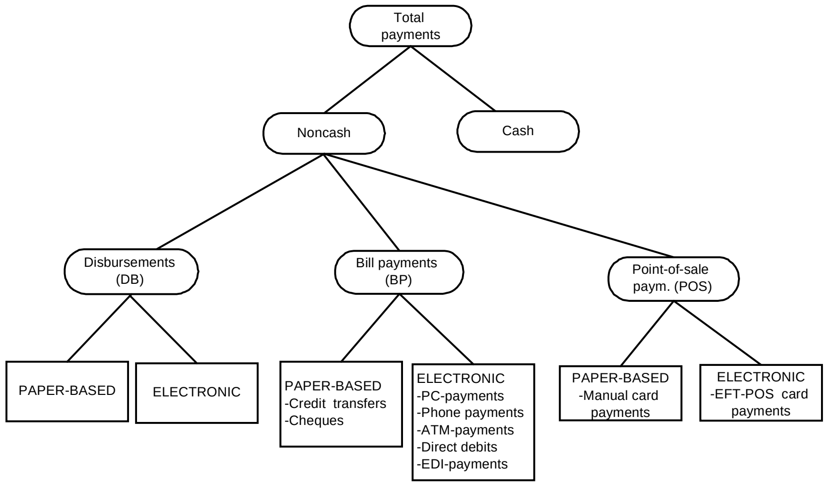


Exhibit 1 summarises our categorisation of the Finnish payments data. We define, in general, *electronic payments* as the ones, where *payment information is transmitted by electronic means from the payer to the bank* (credit transfers), or *from payee to the bank* (debit transfers). The interbank transfers of payments between payers' and payees' banks have been fully electronic in Finland over the sample period. In case of *paper-based payments, payment information is transmitted manually on paper.* A brief explanation of the items falling into the various payment categories is in order.

POS-payments represent almost exclusively consumers' small value payments of day-to-day purchases of retail goods and services: groceries, bus tickets and so forth. As cash is also mainly used for POS-payments, noncash POS-transfer instruments represent its main substitutes. The share of POS-transfers in the total transfer volume is much bigger than in the total transfer value, since the average value of the POS-transfers (FIM 230 over the sample period) is much smaller than the average value of all noncash transfers (FIM 16 300**)**. Payments by credit or debit cards via EFT-POS -terminals represent electronic POS-transfers. Paper-based noncash POS-transfers constitute manually handled card payments only, since in Finland cheques were not used for POS-transactions to significant extent during the sample period.[5] They were mainly used by firms for large bill payment transactions, and their average value was quite high (FIM 140 000).

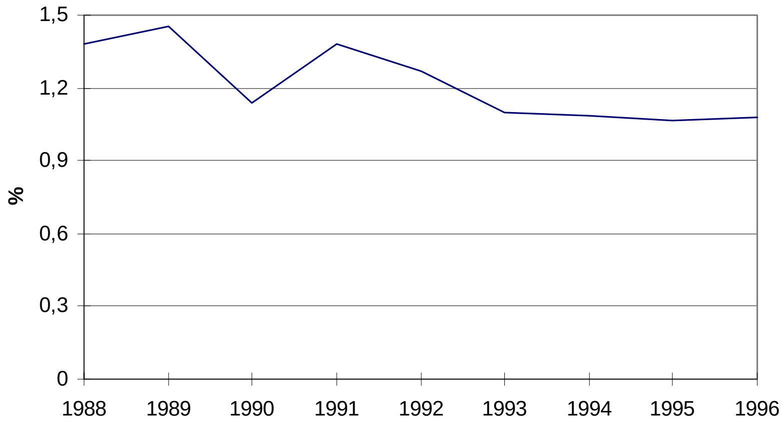
As regards *cash*, the problem is to get data characterising the flow of cash payments in the economy, which is very difficult to proxy with stock information about the amount of cash outstanding outside the banking sector. To tackle this problem, we use two independent approaches.[6] First, we use the existing exact information on the cash withdrawn from cash dispensing ATMs, which constitutes a bulk of the flow of cash used for transactions purposes in Finland. These data are then adjusted for the amount of cash withdrawn from branch

[5] This does not hold, naturally, for countries that rely heavily on cheque use, notably France, the UK and the US.
[6] The companion paper Humphrey et al. (1998) presents yet another approach based on a novel method of using information on currency stock and noncash transfers to approximate the flow of cash payments.

offices over-the-counter to produce an estimate of the total amount of cash distributed through the banking system by using information from banks and a survey by Virén (1993).[7] The second approach is to approximate the value of cash used in transactions by the nominal value of retail trade minus noncash POS transfers. The estimates obtained through these two approaches are very close.

We do not have information on the number of transactions effected with cash, and hence for cash value-based estimations only are conducted. Surveys suggest that the share of cash is much higher in volume than value terms, since cash is used for the lowest value payments of all instruments.[8] In Finland, cash has accounted only for an average of roughly 1,2 per cent of all payment expenditures according to our approximations (Figure 3).

Figure 3. **Share of cash payments (our estimate) in total value of payments**



Bill payments represent transactions by consumers, businesses and local and central government for paying housing, utility and service, large purchases of durable goods, business-to-business payments and government purchases. Credit transfers are the primary means of effecting bill payments in Finland, as in many continental European countries. Consumer initiated electronic bill payments comprise payments via developed ATMs ('payment kiosks'), home-banking transactions via phone or PC, and direct debits, which refer to payments the payer has authorised in advance to be debited automatically from his account. The main method for consumers to effect paper-based credit transfers is to hand or send the bill to the bank to be effected at the due date. Businesses' and goverments' bill payments have been almost completely electronic via computer terminals and online transfer of payment information (eg EDI) for quite some time. Urgent financial market and business credit transfers on the same value date are, however, effected by paper-based means (most often via fax). The average value

[7] The value of ASM-withdrawals has increased from FIM 26bn to FIM 82bn, ip. 20 % during the sample period (1988–1996). The share of cash withdrawn over the counter is estimated to have decreased from 70 % to 20 % of all cash withdrawds in 1988–1996.

[8] Cash transactions are estimated to represent 78 % of the number of all transactions in the Netherlands, 83 % in Finland and the US, 86 % in Germany, and 90 % in the UK (Boeschoten 1992, Humphrey 1984 and Virén 1993).

of these transactions is quite high, which causes the overall average value of bill payments to rise to quite a high figure (FIM 24 100).

The data allow us to investigate separately consumers' bill payments, which are subject to a more recently started, and still immature electronification process. ATM-payments have been the most rapidly growing transfer method for consumers. Their share in consumer bill payments has increased from 0 to 29 per cent over the sample period 1988–1996. Direct debits have not become so popular in Finland as in certain other countries. PC- and phone-payments could be expected to increase quite fast in the future, since around 50 per cent of banks' private customers have already taken up home-banking contracts. However, the share of PC- and phone-payments in consumers' bill payment transactions was only 5,5 per cent in 1996, but increasing rapidly.

Disbursements constitute *regular* business and government payroll and transfer payments. Practically all disbursements have been effected by electronic, nonpaper means for quite a long time in Finland. The average value of disbursements falls between overall bill payments and POS-payments (FIM 2 650 over the sample period).

Figures 4 and 5 show that the change in the overall degree of electronification has been quite substantial over the sample period, especially in transaction volume terms.

Figure 4. **Share of electronic payments in total volume of noncash transactions**

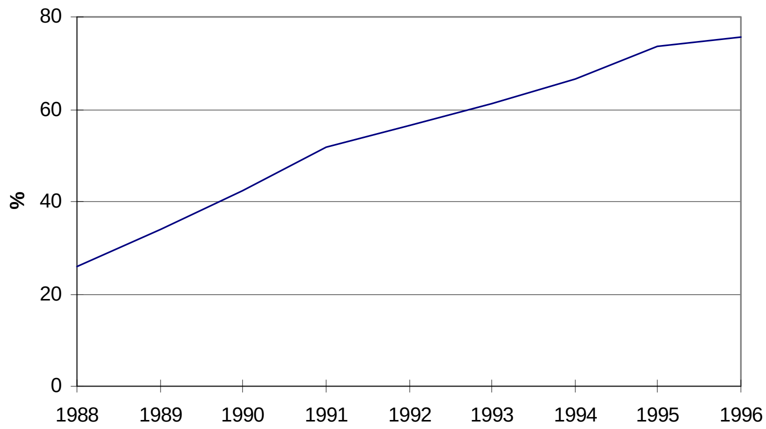
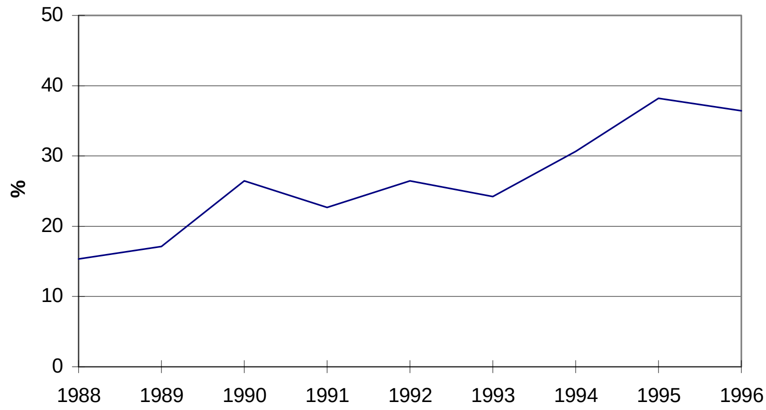


Figure 5. **Share of electronic payments in total value of noncash transactions**



In each of the payment classes, we analyse the adoption of electronic payment methods as ’S’-styled learning processes. We also look at the total payments to get a view on the electronification of the entire payment traffic. Before turning to the estimation results, however, let us first discuss the methodological issues.

3 Methodological issues

There is evidence that demographic factors strongly affect the speed at which people adopt new payment innovations.[9] Hence, the diffusion of consumers’ electronic payment means according to a ’S’-curve model can be viewed as a process through different demographic groups, where the young and wealthy individuals are the likely first adopters of a new innovation. These first adopters are then imitated by the other groups as the innovation matures, becomes more commonplace and accepted by a large number of vendors. Typically a slow start to diffusion is followed by an accelerating phase. At some stage, however, the pace usually begins to slow down, as quite often some individuals are reluctant to adopt all new ideas. It may well be that some are never going to adopt a particular innovation, thus implying saturation of the process at below the 100 per cent diffusion level.

In some cases only one innovation underlies the electronification process, e.g. card payments effected via EFT-POS terminals shifting POS-transfers into electronics. There are other cases, like household bill payments, in which there are simultaneous innovations (ATMs, phone- and PC-banking and direct debits) advancing in a more or less congruent manner. Then we are actually dealing with a ’composite’ curve of numerous innovations, which also follows the ’S’-shaped pattern.

---

[9] E.g. the survey by Kennickell and Kwast (1997) finds that household heads under the age of 35 are considerably more apt to use PCs for payments in the US than the older ones. Wealth is also, according to them, an important explanatory variable of the switch to new electronic payment techniques.

Model selection. The two basic learning curve models used in the literature are the (simple) *logistic* and *Gompertz*-curves.[10] From these, many other and more complex models have been developed.

The logistic curve is defined as:

$$X_t = \frac{a}{(1 + c\exp(-bt))} + \varepsilon_t , \tag{3.1}$$

and Gompertz-curve as:

$$X_t = a\exp(-c(\exp(-bt)) + \varepsilon_t , \tag{3.2}$$

where X_t is *the share of payments* (e.g. electronic POS-transfers) *investigated in each payments class* (e.g. total POS-transfers) at time t. The *saturation level*, to which the diffusion process converges, is denoted by a. The *coefficient of diffusion*, b, determines the slope of the curve, and *the scaling coefficient*, c, the vertical position of the curve. ε is an error term. The main difference between the two curves is that the logistic curve is symmetric about is point of inflection, but the Gompertz-curve is not.

We concentrate our estimation efforts on the two basic models, since we consider them to make up a sufficiently rich set of models for our purposes. These models have proved to fit the data well in many applications and they produce good fits in our own estimations. Thus, there seem to be little need to experiment with more complex models. Also only three parameters need to be estimated, which is important given the limited size of our data. Finally, the numerous comparisons of learning curve models by Meade and Islam (1995a) imply that the two simple low-parameterised models tend to outperform more complicated models in terms of forecasting performance.

Estimation procedure and model selection. Estimates were obtained both restricting the saturation level to 100 per cent and letting the saturation level to estimate freely. Free estimation is preferred a priori, since it may well be that some payments in a category will never shift to electronics. For example, it may not be worth while for small boutiques to install electronic card reading technology, but instead stick to cash or manual handling of cards. It is also possible that elderly people in particular may be reluctant to shift to electronic forms of payment completely. In any case, both results with freely estimated saturation levels and constrained saturation levels, and corresponding forecasts, are presented. Forcing saturation to 100 per cent results in forecasts of faster future diffusion than does constructing forecasts on the basis of the free parameter estimation when free estimation saturates before the 100 per cent level.

To control for the differences specific to each banks' clientele, individual bank dummies are attached to all three 'basic' parameters a, b and c, for all but one bank in the sample to avoid singularity. Hence, the estimation of (3.1) or (3.2) corresponds to nonlinear fixed effects least squares (LS)-estimation using panel

[10] See e.g. Meade (1988), Young and Ord (1989), Gamerman and Migón (1991 and 1993), and Meade and Islam (1995a).

data. The adoption of bank dummies leads to twelve estimated parameters at maximum, leaving 24 degrees of freedom.[11]

The purpose of the model selection exercise is to pick the model yielding the most accurate forecast in statistical terms. We calculate the Mean Aggregate Forecasting Error (MAFE) for each model as a weighed average of the deviations between the observed historical values and fitted values concerning each bank in the sample. Banks' shares in the payment traffic in question constitute the respective weights, which vary across the yearly cross-sections. The model yielding the lowest MAFE is then selected as the preferred one.

Forecasting procedure. L-period ahead forecasts are constructed in the following way for logistic and Gompertz-curves, respectively:

$$E(X_{t+L}) = \frac{a}{(1 + c\exp(-bL))} \tag{3.3}$$

$$E(X_{t+L}) = a\exp(-c(\exp(-bL))), \tag{3.4}$$

where a, b and c are the estimated parameters, and E the expectations operator.[12]

We observe electronification processes at different stages of the learning curve, and in some cases, for example, the dampening effects do not yet emerge in the data. In these circumstances forecasting is the most valuable exercise, as there is no indication of the convergence of the diffusion process. However, in many cases, as we will see in section 4, both the phase of accelerating and dampening diffusion take place within the sample period.

4 Estimation results and forecasts

In each case, the asymmetric Gompertz -curve is selected as the preferred model. The differences between logistic and Gompertz-curves were small in terms of the MAFEs, but on the aggregate level constantly favour the latter. At the bank-level, the logistic model produced a smaller MAFE in very few cases. Estimation results and forecasts for both Gompertz and logistic models are summarised in Tables 1

[11] With a large number of observations it is recommended (e.g. in Young and Ord 1989) to use discounted LS estimation, and to put a smaller weight on the observations extending far back in time than on the more recent observations. They note, however, that with only a few data points the discounting procedure would not provide significant improvement in the forecast. We think that the latter case holds here, and we chose to neglect discounting.

[12] The third commonly used way to generate forecast is the so-called local logistic approach, namely: $E(X_{t+L}|X_t = x_t) = \frac{ax_t}{(x_t + (a - x_t)\exp(-bL)}$. It differs from simple logistic approach by putting more weight on the last observation of the data and thus yields differing forecasts if the last observation is significantly different from the fit, ie the value predicted by the logistic model. This 2-parameter method performed worse than the 3-parameter models in our case and is thus not reported.

to 5 with respect to the various payment classes.[13] Parameter estimates were robust with respect to the choice of starting values.

The main overall result is that the ’S’-curve approach fits the data well. The adjusted R-squared exceeds 90 per cent in almost all cases. Thus the nature of payment pattern change can, as can many other technological innovations, be characterised as a process following ’S’-shaped learning curve. We report aggregate results concerning the entire payment traffic. The aggregate forecasts are constructed by weighting the individual banks’ forecasts with constant weights based on their shares in payment traffic in 1996. The results all refer to payment transaction volumes except in the cash-substitution model. In each case we depict the preferred model fit and forecast (Gompertz-curve) also graphically.

<u>Share of cash in total POS-payment value.</u> As can be seen from Figure 3, the share of cash payments in the total value of payments declined a little during first six years of the sample, but remained fairly steady during the last three years.

As noncash transcations are the main substitute for cash, we fitted the learning curves to the shares of cash POS-transactions in the total value of (noncash POS-transfers plus cash) POS-payments. The results (Table 1) concerning the free Gompertz-model indicate that the use of cash has almost declined to its saturation level already, estimated freely at 63 per cent. The phase of fast substitution has apparently already taken place. From the last observation of around 70 per cent, the share of cash is predicted to fall to 65 per cent in the next 10 years, being then very close of its saturation level. In this case, the logistic model has a considerably worse fit, predicting a saturation level of 72 %, thus indicating that the cash-substitution process is already completely saturated.

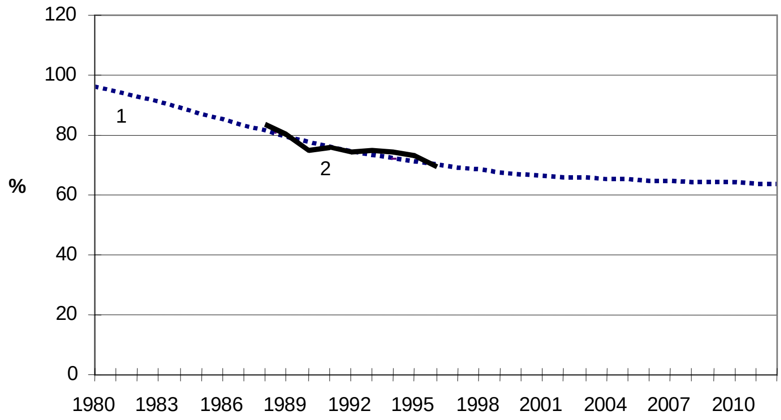
[13] In some cases, the full model containing twelve parameters (ie bank dummies for each of the three ’basic’ parameters a, b and c failed to converge due to insignificant differences across banks. The solution adhered to was to reduce the number of dummies.

Table 1. **’S’-curve models for cash-based POS payments (transaction values)**

		Saturation level free Estimated average share of cash payment Gompertz	 Logistic
Observed shares	1989	0,83	
	1996	0,69	
Forecast	1997	0,69	0,72
	1998	0,68	0,72
	1999	0,68	0,72
	2000	0,67	0,72
	2001	0,67	0,72
	2002	0,66	0,72
	2003	0,66	0,72
	2004	0,65	0,72
	2005	0,65	0,72
	2006	0,65	0,72
	level %	Years to reach the level	
Forecast	70	reached	never
	65	8	never
	60	never	never
	55	never	never
	50	never	never
Estimated aggregate saturation level (a)		0,63*	0,72**
(Standard error)		0,11	0,02
Estimated aggregate coefficient of diffusion (b)		0,790*	1,02*
Estimated aggregate scaling coefficient (c)		0,147	0,51
MAFE %		1,82	2,06
Wald test prob.***		0,0000	0,0000
Adjusted R-squared		0,811	0,794

* Significant at 1 % level
** Significant at 5 % level
*** Test for rejecting model with free saturation level, prob. value

Figure 6. **Share of cash-based POS payments in total value of POS-payments, Gompertz (free saturation)**



1 Gompertz fit and forecast
2 Data (our estimate)

The fact that the saturation occurs at quite a high level of cash use for POS-payments may sound somewhat surprising. Many have predicted that substitution of cash continues at an accelerating rate. However, the result seems intuitively acceptable for current payment technologies. The noncash forms of POS-payment, namely card payments have been available for quite a long time now, and thus transition from cash to cards may have already occurred to a large extent. Moreover the diffusion of EFT-POS terminals seems to have already reached saturation in Finland. The number of the terminals in Finland per 1 000 inhabitants rose from 2,3 in 1988 to 10,2 in 1996. In international comparisons, card use has been quite frequent in Finland indicating that in Finland cash is relatively seldom used. Investigation of, say, the ratio of outstanding cash to GDP suggests the same (eg Humphrey et al. 1996, Humphrey et al. 1998).

The factor which may change the result of a rather high saturation level of cash use, and perturb the forecasted pattern, is the emergence of new forms of payment means that substitute for cash more closely than cards do, especially e-cash loaded on chip card. Its proponents tend to market it as a 'true' replacement of cash. The key question is indeed the future effect of e-cash on the process of cash substitution. Will e-cash constitute a shock which causes a level change in cash substitution, or will it just affect the existing trend in a less dramatic manner, or will it be just another facet of the electronification of POS-payments, without strong impact on the underlying trend captured in our estimations? Since the e-cash users still preriminary, these questions remain principally open at this stage.

Share of electronic POS-transfers in the total POS-transfer volume. These results are presented in Table 2 and Figure 7. Characteristic is that in the freely estimated case a saturation level of approximately 89 per cent (88 % in logistic case) of electronic payments has already been reached. Forcing saturation to the 100 per cent level worsens the fit significantly.

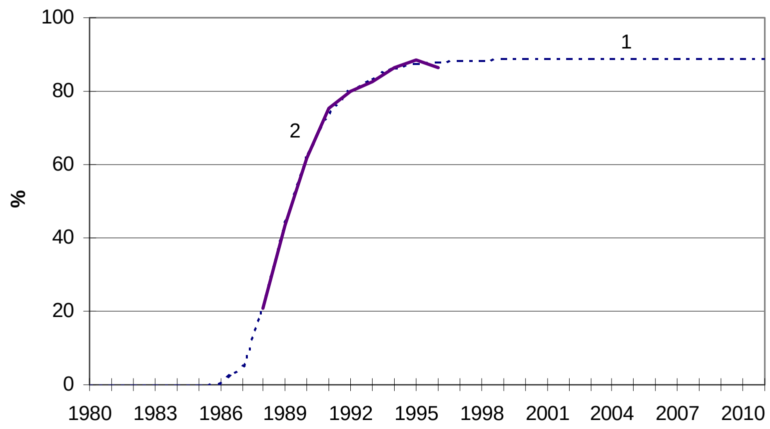
These results are probably due to the fact that EFT-POS terminals, which allow the electronic handling of card payments, have already been widely adopted by retailers, and are unlikely to spread significantly wider. Also a large number of consumers already have payment cards in their possession. Hence, the result obtained under free estimation seems quite plausible. Those businesses without a terminal are usually relatively small, and thus are unlikely to find installing an EFT-POS terminal worthwhile. Diffusion of e-money could change this pattern in the future, since there is an indication that the machines to read e-cash from chip cards could be significantly cheaper than the EFT-POS terminals. E-cash could then expand the number of retailers accepting payment cards from that determined by the current technology.

Table 2. **'S'-curve models for electronic POS-transfers (transaction volumes)**

		Saturation level free		**Saturation constrained to 100 %**	
		Estimated average share of electronic payments			
		Gompertz	Logistic	Gompertz	Logistic
Observed shares	1988	0,21			
	1996	0,86			
Forecast	1997	0,89	0,87	0,97	0,98
	1998	0,89	0,88	0,98	0,99
	1999	0,89	0,88	0,99	0,99
	2000	0,89	0,88	0,99	1,00
	2001	0,89	0,88	0,99	1,00
	2002	0,89	0,88	1,00	1,00
	2003	0,89	0,88	1,00	1,00
	2004	0,89	0,88	1,00	1,00
	2005	0,89	0,88	1,00	1,00
	2006	0,89	0,88	1,00	1,00
	level %	Years to reach the level			
Forecast	85	reached	reached	reached	reached
	90	never	never	reached	reached
	95	never	never	reached	reached
	100	never	never	6	4
Estimated aggregate / imposed saturation level (a)		0,89*	0,88*	1	1
Standard error		0,005	0,0002		
Estimated aggregate coefficient of diffusion (b)		0,711*	0,965*	0,437*	0,548*
Estimated aggregate scaling coefficient (c)		2,857*	7,329*	2,006*	3,958*
MAFE %		1,94	2,28	9,79	11,39
Wald test prob.**		0,000	0,000		
Adjusted R-squared		0,989	0,988	0,898	0,86

* Significant at 1 % level
** Test for rejecting model with free saturation level, prob. value

Figure 7. **Share of electronic POS-transfers in the total volume of POS-transfers, Gompertz (free saturation)**



1 Gompertz fit and prediction
2 Data

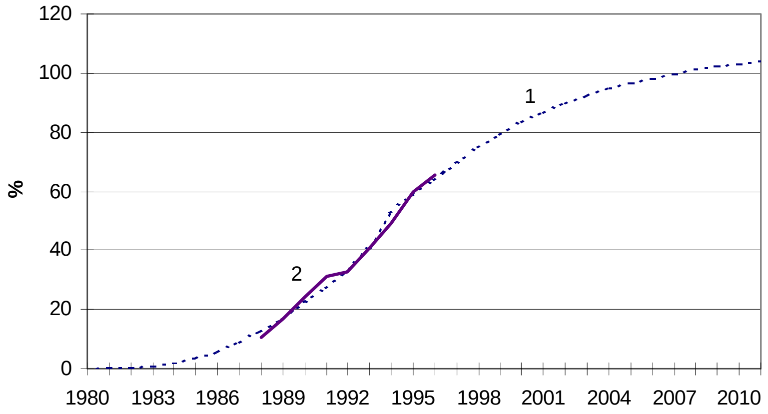
<u>Share of electronic bill payments in total bill payment volume.</u> Table 3 and Figure 8 summarise the results for total electronic bill payments. According to the results, the diffusion process is still going on. Forecasts based on a freely estimated saturation level imply that the bill payments will turn completely electronic by ten years from now. Note that the Gompertz model produces freely a saturation level slightly exceeding 100 per cent. It has, however, a rather large standard error, and according to Wald-test hypothesis of 100 per cent saturation level cannot be rejected. The logistic model yields a lower saturation level, namely 91 per cent. When saturation is constrained to 100 per cent, the share of electronic payments continues to rise rapidly, e.g. to 90 per cent level in 9 years based on the Gompertz-model and in 6 years based on the logistic model.

Table 3. **'S'-curve models for electronic bill payments (transaction volumes)**

		Saturation level free		Saturation constrained to 100 %	
		Estimated average share of electronic payments			
		Gompertz	Logistic	Gompertz	Logistic
Observed shares	1988	0,11			
	1996	0,66			
Forecast	1997	0,70	0,70	0,69	0,72
	1998	0,75	0,74	0,73	0,77
	1999	0,79	0,78	0,77	0,82
	2000	0,83	0,81	0,80	0,86
	2001	0,87	0,84	0,83	0,89
	2002	0,90	0,86	0,86	0,91
	2003	0,93	0,87	0,88	0,93
	2004	0,95	0,88	0,90	0,95
	2005	0,97	0,89	0,91	0,96
	2006	0,99	0,89	0,92	0,97
	level %	Years to reach the level			
Forecast	75	2	3	3	2
	85	5	6	6	4
	90	6	12	9	6
	95	8	never	13	8
	100	11	never	> 15	> 15
Estimated aggregate / imposed saturation level (a)		1,09*	0,91*	1	1
Standard error		0,21	0,29		
Estimated aggregate coefficient of diffusion (b)		0,190*	0,384*	0,212*	0,327*
Estimated aggregate scaling coefficient (c)		2,99*	14,95*	3,01*	14,99*
MAFE %		5,87	6,81	5,58	8,00
Wald test prob.**		0,660	0,00001		
Adjusted R-squared		0,957	0,955	0,958	0,957

* Significant at 1 % level
** Test for rejecting model with free saturation level, prob. value

Figure 8. **Share of electronic bill-payments in total volume of bill payments, Gompertz (free saturation)**



1 Gompertz fit and prediction
2 Data

The results for consumers' bill payments are summarised in Table 4 and Figure 9. Compared to total bill payments, the process of electronification will become saturated earlier according to our estimates. Free estimation produces saturation levels significantly below 100 per cent (Gompertz 81 %, and logistic 67 %). The results indicate that at the moment the diffusion process is still in the stage of fast growth, but about to slow down in the near future.

Free estimation seems again more sensible than constrained, since some clients are likely to keep the paper-based bill payment techniques also in the future. In terms of the Gompertz-model the share of consumer electronic payments reaches 75 per cent in 8 years. The logistic model decelerates the rate of diffusion and forecasts that the 90 per cent level is achieved in 7 years.

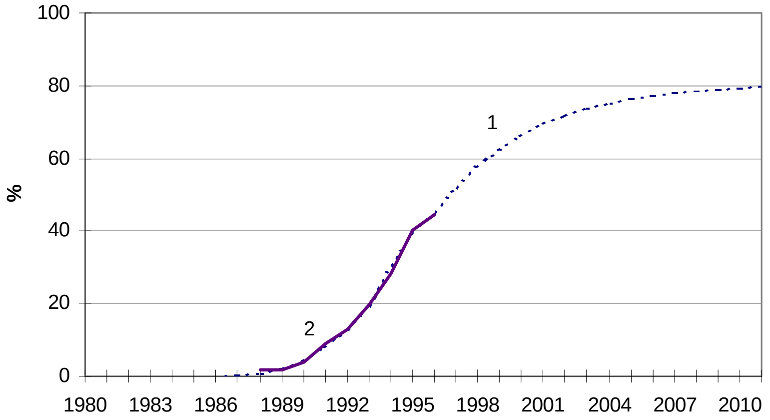
The electronification of consumers' bill payments has been quite substantial over the sample period, from almost 0 per cent up to 45 per cent at the end of the period. As the logistic model is symmetric about its point of inflection, it therefore tends to predict a similarly rapid growth in the future, whereas the Gompertz-model, by allowing for asymmetrity, lets the growth trend slow down, as already visible in the data. Hence, the Gompertz-model performs better statistically than the logistic model in this case.

Table 4. **'S'-curve models for electronic consumer bill payments (transaction volumes)**

		Saturation level free		Saturation constrained to 100 %	
		Estimated average share of electronic payments			
		Gompertz	Logistic	Gompertz	Logistic
Observed	1988	0,02			
shares	1996	0,45			
Forecast	1997	0,52	0,52	0,53	0,56
	1998	0,57	0,57	0,60	0,65
	1999	0,62	0,60	0,65	0,73
	2000	0,66	0,63	0,71	0,79
	2001	0,69	0,64	0,75	0,84
	2002	0,72	0,65	0,78	0,88
	2003	0,74	0,66	0,81	0,90
	2004	0,75	0,67	0,84	0,93
	2005	0,77	0,67	0,86	0,94
	2006	0,77	0,67	0,88	0,96
	level %	Years to reach the level			
Forecast	75	8	never	5	4
	85	never	never	9	6
	90	never	never	12	7
	95	never	never	> 15	10
	100	never	never	> 15	> 15
Estimated aggregate / imposed saturation level (a)		0,81*	0,67*	1	1
Standard error		0,09	0,05		
Estimated aggregate coefficient of diffusion (b)		0,32*	0,594*	0,254*	0,467*
Estimated aggregate scaling coefficient (c)		8,79*	132,77*	8,42*	124,71*
MAFE %		10,04	15,00	10,49	27,47
Wald test prob.**		0,035	0,000		
Adjusted R-squared		0,978	0,969	0,945	0,967

* Significant at 1 % level
** Test for rejecting model with free saturation level, prob. value

Figure 9. **Share of electronic consumer bill payments in total volume of consumer bill payments Gompertz (free saturation)**



1 Gompertz fit and prediction
2 Data

<u>Share of total electronic noncash payments in total volume of noncash payments.</u> Total noncash electronic payments include electronic POS and bill payments and disbursements. The respective results are shown in Table 5 and in Figure 10.

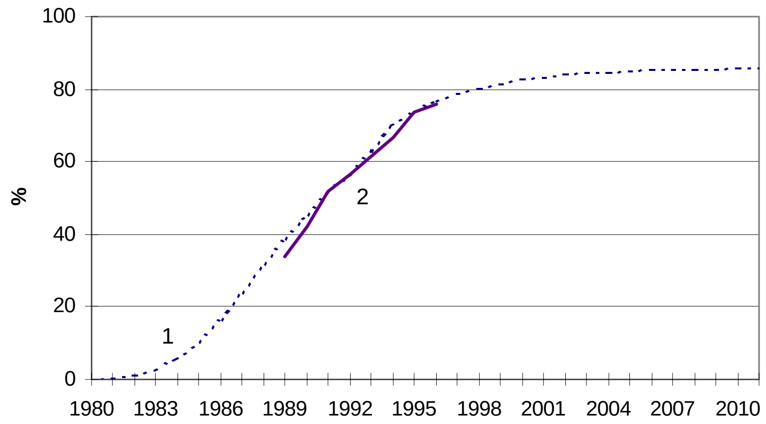
Gompertz and logistic models produce near identical results. In the freely estimated models the process of electronification is already slowing down, and appreaching saturation level (Gompertz 86 %, and logistic 85 %). If saturation level is set to 100 per cent, the forecasted growth goes on stronger, but the essential result of slowing overall electronification remains the same. Since disbursements are already practically all electronic, and also POS-payments are 90 per cent electronic (and saturated at that level) the only remaining area of growth lies, in practise, in electronic consumer bill payments. Otherwise the process of electronification has already advanced quite far in Finland. Nevertheless, since bill payments dominate in transaction volumes, further electronification of household bill payments in line with our forecasts would generate significant efficiency gains.

Table 5. **'S'-curve models for total electronic noncash payments (transaction volumes)**

		Saturation level free		Saturation constrained to 100 %	
		Estimated average share of electronic payments			
		Gompertz	Logistic	Gompertz	Logistic
Observed	1988	0,34			
shares	1996	0,76			
Forecast	1997	0,79	0,79	0,82	0,83
	1998	0,80	0,80	0,84	0,86
	1999	0,82	0,81	0,87	0,88
	2000	0,83	0,82	0,89	0,91
	2001	0,83	0,83	0,90	0,92
	2002	0,84	0,83	0,92	0,94
	2003	0,85	0,84	0,93	0,95
	2004	0,85	0,84	0,94	0,96
	2005	0,85	0,84	0,95	0,97
	2006	0,85	0,84	0,96	0,97
	level %	Years to reach the level			
Forecast	80	1	1	reached	reached
	85	7	14	3	2
	90	never	never	5	4
	95	never	never	9	7
	100	never	never	> 15	> 15
Estimated aggregate / imposed saturation level (a)		0,86*	0,85*	1	1
Standard error		0,06	0,04		
Estimated aggregate coefficient of diffusion (b)		0,283*	0,37*	0,205*	0,263*
Estimated aggregate scaling coefficient (c)		1,45*	2,83*	1,44*	2,80*
MAFE %		3,59	3,88	5,01	5,23
Wald test prob.**		0,007	0,0001		
Adjusted R-squared		0,951	0,943	0,951	0,938

* Significant at 1 % level
** Test for rejecting model with free saturation level, prob. value

Figure 10. **Share of electronic payments in the volume of total noncash payments, Gompertz (free saturation)**



1 Gompertz fir and prediction
2 Data

Based on the free Gompertz-curve estimate, the aggregate share of electronic payments in the total value of payments would converge to a level corresponding relatively closely to the saturation levels obtained for transaction volumes, but the diffusion process up to the saturation level is predicted to be much slower. [14] Constrained estimation imputing the 100 per cent saturation level accelerates the electronification process, but yields, by and large, a similar forecast of rather slow process. The model fit is considerably worse for values than volumes. Also the quality of the data is much lower in value than volume terms. For these reasons we chose not to present these results in detail.

The general finding is that the process of electronification is found to be still quite immature in terms of values, which thus differs from the process in terms of transaction numbers. Thus focusing on value-based estimate will underestimate the extent of electronification. This is due to the fact that large value transactions are more paper-based than small ones, particularly due to the large value financial market transactions.

[14] In some instances individual banks' transaction value data needed to be complemented with proxies of average transaction values multiplied by the volume of transcations. Value-based estimate omit one bank from the data.

5 Institutional factors and evolution of payment infrastructure

As reported in the previous chapter, the diffusion of electronic payment means has been rapid in Finland, and advanced far. Before concluding our analysis, we now briefly discuss some factors which, based on the Finnish experience, might help to explain banks' investments in the respective payment infrastructure and the rapidness of the customer adaption of electronic payments. We consider both (A) supply-side and (B) demand -side factors. Instead of trying to be exhaustive, we just want to illustrate the importance of these factors.

(A) Supply-side. Probably the most important factor explaining banks' extensive investment in Finland is cooperation among them. It has been extensive since late 1980's, when banks combined their payment transaction systems by establishing bilateral communication links in which the transmission of payment data takes place in the form of batch transfers. In 1993 bank and postal giro forms were standardised which established full compatibility between the two systems, and finally, in 1994 a joint company, Automatia, was established by all banks to manage the network of completely compatible cash dispensing ATMs. Also in payment ATMs compatibility emerged. The largest of the Finnish Banks, Merita (now Merita Nordbanken due to the merger with Swedish Nordbanken), has, however, later withdrawn from the payment ATM network cooperation. Competition policy has obviously been an important factor, as the the relatively tolerant antitrust policies in Finland have allowed the cooperation between banks to take place.[15]

The primary reasons why cooperation encourages the instalment of electronic payment technology, can be roughly divided into cost benefits (scale economies) and customer benefits (wide acceptability and compatibility).

The scale economies in electronic payment transfers stem from the fact that the fixed cost of setting up the necessary communication networks and terminal systems far exceed their operating costs, which renders small marginal cost of a transactions volume increase in these systems.[16] Marquardt (1994) calls these network economies, since the addition of participants in electronic transfer systems reduces both the average and marginal unit costs of processing payment transfers for the group as a whole. Significant cost savings can be realised by setting up joint systems, or by merging individual systems to delete overlapping functions and computer systems. The incentives to cooperate should be much smaller in labour-intensive paper-based payments, since any scale economies in the processing of them are bound to be smaller than those in electronic payments. The network economy effect is enhanced by the fact that consumers prefer services that offer the widest applicability, eg cards that are accepted by most retailers or compatible with most EFT-POS terminals and ATMs. Wide availability and extensive compatibility increase significantly user convenience

---

[15] The European competition policy has been behaviour-oriented trying to detect cases when firms exploit their dominant market position. To ensure that payment system cooperation does not impede competition at the customer level, the European Commission has defined the applicable competition policy for the European Union (see EC 1992).

[16] Unfortunately, there are only a few studies that attempt to measure the degree of scale economies associated with electronic payments. We are only aware of studies assessing and finding evidence of scale economies in ATM networks (see Humphrey 1994 for a review).

and reduce customer transaction costs. Hence, there exist significant positive network externalities in modern payment systems (see eg. Neven 1993).

If the banking sector is dominated by a few banks, as in Finland, cooperation is understandably easier. Some results also indicate that cooperation is most likely when banks are symmetric and banking sector concentrated. If the structure of banking is asymmetric, ie there are both small and large banks, an apparent free-rider problem rises (See eg Kauko, 1998). The problem is due to the fact (see Katz and Shapiro 1986 for a general treatment of the problem) that small banks are usually able to obtain larger benefits from cooperation than large banks. For example, if a cooperative payments ATM network is being built, the small banks will benefit more relatively, as they can offer their customers widely available services, which they would have been unable to provide without cooperation, and to exploit the scale economies associated with electronic payment services. If the large banks are unable to price access to compensate for the lost competitive advantage, they have greater incentives to invest on their own excluding smaller banks from the system. Thus increasing asymmetry may imply less cooperation, an example of which might be the decision of Merita – formed in 95 in a merger of the two largest Finnish banks and thus significantly larger than the other banks – recent decision to quit cooperation in payment ATMs.

Pricing incentives can clearly be used in shaping the evolution of the use of payment instruments. An example are the float benefits accrued by the cheque users, which have according to Humphrey (1984 and 1995) resulted in the U.S. in the persisting dominance of the cheques over no-float or low-float alternatives: giro payments, ACH-payments, and EFT-POS and other debit card payments. The relative prices for the various instruments have therefore strongly encouraged the use of cheques in the U.S. In Finland banks have used significant pricing incentives to enhance the use of electronic methods of payments. ATM bill payments have traditionally been free-of-charge, whereas manually handled over-the-counter payments are relatively expensive. The pricing of payment services has been such that consumers have paid indirectly through lower interest earned on transactions deposits (cross-subsidisation of payment costs through interest income[17]) or monthly fees for eg debit cards, credit cards and giro-facilities. This makes the marginal cost of an additional transaction zero, encouraging the use of debit and credit cards once they have been obtained.

The convenience of electronic methods of payment for the user and existing good infrastructure enabling widespread utilisation of new payment methods are also factors supportive to the diffusion of electronic payments. Electronic means of payment, e.g. payment ATMs, are usually quite fast to use when compared to traditional over-the-counter banking practices, as e.g. queues to payment ATMs are generally rather short etc. Electronic forms payment also imply increased flexibility because their use is typically not tied to banking hours. Many banks have payment ATMs which are available for use even after the bank branch itself has closed. The same naturally applies to phone and PC banking services. Thus the time and flexibility benefit encourage the customers to shift away from traditional means of payment.

<u>(B) Demand-Side.</u> The demand-side factors explaining the rapid diffusion of electronic payments in Finland are harder to specify than supply-side ones.

[17]See Tarkka (1995) for a review of the literature examining cross-subsidisation in the pricing of payment services.

New methods of payment have certain infrastructural requirements on customers as well. For example, wide availability of ordinary and mobile phones and computers is essential in facilitating rapid expansion of phone- and PC payments. As Finland has the highest mobile phone density in the world and a large number of home PCs, wide adoption of home- and phonebanking services has been possible. Also the Finnish public has generally been very willing to accept new innovations and to adopt to using new technology, which may to some extent be ralated to the relatively high levels of education and the extensive use of computers throughout the society. High levels of computer literacy may also have helped people to accustom to use other payment innovations e.g. payment ATMs.

Finally, in the presence of network externalities, the expectations of the general public are of importance for the adoption and diffusion of a new product, e.g. a new payment method. Adopting new means of payment imply costs, as people have to spend some time learning to use the new devices etc. However, due to network externalities consumers are more willing to adopt new products if they believe that these products will eventually be widely used. The significant degree of cooperation among major Finnish banks may well have enhanced the general confidence that card-based payment methods will become widely available, thus increasing willingness to adopt them.

6 Conclusions

In this paper we have used ’S’-shaped learning curves to characterise the electronification of noncash payments and cash substitution in Finland. The quality of the Finnish data allowed us to measure these processes by making it possible to separate noncash payments by ’end use’. According to our results ’S’-curves fit the data well. Electronification process has been rapid, and advanced far. As a result the characteristic ’S’-curves are steep and have relatively short slow-growth phases at both ends.

Cash substitution in Finland seems to be saturating already. The use of cash in POS transfers is forecasted to remain rather high, not falling below 65 per cent during the next ten years. This result may, however, be altered by new payment innovations, especially e-cash. The electronification processes of different types of transfers are at different stages. In noncash POS transfers the share of electronic transfers already seems to have saturated, reaching approximately 90 per cent level. In bill payments the electronification process is still proceeding rapidly. Electronic payments are forecast to have a share in excess of 90 per cent of all bill payments in eight years. In consumer bill payments the share of electronic payments is also rising, but more slowly and seems to stay lower in the end, not exceeding 80 per cent in ten years. The overall results indicate that the electronification process is at the moment proceeding rapidly but starting to slow down. Our results forecast that in ten years time approximately 85 per cent of all noncash payment transfers are electronic.

Several factors explain the rapid electronification of payments in Finland. The prevailed symmetry and concentration of banks and tolerant competition policy towards banks' payment cooperation have encouraged banks to cooperate in the development of new electronic payment systems in order to achieve scale economies and network benefits. Banks have also through pricing incentives actively supported the adoption of electronic means of payment with the aim of saving their expenses. These circumstances have helped to sustain high level of investment in new payment infrastructure. Thus the rapidity of electronification in Finland can be partially explained by favourable institutional conditions. Consumer propensity to adopt new payment instruments has apparently also been high according our steep ’S’-curve results.

Appendix 1

Annual volumes and average values of different means of payment

Variable	Annual volumes in thousands (1988)	Average value in FIM (1988)	Annual volumes in thousands (1996)	Average value in FIM (1996)
Paper-based disbursements	9368,50	2915	1175,30	4780
Electronic disbursements	70014,10	2572	86882,20	2682
Paper-based bill payments	261701,80	n.a.	157195,10	30885
Electronic bill payments	30503,60	93049	254160,90	16944
Paper-based POS payments	70109,20	210	24878,20	296
Electronic POS payments	18369,30	179	157883,50	239
ATM cash withdrawals	77018,35	344	212388,00	387

Source: Finnish Bankers' Association

References

Boeschoten, W. (1992) **Currency Use and Payment Patterns.** Financial and Monetary Policy Studies, 23, Kluwer Academic Publishers, Norwell, MA, the US.

Commission of the EC (1992) **Making Payments in the Internal Market.** Discussion paper COM 90 447 Final, September.

Gamerman, D. – Migón, H. (1991) **Forecasting the Number of AIDS Cases in Brazil.** The Statistician, 40, 427–442.

Gamerman, D. – Migón, H. (1993) **Generalized Exponential Growth Models: A Bayesian Aproach.** International Journal of Forecasting, 12, 573–584.

Humphrey, D. (1984) **The US Payment Systems. Costs, Pricing, Competition and Risk.** Monograph Series in Finance and Economics, 1&2, New York University, NY, the US.

Humphrey, D. (1995) **Payment Systems, Principles, Practice and Improvements.** World Bank Technical Paper No 260, Washington D.C., the US.

Humphrey, D. – Sato, S. – Tsurumi, M. – Vesala, J. (1996) **The Evolution of Payments in Europe, Japan and the United States: Lessons for Emerging Market Economies.** World Bank Policy Research Working Paper, 1676, October, Washington D.C., the US.

Humphrey, D. – Pulley, L. – Vesala, J. (1998) **The Check's in the Mail: Why the US Lags behind in the Adoption of Cost Saving Electronic Payments.** Draft working paper, Florida State University, FL, the US.

Kauko, K. (1998) **Developing the Interbank Payment System Efficiency of Public Versus Private Investments.** Bank of Finland Discussion paper 28/98, Bank of Finland, Helsinki, Finland.

Katz, M. – Shapiro, C. (1986) **Product Compatibility in a market with Technological Progress.** Oxford Economic Papers, Vol 38, November, 146–165.

Kennickell, A. – Kwast, M. (1997) **Who Uses Electronic Banking? Results from the 1995 Survey of Consumer Finances.** In proceedings of the 33rd annual conference on Bank Structure and Competition, Federal Reserve Bank of Chicago, May, IL, the US.

Marquardt, J. (1994) **Payment System Policy Issues and Analysis.** In Summers, B. ed. The Payment System: Design, Management and Supervision, International Monetary Fund, Washington D.C., the US.

Meade, N. (1988) **A Modified Logistic Model Applied to Human Populations.** Journal of Royal Statistical Society, 151, 3, 491–498.

Meade, N. – Islam, T. (1995a) **Forecasting with Growth Curves: An Empirical Comparison.** International Journal of Forecasting, 11, 199–215.

Meade, N. – Islam, T. (1995b) **Prediction Intervals for Growth Curve Models.** International Journal of Forecasting, 14, 413–430.

Neven, D. (1993) **Structural Adjustment in European Retail Banking: Some views from Industrial Organisation.** In 'European Banking in The 1990s', J. Dermine (Editor), Basil Blackwell, London.

Tarkka, J. (1995) **Approaches to Deposit Pricing; A Study in the Determination of Deposit Interest and Bank Service Charges.** Bank of Finland Studies E2, Bank of Finland, Helsinki, Finland.

Virén, M. (1993) **Use of Payment Media and Demand for Currency in Finland.** Bank of Finland, Helsinki, Finland.

Young, P. – Ord, J. (1989) **Model Selection and Estimation for Technological Growth Curves.** International Journal of Forecasting, 5, 501–513.