BANK OF FINLAND
DISCUSSION PAPERS

1/2000

**Jussi Snellman – Jukka Vesala – David Humphrey**

Research Department
1.3.2000

# Substitution of Noncash Payment Instruments for Cash in Europe

**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** – David Humphrey*****

Research Department
1.3.2000

# Substitution of Noncash Payment Instruments for Cash in Europe

The views expressed are those of the authors and do not necessarily correspond to the views of the Bank of Finland or the ECB.

* Bank of Finland, Research Department, P.O.Box 160, FIN-00101 Helsinki, Finland. e-mail: jussi.snellman@bof.fi. All correspondence should be addressed to Jussi Snellman.
** European Central Bank, e-mail: jukka.vesala@ecb.int. Jukka Vesala was employed by the Bank of Finland Research Department when this research was carried out.
*** Florida State University. e-mail: dhumphr@garnet.acns.fsu.edu.

We are indebted to Juha Tarkka for suggesting us an outline of the method for approximating cash payment flows, and to David Mayes, Oz Shy, Jouko Vilmunen and Matti Virén for most helpful comments and suggestions. Remaining errors are ours.

ISBN 951-686-647-6
ISSN 0785-3572
(print)

ISBN 951-686-648-4
ISSN 1456-6184
(online)

Suomen Pankin monistuskeskus
Helsinki 2000

# Substitution of Noncash Payment Instruments for Cash in Europe

## Bank of Finland Discussion Papers 1/2000

Jussi Snellman – Jukka Vesala – David Humphrey
Research Department

## Abstract

The substitution of noncash (check, giro, and credit and debit card) payments for cash transactions is difficult to gauge because there are no data series on the actual value or volume of cash transactions in any country. However, determining the degree of cash substitution is important because it will negatively affect the central banks' and governments' seigniorage revenue. We utilise a novel method for approximating the volume of cash transactions using public information on currency stocks and noncash payments. Applying this method, we estimate how cash has been substituted by other payment instruments in 10 European countries. We also provide a forecast of future cash use by country. We find that the trend in cash substitution across countries is quite similar. However, the countries themselves are at significantly different stages of this substitution process. The spread of debit and credit card payments has been the key factor behind the substitution away from cash as use of e-cash innovation is still in its infancy. Country-specific differences in the substitution process are largely explained by differences in the level of implementation of each country's card payment technology.

Keywords: Cash substitution, learning curves, seigniorage

# Käteisen korvautuminen vaihtoehtoisilla maksutavoilla Euroopassa

## Suomen Pankin keskustelualoitteita 1/2000

Jussi Snellman – Jukka Vesala – David Humphrey
Tutkimusosasto

## Tiivistelmä

Käteismaksamisen korvautumista vaihtoehtoisilla maksutavoilla (sekit, tilisiirrot ja pankki- ja luottokorttimaksut) on ollut vaikea arvioida, koska käteismaksujen määrästä tai arvosta ei ole saatavissa tilastoaineistoa. Käteissubstituution vaiheen selvittäminen on kuitenkin tärkeää, koska käteisen määrän väheneminen paitsi pienentää keskuspankin ja valtion seignoragetuloja. Kehitämme tässä keskustelualoitteessa uuden menetelmän käteismaksujen määrän arvioimiseksi hyödyntäen käteisvarannoista ja ei-käteismaksuista saatavissa olevaa julkista informaatiota. Tätä menetelmää käyttäen estimoimme, kuinka vaihtoehtoiset maksutavat ovat korvanneet käteisen käyttöä kymmenessä Euroopan maassa, ja ennustamme käteisen käytön maakohtaista muuttumista. Tuloksiemme mukaan käteissubstituution trendi on varsin samanlainen eri maissa, mutta prosessin vaihe maittain vaihtelee suuresti. Merkittävin käteissubstituutiota selittävä tekijä on ollut pankki- ja luottokorttimaksujen yleistyminen, koska elektronisen rahan käyttö on yhä alkuvaiheissaan. Maakohtaiset erot voidaan suurimmaksi osaksi selittää maksukorttitekniikan käytön laajuuden avulla.

Asiasanat: käteisen korvautuminen, oppimiskäyrät, seignorage

# Contents

# 1 Introduction

This paper develops and implements a methodology for determining the extent that noncash payment instruments have substituted for cash transactions at the point of sale in 10 European countries over 1987–1996. We also develop forecasts of future cash use since this can affect government seigniorage revenues and the related need to invest in cash printing, storage, and distribution facilities. In addition, if cash use is forecasted to fall to low levels in the future, governments would need to seriously consider establishing a "sinking fund" from current tax revenues to redeem the value of excess currency holdings. Past reductions in the stock of currency outstanding have been associated with cyclical downturns and rapid phases in the ongoing substitution of noncash for cash payments. Based on our analysis, the near term threat of central banks having to redeem large amounts of cash seems to be small. However, this situation could change if new payment innovations, such as e-cash (cash-in-a-chip card) become popular.

Information on the value and especially volume of cash transactions is quite scarce and only exists for a few points in time and then in only a few countries. Thus it has been necessary, as well as commonplace, to infer cash use from simple indirect indicators such as changes in the stock of currency outstanding or from the ratio of cash to GDP, cash to M1 balances, or cash holdings per capita both within countries over time or pooled across countries. We develop a different approach and infer cash use for transactions purposes from the relationship between currency stocks and the volume of noncash point-of-sale (POS) transactions that directly substitute for cash as a means of payment. Inverted money demand equations are estimated that incorporate standard theoretical influences (income and nominal interest rates) as well as an expected negative relationship (substitution effect) between currency stock and noncash payments. These estimates are then used to derive the share of cash in total POS transaction value in each of 10 European countries.

Using a Gompertz S-curve methodology, the time pattern of these POS payment shares captures the cash substitution process we are seeking as well as provides a forecast of future cash use by country.[1] Since the cash substitution process is found to be driven principally by the expanded use of debit and credit cards at the point of sale, the diffusion of this card-based innovation is captured by an S-shaped curve.[2] From a theoretical standpoint, it is of interest to determine if payment patterns in Europe identified by our analysis are converging or if they are largely country-specific. That is, do payment structures differ because countries are only at different points along essentially the same payment growth path or do the differences reflect separate and unique growth paths, perhaps due to different laws, institutions, or traditions. In the first situation, which we find to be the case for Europe, the pattern of cash substitution in countries further down this

[1] 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.

[2] A companion paper (Snellman and Vesala, 1999) employs S-curve analysis to assess changes in payment instrument use using the more detailed payment data available for Finland. A related analysis focuses on the substitution of electronic payments for checks in the U.S. (Humphrey, Pulley, and Vesala, 2000).

essentially common growth path provides a forecast of future development for countries that have just started.

In what follows, Section 2 outlines the evolution of currency stocks and composition of noncash payments for the 10 countries under study. Section 3 investigates how the differing levels of the relative amount of currency outstanding could be explained by the "development stage" of card payment infrastructure and ATM intensity in line with the notion that card payments are the most important substitute for cash. In Section 4, we discuss the method used to estimate cash payment flows and to assess changes in the share of cash in the total value of POS payments. Section 5 reports our S-curve results and forecasts while Section 6 concludes and discusses some implications of our analysis.

# 2 Evolution of noncash payments and currency stocks in Europe

The ability to substitute one payment method for another depends importantly on what the "end use" of the payment is. Three major end uses are:

1. point-of-sale (POS),
2. bill payment, and
3. disbursement transactions.[3]

Distinct payment needs underlie each of these transaction categories. Thus the various payment instruments – cash, check, giro, and debit and credit cards – substitute among, but not much across, these classes. POS payments represent almost exclusively consumers' small value payments for day-to-day purchases of retail goods and services: food, clothing, local transportation, pay phones, vending machines, and so forth. Bill payments represent transactions by consumers, businesses and government for paying housing, utility, other service bills, durable goods, purchases business-to-business payments, and government purchases. Finally, disbursements constitute regular and often recurring business and government payroll and transfer payments.

## 2.1 Noncash payments replacing cash

The recent surveys by Humphrey, Pulley, and Vesala (1996) and Hancock and Humphrey (1998) make it clear that in all developed countries consumers and businesses have essentially the same set of payment instruments available to use in the above classes of transactions, but the intensity of use of the various instruments is often markedly different across countries. Users of payment services consider a wide range of attributes when contemplating the costs and benefits in choosing which payment instrument to use. Explicit user costs, float benefits, opportunity costs, speed of settlement, complexity and convenience of

[3] Common practise is to classify payments into credit or debit transactions, but this neglects the aspect of actual "end use" of the various instruments. Our three classes can comprise both credit and debit transactions.

use, susceptibility to loss or error, privacy, and wide acceptability represent, according to Marquardt (1994), the key attributes. Table 1 reveals the considerably specialized use of the different payment instruments in Europe.

Table 1. **Average value of noncash payment in ECU[1], 1996**

| | Check payments | All debit and credit card payments | EFT-POS[2] card payments | Giro-payments |
|---|---|---|---|---|
| Belgium | 2666 | 60 | 59 | 9142 |
| Denmark | 1907 | 49 | 47 | Na |
| Finland | 46312 | 44 | 43 | 3158 |
| France | 454 | 48 | 48 | 13981 |
| Germany | 2805 | 85 | 80 | 10782 |
| Italy | 1873 | 93 | 89 | 31208 |
| Netherlands | 74 | 46 | 45 | 5470 |
| Sweden | Na | 101 | 73 | 1178 |
| Switzerland | 1375 | 100 | 76 | 51276 |
| United Kingdom | 626 | 47 | Na | 12250 |

Data Sources:BIS (1998), EMI (1996).
Notes:
1 Converted using 1996 average exchange rates (source IMF: International Financial Statistics)
2 EFT-POS payments are card payments (credit and debit card) effected via EFT-POS terminals.

We are here mostly interested in the noncash payments that replace cash. As seen in Table 1, card payments, like cash, have a low average value and are used quite exclusively for small value retail payments. The diffusion of terminals for electronic funds transfer at the point-of-sale (EFT-POS) has made cards especially convenient to effect these type of payments.[4] When the terminals operate on-line with real-time linkages to account data, the use of magnetic cards provides immediate settlement of transactions at the moment of exchange. Hence, these card payments combine the finality advantage of legal tender (cash) with the efficiency advantages of deposit money. The party accepting either instrument incurs little risk since settlement can occur immediately and the need to check the quality of the payment instrument is virtually eliminated.

Since cash is most often used for everyday small value retail purchases, debit card payments (especially via on-line EFT-POS terminals) are its closest substitute in modern payment systems. Electronic money (e-cash) loaded on chip-cards could be an even closer substitute, particularly when open circulation (reuse of received e-cash) is allowed, but its current use is quite small and preliminary. The average value of a credit (or charge) card payment is slightly larger than a debit card payment, but credit cards can still be regarded largely as a substitute for

[4] Note that often both credit and debit cards can be used to pay via EFT-POS terminals. Typically, the value of EFT-POS payments is very close to the average value of credit and debit card payments. Any differences here are due to including paper-based and electronic payments in card transactions but only the latter in the EFT-POS data.

cash at the point-of-sale. The credit (deferred payment) facility associated with these payments encourages their use for larger value retail purchases (e.g. consumer durables).

As indicated in Table 1, there is much more variation in the average value of checks than debit and credit cards across Europe. In France, for example, many small value retail payments are still effected via checks, and the annual number of transactions with this instrument is relatively high. In contrast, in Finland checks are mainly used for business payments whose average value is large. Giro payments seem to be quite seldom used for POS payments. They represent most frequently bill payments and disbursements by individuals, companies and government authorities.[5]

In most European countries the diminishing share of checks in non-cash transactions, seen in Table 2, has mainly benefited electronic debit and credit card payments, while the share of giro-payments has been relatively stable. This suggests that card payments have strongly replaced checks in low value retail payments in countries that have historically used checks intensively. In France and the UK the relative share of both card payments and direct debits (preauthorized bill payments) has increased indicating that both card payments and direct debits have replaced checks. Germany and the Netherlands are exceptions: in these countries automated direct debits, have become a common means to effect low value, recurring, bill payments at the expense of checks and paper-based giro payments, while the diffusion of card payments and expansion of EFT-POS infrastructure has been relatively late. Overall, however, the use of debit and credit cards has been strongly supported by the diffusion of EFT-POS terminals.

As illustrated in Table A1.1 in the Appendix 1, the number of EFT-POS terminals per person and the number of transactions handled are greatest in Finland, Denmark and France. Belgium and the UK are also relatively advanced in this regard. In these countries the use of payment cards is also most advanced in general. Cooperation in the establishment of infrastructure, the wide acceptability and compatibility of cards issued by different institutions, and seemingly effective competition among institutions for customers has permitted the rapid diffusion of on-line card-based POS payments in these countries.[6]

Based on the discussion above, the biggest problem in categorising payments by “end use” and separating out POS payments in the publicly available data is that checks may be used for all three types of payment end uses. To address this problem, we approximate the value of POS check payments in each country by assuming that the average value of a POS check payment equals the average debit or credit card payment value over the sample period.

[5] The variation across countries in the average giro payment values is large because they represent both recurring bill payments, payroll disbursements, and large value financial transactions. As these proportions differ across countries, so do the average values shown in Table 1.

[6] Kearney (1993) discusses extensively the French case and Humphrey, Pulley, and Vesala (1996) present evidence for other countries.

Table 2. **Percentage shares of noncash payment instruments**

| | Check payments | | Debit and credit card Payments | | Giro- Payments | |
|---|---|---|---|---|---|---|
| | 1987 | 1996 | 1987 | 1996 | 1987 | 1996 |
| Belgium | 33 | 9 | 6 | 21 | 61 | 69 |
| Denmark | 38 | Na | 3 | Na | 59 | Na |
| Finland | 8 | 0 | 18 | 36 | 74 | 63 |
| France | 65 | 49 | 8 | 20 | 27 | 31 |
| Germany | 9 | 6 | 1 | 4 | 91 | 89 |
| Italy | 51 | 33 | 1 | 10 | 49 | 57 |
| Netherlands | 19 | 3 | 0 | 20 | 81 | 76 |
| Sweden | 20 | Na | 6 | Na | 74 | Na |
| Switzerland | 9 | 2 | 4 | 18 | 88 | 80 |
| United Kingdom | 58 | 33 | 10 | 29 | 32 | 38 |

Data Sources: BIS (1989, 1998), EMI (1996).

## 2.2 Analysis of cash substitution based on currency stocks

Cash is losing ground to various forms of noncash payments, mostly to plastic card payments that are the strongest present substitutes for cash. The reduction in cash use can be seen in some commonly employed indicators of cash use. As shown in Table 3, the share of cash in M1 (cash plus transferable demand deposits) has fallen in all countries except Italy. As an unweighted average across eight countries, the share of cash in M1 has fallen from 23.1 per cent in 1987 to 17.3 per cent in 1996, a drop of 25 per cent. Thus the stock of cash holdings has fallen relative to deposit money balances used for noncash transfers among bank accounts. In the Netherlands and Finland, these reductions are quite large (38 % and 60 % respectively).

Table 3. **Cash holdings and annual noncash transactions per person**

| | Cash to M1 ratio % | | Cash to GDP ratio % | | Value of cash holdings per person in ECUs | | Noncash transactions per person | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1996 | 1987 | 1996 | 1987 | 1996 | 1987 | 1996 |
| Belgium | 37.9 | 30.3 | 7.77 | 5.32 | 968 | 1091 | 74.2 | 114.0 |
| Denmark | 10.6 | 9.5 | 2.85 | 3.05 | 493 | 800 | 104.1 | Na |
| Finland | 24.1 | 6.7 | 1.89 | 2.40 | 291 | 456 | 98.8 | 139.2 |
| France | 15.2 | 14.2 | 4.24 | 3.28 | 590 | 679 | 123.2 | 173.9 |
| Germany | 22.1 | 18.2 | 3.99 | 4.53 | 637 | 1024 | 103.1 | 143.0 |
| Italy | 13.7 | 16.6 | 5.18 | 5.34 | 596 | 889 | 24.6 | 31.9 |
| Netherlands | 32.1 | 19.8 | 7.67 | 5.80 | 977 | 1170 | 103.1 | 158.9 |
| Sweden | Na | Na | 5.16 | 4.29 | 847 | 957 | 84.5 | Na |
| Switzerland | 28.7 | 22.9 | 9.35 | 8.08 | 2201 | 2637 | 42.8 | 81.4 |
| United Kingdom | Na | Na | 3.43 | 2.80 | 348 | 435 | 81.3 | Na |

The middle columns of Table 3 depict two other commonly used indicators of cash use: the ratio of cash to GDP and the value of currency held per person (in ECUs). The cash/GDP ratio has fallen from 5.2 (unweighted average over 10 countries) in 1987 to 4.5 in 1996, a reduction of 13%. And, while the nominal value of cash held per person in Europe rose by 34% (unweighted average) dividing this value by the change in each country's cost of living index (not shown) indicates that the change in real cash holdings per person fell by an average of almost 7%. Indeed, 7 out of the 10 countries experienced an absolute decrease in real cash holdings per person.

There are measurement problems associated with these kind of indirect indicators of cash use. First, cash balances can be held for prudential or speculative purposes (hoarding) as well as for transaction purposes. Cross-country evidence presented by Boeschoten (1991 and 1992) suggests that hoarding is especially important in Germany, Switzerland, and the Netherlands,[7] and of very low importance in Denmark, Finland, France, Norway, and the UK.[8] Countries where hoarding is found to be important are also the ones that have traditionally had large cash to GDP ratios. Second, simple analysis of ratios cannot separate the substitution effect from the income effect. Namely the business cycle can explain some of the implied reduction in the use of cash since the demand for cash falls during recessions.

While there are measurement problems in using currency stock information to gauge cash use, the diminishing relative use of cash is supported by looking at the growth in non-cash payments per person over this period. Over 1987–1996, the unweighted average number of noncash transactions per person rose from 81 per year to 120, a rise of 48 per cent. This four per cent annual increase in per person noncash transactions far exceeds the growth in real GDP and indicates a substitution of noncash for cash payments.

[7] A low circulation rate of high denomination banknotes is used as an indicator of hoarding.

[8] According to Boeschoten (1992) Belgium, Italy, Sweden, as well as Canada and the US, fall between these two polar groups of countries.

# 3 Level of currency balances, ATMs, and card payment infrastructure

The previous discussion suggests a negative relationship between cash use and the level of payment infrastructure development, particularly with respect to the diffusion of EFT-POS terminals.[9] The availability of EFT-POS terminals in retail stores and other outlets has significantly expanded the use of debit and credit cards and reduced reliance on cash for retail payments. Besides a diminished need for retailers and consumers to hold cash balances, retailers save time compared with manually processing card payments and consumers have an accurate record of their transactions. While there have been significant differences in the diffusion of EFT-POS terminals across countries (Appendix 1), the overall use of these terminals is negatively correlated with measures of currency use.

The international evidence from the 1980s suggested that ATM terminals had a positive effect on currency demand.[10] This has been explained by the increased ease of making cash withdrawals. However, the Baumol-Tobin model of transaction demand for money based on inventory theory predicts the opposite (Niehans, 1978).[11] Namely, ATMs should lower the transaction cost to consumers of making a cash withdrawal compared to the traditional over-the-counter withdrawal at a branch office. ATMs are usually available 24 hours a day and are (at present) widely dispersed in convenient locations. With lower transaction cost, the number of cash withdrawals should rise, permitting the value withdrawn each time to fall even while maintaining the same value of cash purchases. The net result should be a reduction in average cash balances held and thus a negative effect on currency stock outstanding.

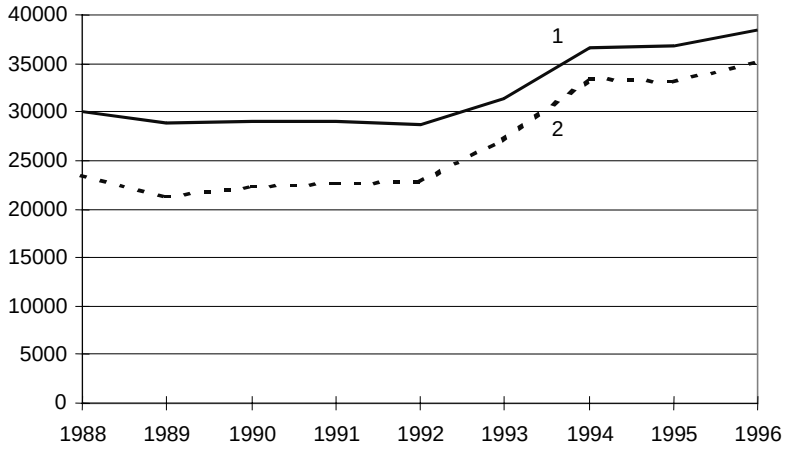
The failure to detect such a negative effect in earlier studies is likely due to the fact that people need time to make the behavioural adjustment associated with more frequent cash withdrawals leading to a significantly lower value withdrawn each time (and thereby economise on cash holdings). Figures 1a and 1b provide some support for the existence of a "learning period" just described. As Figure 1a shows, the number of transactions per ATM have generally increased in step with ATM expansion over time, albeit at a decreasing rate (Appendix 1). As shown in Figure 1a, the frequency of cash withdrawals per ATM started to rise around 1992. At about the same time, the average (nominal) value of each cash withdrawal started to fall, as illustrated in Figure 1b. In real terms, the decline is even larger.

[9] Humphrey, Pulley, and Vesala (1996) report that across 14 developed countries for 1993 there was a statistically significant negative relationship between the availability of EFT-POS terminals and the ratio of cash holdings to GDP, holding constant income and interest levels and other important explanatory factors. Boeschoten (1992) presents a similar result using earlier data.

[10] See Paroush and Ruthenberg (1986), and Boeschoten (1992) for cross-country estimates. Boeschoten (1992) discusses the possibility of ATMs having a two-fold effect on currency demand.

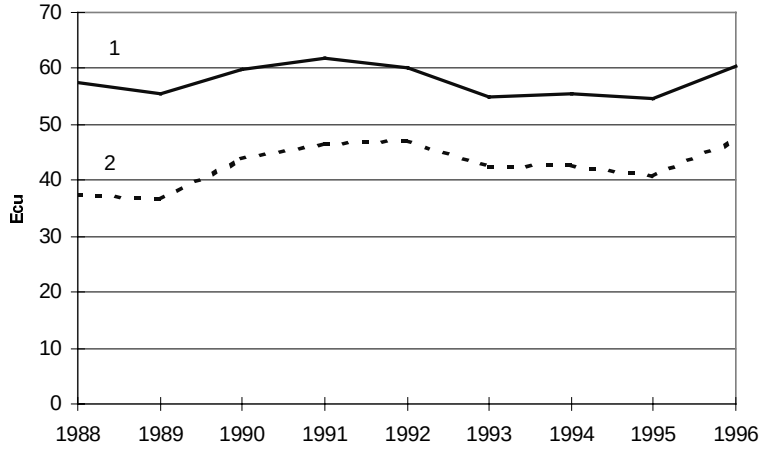
[11] Santomero's and Seater's (1996) general result that "…efforts by banks to lower the cost of using (a particular form of money) may well reduce the average holdings of that money…" would predict the same.

Figure 1a. **Average number of ATM transactions per machine per year**




1 10 countries
2 Euro 6

Figure 1b. **Average ATM transaction value in ECU**




1 10 countries
2 Euro 6

To more clearly identify the various effects on the demand for cash, it is necessary to develop a more complete model, one that includes the effects of changing income and interest rates as well as the substitution of noncash payment instruments for cash and the separate effect from expanded use of ATMs. To this end, we specify and estimate the following equation using pooled cross-country time-series data from 10 European countries (indexed by i) over 1987–1996:

$$\ln\left(\frac{\text{CURR}}{\text{POP}}\right)_{it} = \phi_0 + \phi_1 \ln\left(\frac{\text{GDP}}{\text{POP}}\right)_{it} + \phi_2 \ln r_i + \phi_3 \ln(\text{EFTPOP})_{it}$$
$$+ \phi_4 \ln(\text{CARDPOP})_{it} + \phi_5 \ln(\text{ATMPOP})_{it} + \varepsilon_{it}, \qquad (3.1)$$
$$i = 1,...,10, \quad t = 1987 - 1996$$

CURR = total value of currency outstanding outside the banking sector in ECUs,
POP = number of inhabitants,
GDP = value of GDP in ECUs,
r = nominal money market interest rate,
EFTPOP = number of EFT-POS terminals per capita,
CARDPOP = number of debit and charge cards outstanding per capita,
ATMPOP = number of (cash dispensing and payment) ATMs per capita,
$\varepsilon$ = error term.

In equation (3.1), GDP per person (income effect) and the nominal interest rate (opportunity cost of holding cash) capture the standard transactions demand for money influences on per person currency holdings (Niehans, 1978).[12] The equation is in log-linear form and so income and interest rate elasticities are separately identified, as are the three influences reflecting changes in retail payment infrasructure. Two variables – the number of EFT-POS terminals per person and the number of payment cards outstanding per person – should reflect the substitution of debit and credit card payments for cash while a third variable – the number of ATMs per person – indicates the effect of a substitute cash delivery method. We estimate (1) with OLS and report the results in Table 4. The basic statistics for the variables used in the estimation are presented in Appendix 2.

Table 4. **Determinants of currency holdings per person, panel data 1987–1996**

| | |
|---|---|
| $\phi_0$ Intercept | -15.7* |
| | (0.17) |
| $\phi_1$ GDP/POP | 1.65* |
| | (0.17) |
| $\phi_2$ r | –0.24* |
| | (0.09) |
| $\phi_3$ EFTPOS | –0.09* |
| | (0.03) |
| $\phi_4$ CARDPOP | –0.09 |
| | (0.06) |
| $\phi_5$ ATMPOP | –0.20* |
| | (0.07) |
| $R^2$ | 0.61 |
| # of observations | 94 |

* Significant at the 99 % confidence level. Standard error in parentheses.

[12] One factor increasing the demand for currency balances is the size of illegal activities and the "gray economy". Unfortunately, due to the lack of reliable estimates of this effect, this influence can not be included in our analysis.

The coefficients on GDP per capita and on the nominal interest rate have the predicted signs and reasonable values. The estimated income elasticity implies a strong income effect and appears to be at the high-end of the results appearing in the literature. However, the substitution effect is not usually specified in empirical demand for cash models. Its specification here is associated with a reduced use of cash which would otherwise likely show up as a smaller income effect and a larger negative response to interest rates. Increasing EFT-POS terminals significantly reduces the usage of cash, as expected, and the number of cards outstanding also has a negative sign, although it is not statistically significant.

Finally, the effect of expanded use of ATMs is significantly negative, as inventory theory would predict. Thus our use of more recent data yields a negative relationship between ATM use and cash balances while earlier studies (using earlier data before much behavioral change occurred) suggested that the relationship was positive. Overall, ATMs have lowered cash balances demanded by the public.[13]

# 4 Evolution of cash payment flows

Although indirect indicators of cash use exist using currency stocks (e.g. Table 3), very little information is available regarding direct currency payment flows. The limited data that are available are illustrated in Table 5. While the reported value share of cash in all payments at the point of sale is large (from 68 per cent in France to 98 per cent in Germany), its corresponding value share in all types of transactions (POS, bill payments, disbursements) is very small (between 2 per cent and 5 per cent for the same two countries).

Table 5. **The share of cash payment value and payment volume estimates for 1987**

| Country | Payment value share: | | Payment volume share: |
|---|---|---|---|
| | Cash / POS payments % | Cash / All payments % | Cash / All payments % |
| Finland | 77 | -- | 83 |
| France | 68 | 2 | 75 |
| Germany | 98 | 5 | 86 |
| Netherlands | 96 | -- | 90 |
| Sweden | 85 | < 10 | -- |
| UK | 96 | -- | 90 |

Sources: BIS (1989), BIS (1993), EMI (1996), Humphrey, Pulley, and Vesala (1996).

[13] ATM and EFT-POS densities are positively correlated across countries and thus are somewhat collinear exogenous variables. However, the exclusion of ln(EFTPOP) from the model does not have much effect on the coefficient for ln(ATMPOP). The logarithmic specification presented here was found to perform better than a specification in absolute terms.

Clearly, the payment "end use" category most amenable to cash substitution relates to purchases at the point of sale. The value share of POS cash use (Table 5, Column 1) often is as high as the volume share of cash use in total transactions (Column 3). Thus, in both value and volume terms, POS transactions – with its low average value per transaction – is where cash is most heavily used. Unfortunately, data on transactions effected with cash concern only a few points in time and only for a limited set of countries. In what follows, we develop a method to estimate cash payment flows.

## 4.1 Method of approximating cash payment flows[14]

Our method of inferring cash use for transactions purposes relies on the correlation between currency stocks and a measure of the intensity of noncash POS transactions that substitute for cash as a means of payment. Using this method, we estimate the share of cash in POS transactions in 10 European countries over 1987–1996. Cash and noncash payments are analysed in terms of their values, not volumes, since the seigniorage and cash redemption policy issues we are concerned with are connected with the value of currency outstanding (not the frequency of transactions conducted with cash).[15]

In our model, the value of point-of-sale payments at time t is proportional to the level of income (nominal GDP) in a country and all POS transactions are effected by using either cash (CASH) or noncash payment instruments (NCP):

$$CASH_t + NCP_t = f(GDP_t), \quad f' > 0, \tag{4.1}$$

CASH = flow of cash used for transaction purposes,
NCP = total value of noncash POS payments.

As traditionally modelled, the demand for currency balances (CURR) is determined by transaction demand for cash, and the desire to hold interest bearing transferable deposits whose interest rate varies with the market interest rate (r):

$$CURR_t = g(CASH_t, r_t), \quad g_1' > 0, \quad g_2' < 0. \tag{4.2}$$

CURR = total value of currency outstanding the banking sector,
r = nominal money market interest rate.

Combining (4.1) and (4.2), the size of the currency stock is expressed as a function of income, the value of noncash transfers at the POS, and the nominal interest rate:

$$CURR_t = g((f(GDP_t) - NCP_t), r_t). \tag{4.3}$$

[14] We are grateful for Juha Tarkka for providing very useful ideas especially regarding this section.
[15] Analysis of cash and noncash transaction volumes would be appropriate if we were instead concerned here with payment system efficiency, since the value of a transaction has little bearing on the amount of resources consumed when payments are processed.

Approximating (4.3) by linearisation yields:

$$\mathrm{CURR}_t = g_1' f' \mathrm{GDP}_t - g_1' \mathrm{NCP}_t + g_2' r_t. \qquad (4.4)$$

This is the basic theoretical premise underlying the observed negative correlation between noncash payments and currency balances, since transaction demand for cash has an increasing effect on the stock of currency held ($g_1' > 0$). Measuring $g_1'$ which can be done on the basis of (4.4) opens the way to estimating the flow of POS cash payments.

For an empirical implementation of the equation (4.4), the underlying relations (4.1) and (4.2) can be equally well expressed in terms of annual changes, with linear approximations for functions f and g:

$$\Delta\mathrm{CASH}_t + \Delta\mathrm{NCP}_t = \phi\Delta\mathrm{GDP}_t, \qquad (4.1')$$

where $\Delta$ = difference operator, and $\phi = f'$, and

$$\Delta\mathrm{CURR}_t = \alpha_1\Delta\mathrm{CASH}_t + \alpha_2\Delta r_t, \qquad (4.2')$$

where $\alpha_1 = g_1', \alpha_2 = g_2'$.

The parameter $\alpha_1$ measures the cash substitution effect – the structural change in payment patterns that reduces the use of cash in favour of noncash payments. By the theoretical constraint $(g_1' > 0)$, $\alpha_1$ should be positive.

By combining (4.1') and (4.2') we can write:

$$\frac{1}{\alpha_1}\Delta\mathrm{CURR}_t - \frac{\alpha_2}{\alpha_1}\Delta r_t + \Delta\mathrm{NCP}_t = \phi\Delta\mathrm{GDP}_t. \qquad (4.3')$$

Solving (4.3') for the value of the change in noncash POS payments gives us:

$$\Delta\mathrm{NCP}_t = \beta\Delta\mathrm{CURR}_t - \alpha_2\beta\,\Delta r_t + \phi\,\Delta\mathrm{GDP}_t, \qquad (4.5)$$

where a reparametrisation $-\frac{1}{\alpha_1} = \beta$ (which should be negative) is used.

From (4.2') we obtain the following approximation of the annual change in the flow of cash used for transactions purposes:

$$\Delta\mathrm{CASH}_t = -\beta\,\Delta\mathrm{CURR}_t + \alpha_2\beta\Delta r_t, \qquad (4.6)$$

which completes the derivation of our empirical methodology for estimating cash payment flows. An empirical counterpart of equation (4.5) can be used as an estimating equation for the parameters $(\beta, \alpha_2)$ which in turn determine the changes in cash payment flows according to the equation (4.6).

## 4.2 Estimation of cash payment flows

In the empirical implementation of (4.5) and (4.6), first, the parameter $\beta$ should not be modelled as a constant. It should instead be modelled to vary across time and by countries to reflect changes in the substitution process over time, a process that depends on the stage of development of noncash payment infrastructure in a country. Based on our earlier analysis, we specify that the development stage of card payment technologies is the most relevant in this context since debit and credit card payments via EFT-POS terminals are the closest substitutes for cash. We measure this effect related to the level of payment technology via the diffusion of EFT-POS terminals (as given in the estimating equation (4.7) below).

Second, the dependent variable (noncash POS payments) needs to be operationalised. For many countries, debit and credit card payments are practically the only cash substitute in POS transactions. Thus, in the empirical implementation, we use the card payment value as the measure of noncash POS payments. However, in some countries (notably the UK, France, and Italy), checks may still often be used for POS purchases. Fortunately, check payments are a decreasingly used substitute for cash payments since their use is declining everywhere in Europe (as indicated by Table 2) while card payments are rising and substituting for *both* cash and POS check payments. For this reason, the data on currency stocks are amended to control for the impact of declining check payments with a proxy of checks outstanding used for POS purposes. This proxy is obtained by assuming that the average value of a POS check equals the average value of a debit or credit card payment. Changes in the value of POS checks is approximated by multiplying this average value by the actual number of checks written (large value checks are few in number but have a big impact on the observed average value).[16]

After the above mentioned empirical refinements, we can specify the following fixed effects panel regression model:

$$\frac{\Delta CARD_{it}}{C_{it}} = \alpha_0 + D\lambda + \beta_{it}\frac{(\Delta CURR_{it} + \Delta CHECK_{it})}{C_{it}} + \phi\frac{\Delta GDP_{it}}{C_{it}} - \alpha_2\beta_{it}\Delta r_{it} + \theta ATMPOP_{it} + \varepsilon_{it}, \quad (4.7)$$
$$i = 1,...,10, \quad t = 1988-1996$$

where

$$\beta_{it} = \gamma_0 + D\mu + \gamma_1 EFTPOP_{it},$$

$\lambda = (\lambda_1, \ldots, \lambda_{n-1})'$, $\mu = (\mu_1, \ldots, \mu_{n-1})'$ = vectors of coefficients of country intercept and slope dummies (n = the number of countries),
$D = (D_1, \ldots, D_{n-1})'$ = matrix of country dummies,
C = nominal value of private consumption,
CARD = value of card payments,
CHECK = value of POS checks outstanding (our approximation).

[16] The empirical model performs substantially better when the impact of checks is controlled for.

The normalisation by nominal private consumption (C) controls for country-specific differences in the monetary values concerning the changes in currency stocks, noncash payments, and income. Expressing payment shares in terms of consumption has a natural interpretation since consumption itself is paid for by the various means of payments.

In (4.7), country-specific indicator variables are used to allow for differences in the explained relationship across countries (intercept dummies), and to permit the substitution process between cards and cash payments (and checks) to differ as well (slope dummies).

Finally, ATMPOP is an added exogenous variable which should have a positive effect on card payments: greater availability of these terminals can reduce average cash balances and debit and credit cards can be used for cash withdrawals. Thus ATMs extend benefits of holding payment cards which enhances their acquisition and use.

After (4.7) is estimated, the value of the flow of cash transactions (CASH) can be approximated by the following equation for each country by using the country-specific, time-varying estimate of $\beta_{it}$ which depends on the estimates of ($\gamma_0$, $\mu$, $\gamma_1$) and the number of EFT-POS terminals per capita (EFTPOP):

$$\Delta CASH_{it} = -\beta_{it}(\Delta CURR_{it} + \Delta CHECK_{it}) + \alpha_2 \beta_{1it} \Delta r_{it}, \qquad (4.8)$$

which just restates equation (4.6) to be in line with our empirical specifications.

Turning to estimation and results, equation (4.7) is estimated with OLS as a single equation using the pooled time-series cross-section panel data from the our European countries, yielding 90 observations.[17] Table 6 reports the results of a constrained model containing only the statistically significant dummies.[18]

[17] For Germany only post-unification data are included (i.e. 1991–1996).

[18] Regarding our modeling of the "check effect", likelihood ratio tests were in favour of inserting a separate parameter for checks in (4.7), but the effect on model performance was not significant. Therefore, this was not adopted in order to save degrees of freedom. A separate parameter for POS checks would allow us to identify a separate substitution effect between card and check payments from card and cash payments for those countries where check use is significant (Italy, France and the UK).

Table 6. **Determinants of changes in card use, panel data, 1988–1996**

| | |
|---|---|
| $\alpha_0$ | 0,002 |
| | (0,003) |
| $\lambda_7$ (Italy) | –0,007 |
| | (0,003) |
| $\gamma_0$ | 0,19 |
| | (0,13) |
| $\gamma_1$ | –0,21* |
| | (0,06) |
| $\mu_3$ (Netherlands) | –2,29* |
| | (0,68) |
| $\phi$ | 0,05* |
| | (0,0017) |
| $\alpha_2$ | 0,0003* |
| | (0,000002) |
| $\theta$ | 0,02* |
| | (0,006) |
| R-squared | 0,43 |
| # of observations | 74 |

* Significant at 99 % level.
Standard errors in parentheses.

Wald tests allow us to determine the significance of the full model with all country intercept and slope dummies. Since only two country dummies need to be specified in the final model (one for the intercept and one for the slope $\beta_{it}$, as reported in Table 6, the substitution process across countries is very similar. Except for two countries, changes in card-payment flows (or, inversely, in currency stocks) have apparently not had a significant country-specific component.[19]

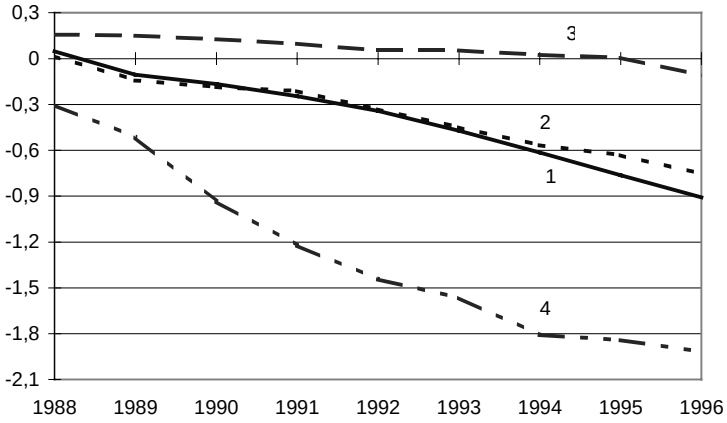
The number of EFT-POS terminals per capita ($\gamma_1$) seems to capture well the effect of advances in card payment technology on the overall substitution parameter $\beta_{it}$.[20] This reflects the increasing ease by which card payments replace cash and checks at the point of sale when the number of terminals is large. The significantly negative value of $\gamma_1$ confirms the negative correlation between cash and noncash POS payments over time. The country-specific time-varying values of $\beta_{it}$ are presented in Appendix 3. Figure 2 illustrates its weighed average for ten European countries,[21] the Euro 6, as well as the highest and lowest country-specific estimates.

[19] The two countries requiring dummies are Italy, which exhibits a lower level of card payments (Table 2) and is reflected in the negative signs of the respective coefficients, and the Netherlands, which exhibits faster than average recent growth in card payments and generates significantly stronger substitution of card payments for cash.

[20] The number of debit and credit cards per capita was used as an alternative specification to EFTPOP. While this had little effect on the estimated parameter $\beta_{it}$, the fit was significantly worse. Describing technological change with a time trend captures almost the same effect as EFTPOP but the nonlinearity of the latter generates a better fit. The growth of EFTPOP tends to be faster than a simple linear function of time.

[21] We use as weights the individual country's share of the combined amount of all noncash payments.

Figure 2. **Estimate of Beta**




1 10 countries
2 Euro 6
3 Germany
4 Finland

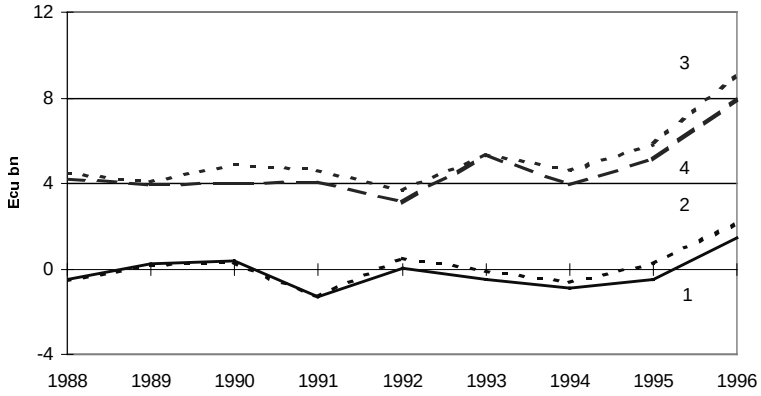
Changes in card payment value are quite elastic with respect to changes in income (GDP). The income elasticity estimate computed from (4.7) is around 2 and is statistically significant. Nominal interest rate changes are also significant but have little impact on the demand for noncash payment media. Apparently, with reasonably low interest rates, the opportunity cost aspect and hence the effect on currency demand is quite negligible.[22] The coefficient of ATMPOP has the predicted positive sign.

## 4.3 Estimated POS payment flows

We now turn to a more detailed discussion of changes in cash and noncash payment flows. Figure 3 illustrates the weighted average of the estimated changes in cash and noncash POS payments obtained from the data for the 10 European countries and the Euro 6, showing a more rapid growth in the latter than the former and the negative correlation. By and large, this pattern holds for every country in the sample. The available data do not allow making projections for years earlier than 1988.

[22] Likelihood ratio tests accepted the theoretical restriction on $\alpha_2$ that it should be negative.

Figure 3. **Annual changes in the value of POS payments, billions of ECU**

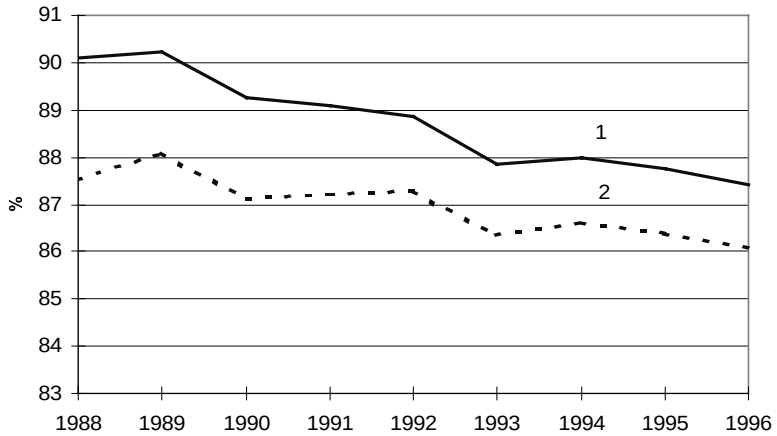



1 Cash: 10 countries (our estimate)
2 Cash: Euro 6 (our estimate)
3 Noncash: 10 Countries (data)
4 Noncash: Euro 6 (data)

Based on our estimates, the total value of cash payments has fallen slightly between 1988 and 1996. As seen in Figure 3, negative changes in cash use in this period have been only partly offset by positive changes toward the end of the period. In contrast, Figure 3 shows that the value of noncash payments experienced a positive increase in year over the period This implies that the overall share of cash in POS payments (S) has declined.

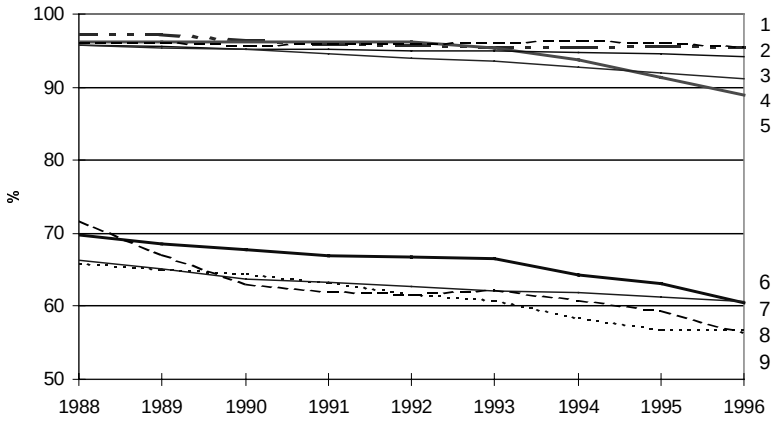
Tying the estimates of changes in the value of cash and noncash payments (Figure 3) to point estimates of the share of cash in POS payments (Table 5) generates a time-series of the share of cash in POS payments (S). These results are illustrated in Figures 4 and 5 and shown in more detail Appendix 3 (which also contains additional explanation of this methodology).

Figure 4. **Estimated share of cash POS payments**




1 10 Countries
2 Euro 6

Figure 5. **Estimated share of cash POS payments, per cent**




| | |
|---|---|
| 1 Italy | 6 Denmark |
| 2 Germany | 7 Belgium |
| 3 UK | 8 France |
| 4 Switzerland | 9 Finland |
| 5 Netherlands | 10 Sweden (not shown)[23] |

As Figure 4 indicates, the average level of cash use remains high in Europe, estimated to be at 87 % (86 % for the Euro 6).[24] However, as seen in Figure 5, there are significant differences between individual countries. In Belgium, Finland, France and Denmark the substitution process has advanced the farthest and the share of cash-based POS payments has fallen to around 60 % in 1996. The estimated level of cash use these countries is noticeably lower than in the other countries.[25] As well, in Finland and France the cash substitution process has already slowed down and, as a result, the income effect on the amount of currency outstanding has started to exert a larger relative influence. Referring to Table 3, it can be seen that Finland, France and Denmark have a relatively low cash/GDP ratio. But in Finland and Denmark this ratio began to increase towards the end of the observation period, giving support to the increased importance of the income effect.

In the Netherlands, and to lesser extent in Switzerland, there seems to be an increase in the pace of cash substitution toward the end of the observation period. In Italy, the substitution process seems to be very slow throughout the entire period. For the other two countries (Germany and the UK) our results indicate a quite similar pattern, namely a rather slow but steadily diminishing share of cash in POS payments.

In general, we feel that we have managed to capture reasonably well the cash substitution process for European countries. Indeed, an independent estimate of cash use in Finland using data not available in the other countries produces quite

[23] Due to incomplete data, Sweden's estimated cash POS-payment share could not be computed after 1993. It's estimated share in 1988 was 84% which grew to 87% in 1995.
[24] These figures reflect a weighted average where payment values are used as weights.
[25] For Belgium and Denmark we, however, had the starting value problem noted in Appendix 3.

the same pattern of cash substitution (Snellman and Vesala, 1999). In addition, the estimated share of cash in total POS payments in the Netherlands in 1992 is exactly the same as the information provided in BIS (1993).

# 5 S-curve analysis of cash substitution

## 5.1 S-curve methodology

S-curve techniques have often been usefully applied to forecast the adoption of new innovations. This technique has been used to forecast telephone adoption and use, the adoption of robots in automobile manufacturing, and many other applications (Meade, 1988; Gamerman and Migón, 1991 and 1993). We now use this technique to forecast the replacement of cash in European countries. Our purpose is to forecast the possible effect of on-going cash replacement on seigniorage revenues and assess the likelihood that this replacement will be so rapid that tax revenues may have to be used to absorb excess currency holdings. To our knowledge this is the first time this technique has been applied to payment patterns. The premise of S-curve analysis is that once a sufficiently large number of people have adopted a payment innovation, others follow at an increasing rate until the dispersion of the innovation matures and the process approaches saturation. In payments, demographic factors – primarily age and income or wealth – affect strongly the speed at which people adopt new innovations.[26]

The two basic innovation diffusion models used in the literature are the *logistic* and *Gompertz* curves (Young and Ord, 1989; Meade and Islam, 1995a). From these, many other and more complex models have been developed. The main difference between the two models is that the logistic curve is symmetric about its point of inflection while the Gompertz curve is free to be asymmetric. Thus the Gompertz curve is more flexible and allows the initial and accelerating portion of the adoption process to differ from (the mirror image of) the later maturing phase of decelerating adoption. For this reason we adopt the Gompertz curve.

The Gompertz curve for the share of cash in total POS payments, which includes the logistic model as a special case, is expressed as

$$S_t = a \exp(-c(\exp(-bt)) + \varepsilon_t. \qquad (5.1)$$

The *saturation level*, to which the payment diffusion process converges, is denoted by a. The *coefficient of diffusion*, b, determines the slope of the curve, and the *scaling coefficient*, c, gives the vertical position and the "flatness" of the curve. As usual, ε is the error term. We consider this model to be sufficiently rich for our purposes. S-curves with three parameters have been found in most applications to outperform less or more parametrised models (Meade and Islam, 1995b). Our curve is also economically parameterised, an important consideration

[26] For example, the survey by Kennickell and Kwast (1997) finds that household heads under the age of 35 are considerably more apt to use a PC for payments in the US than are older individuals. Wealth is also an important explanatory variable as regards the switch to new electronic payment techniques.

since we have a limited number of observations. Our initial S-curve estimates were made by letting the data determine the saturation level of cash replacement rather than set it at 100% replacement giving 0% for cash POS payments since it is not likely that cash will be abandoned altogether. L-period ahead forecasts for the Gompertz curve are from:

$$E(S_{t+L}) = a \exp(-c(\exp(-bL)), \quad (5.2)$$

where a, b and c are the estimated parameters, and E is the expectations operator.

## 5.2 Forecasts of future cash use

Data for our S-curve analysis are the country-specific estimates of the share of cash in POS payments obtained earlier in Section 4 (and reported in Appendix 3). Other than France, Finland, Denmark and Belgium, whose cash substitution process is relatively mature, the higher cash shares estimated for the other countries indicate that they are essentially at the beginning of the substitution process. As France and Finland are farthest along in reducing cash use at the POS, estimation of their separate S-curves (Table 7 and Figures 6 and 7) provides the most information regarding how the substitution process is likely to evolve in other countries.

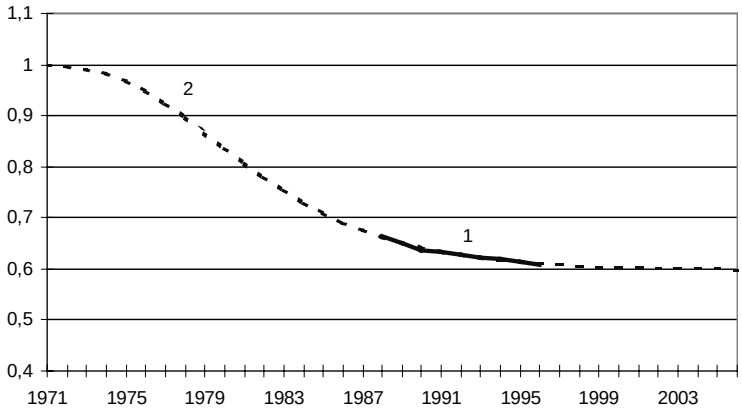
Table 7. **Gompertz S-curve results (1988–1996)**

| | Finland | France |
|---|---|---|
| Estimated shares of POS cash payments: | | |
| 1988 | 0,72 | 0,66 |
| 1996 | 0,56 | 0,60 |
| Saturation level, a | 0,58* | 0,60* |
| | (0,02) | (0,01) |
| Coefficient of diffusion, b | 0,56* | 0,22* |
| | (0,11) | (0,01) |
| Scaling coefficient, c | 0,42 | 0,20* |
| | (0,18) | (0,05) |
| MAFE %[27] | 0,59 | 0,08 |
| Adjusted R-squared | 0,87 | 0,98 |

* Significant at 99 % level. Standard errors in parentheses.

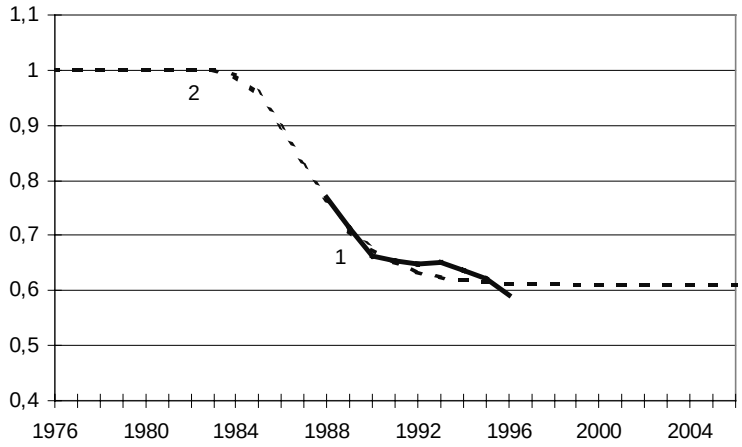
[27] MAFE is the mean aggregate forecasting error and is a commonly used statistic in assessing the forecasting performance of an S-shaped curve. It is calculated as an average of deviations between the observed and fitted values.

Figure 6. **Share of cash POS-payments: France**




1 Projected cash share (S)
2 S-curve extrapolation

Figure 7. **Share of cash POS-payments: Finland**



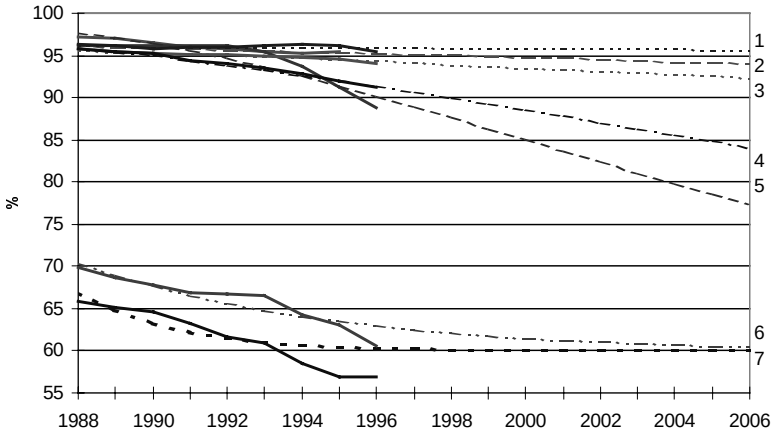

1 Projected cash share (S)
2 S-curve extrapolation

As pictured in Figures 6 and 7, French and Finnish data support our prior contention that an S-curve would be a reasonable characterisation of the cash-substitution process. For both of these countries, the estimated saturation level was approximately 60 %, a level already reached in 1996 (Table 7). The fact that the other European countries are not as far along in the substitution process makes it difficult to accurately extrapolate their future use of cash. However, recall that in Section 4 the substitution of noncash for cash payments was found to be quite similar across countries. Indeed, only two country-specific dummy variables were statistically significant, suggesting that most countries would likely follow a payment path similar to that already achieved by France and Finland. Consequently, to improve the accuracy of our S-curve estimation for the seven remaining countries, we adopt the saturation level estimated for France and

Finland (i.e., a = .60) and estimate the remaining two parameters for each of seven countries.[28] This procedure allows us to characterise the country-specific cash substitution patterns as well as to approximate (if we wished) the time needed to reach a fixed saturation level of 60 per cent.

Using this procedure, we calculate ten-year ahead cash share forecasts for each of the seven countries. These are shown in Figure 8 while Appendix 4 contains the predicted values. Only Switzerland and the Netherlands (in the middle of Figure 8) are forecast to experience much of an additional reduction in cash use by 2006, resulting in predicted cash use levels of 84 % and 77 % respectively by the end of the period. For Germany, Italy, and the UK (at the top of Figure 8), the forecasted substitution pattern indicates a very slow process which leads to cash-use levels from 95 % to 92 % by 2006. Finally, Belgium and Denmark (at the bottom of Figure 8) appear to be close to achieving a degree of maturity in their diffusion process.

Figure 8. **10 year forecast of the share of cash POS-payments, per cent**

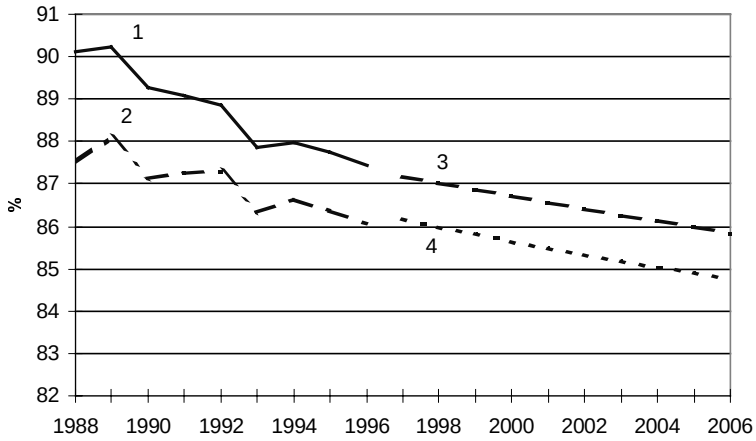



1 Italy
2 Germany
3 UK
4 Switzerland
5 Netherlands
6 Denmark
7 Belgium

Extrapolations of cash use for the nine countries as an average and for the Euro 6 countries are shown in Figure 9.[29] The paths for both averages are very similar, indicating a rather sluggish cash substitution process and a cash share in POS payments of 86 % and 85 % respectively by 2006. As the weight of Germany in these averages is particularly large, the experience of this country has a large impact on the averages shown. Overall, the average substitution process indicates a rather flat S-curve with a long phase of slow diffusion at both the accelerating and decelerating ends of the curve. In contrast, the intermediate phase of rapid diffusion is likely to be quite short, as was indicated by the historical pattern for Finland and France (Figures 6 and 7).

[28] For Sweden, there exists data for only the first six years of our period and thus we have omitted this country from the analysis here (see Appendix 3).
[29] The averages are constructed by using weights based on the amount of total noncash payments.

Figure 9. **Estimated share of cash POS-payments and forecast, per cent**




1 9 countries
2 Euro 6
3 9 countries: forecast
4 Euro 6: forecast

Based on this analysis, three conclusions follow. First, predictions in the popular press and elsewhere that a "cash-less" society is just around the corner are not supported (c.f., Figure 9). Any such development would require a quick adoption of new cash substituting innovations such as e-cash which can not be observed at the moment, and which is uncertain. Second, the most likely saturation point for the share of cash in POS payments – based on the currently available cash substitution technogies is higher than many would expect. And third, it is unlikely that the cash substitution process will be so rapid that it will require tax revenues to redeem large amounts of excess currency, although future seigniorage revenue growth could stagnate.

# 6 Conclusion and discussion

Using data from published international payment statistics, we have attempted to estimate the substitution of noncash for cash payments in ten European countries controlling for the standard money demand theory influences. [30] Our method of approximating the amount of payments effected with cash exploits the negative correlation between changes in currency stocks and noncash payments at the point-of-sale (POS), which represents a substitute for retail cash payments. Our key results are that the nature of the substitution of card payments for cash (and checks) is similar across countries and that the development stage of each country

[30] Some factors that might influence the cash substitution process could not be directly included in the analysis due to a lack of data. This includes data on the relative prices charged by banks for consumer use of different payment media and levels and changes in sales taxes which (in some countries) provides an incentive to hide transactions by using cash.

in this substitution process depends crucially on the diffusion of card payment infrastructure, particularly EFT-POS terminals. Simply put, the current level of technological development of a country's payment system explains its current phase in the cash substitution process.

Our contention that card payments have been the driving force for cash substitution is supported by showing that the density of EFT-POS terminals has had a significant and negative effect on currency outstanding. Importantly, the density of EFT-POS terminals is a key factor affecting the "slope" (i.e., speed) of the cash substitution process. As well, after an initial learning period, ATMs also have had a negative effect on currency outstanding. This is in line with inventory theory: ATMs lower consumer cash withdrawal transaction costs, increase the frequency of withdrawals, reduce the average amount withdrawn each time, and thereby lower the demand for cash holdings for transaction purposes. As the negative relationship between the value of card payments and payments effected with cash or checks was found to be quite similar among the ten European countries examined, countries that are further ahead in the cash substitution process could to be a reasonable guide for future changes in countries lagging behind.

Our estimates of the annual flow of cash payments, and consequently the share of cash in the total value of POS payments, divides European countries into three groups: (1) countries (Belgium, Finland, France and Denmark) in which the cash substitution process, driven by extensive card payment innovation, is mature and close to saturation; (2) countries (the Netherlands, Switzerland) where the process has started to accelerate and shows increasing rates of substitution; and finally (3), countries (Germany, Italy, the UK) which so far show only a modest reduction in the use of cash and are in the initial stages of the substitution process. Historically, since Belgium, Finland, France and Denmark were the first countries to develop substantially their card payment infrastructure in the 1980s, it is not surprising that these same countries are furthest along the path of cash substitution.[31] The current shares of cash in total point-of-sale payment values are estimated to range between approximately 60 per cent in Belgium, Finland, France and Denmark, to 95 per cent in Germany and Italy, which may expect to see a substantial reduction in cash use over time.

Our methodology assumes that the diffusion of card payment innovations, as has been the case for many other innovations historically, follows an S-shaped curve. Different demographic groups, primarily distinguished by age and income level (according to consumer surveys), adopt and begin to substitute card payments for cash with a different time lag. Data for Finland and France both generated well-fitting Gompertz S-curves and indicated that the diffusion of card payment innovations in these countries was relatively mature. Both are close to a saturation point where cash use is expected to stabilise at around 60 per cent of the value of point-of-sale payments. The results also showed that the phase of accelerated substitution away from cash can be quite rapid after a relatively long

[31] The underlying institutional and legal factors affecting investments in payment technologies are extensively discussed in Humphrey, Sato, Tsurumi, and Vesala, 1996, and Humphrey, Pulley, and Vesala, 2000, as well as Snellman and Vesala, 1999. Finland and France demonstrate the influence of widespread cooperation among banks in facilitating the installation of technology required for the modernisation of payments. A single bank is less able to reap the scale benefits related to electronic payments or perhaps even to make the necessary investments. Especially compared to the US, cooperation among European banks in payments has been substantial resulting in more advanced electrification.

period of sluggish change. The similarity of parameters of the fitted S-curves across countries suggests that countries new to this process will likely follow a path similar to that observed for Finland and France. For example, based on our estimated results, by 2000 cash payments in Netherlands are projected to be reduced to 77 per cent of all POS payments but remain high in Italy at 95 per cent (whereas the aggregate European level would fall to 85 per cent).

These forecasts, based on the past experiences of our sampled countries, naturally can not incorporate possible effects resulting from the emergence of important new payment media, such as e-cash (cash loaded on a chip embedded in a card). Proponents of e-cash market it as a "true" replacement for cash, particularly with open circulation since then it would mimic the anonymity and reusability characteristics of cash. The cost of e-cash terminals is likely to be lower than that for EFT-POS terminals which read magnetic stripe cards and the introduction of a single currency in Europe could be a factor that boosts investment in e-cash products (since in a larger market there is a greater potential for realising scale economies). If e-cash becomes popular, the net result would be an expanded opportunity to reduce cash use resulting in a further downward shift (below 60 per cent of all POS payments) in the current projected saturation level of cash use.[32] The magnitude of the cost savings, and hence retailers' incentives for accepting this new instrument, will naturally depend on issuers' pricing policies (Shy and Tarkka, 1998).[33]

In Belgium, Finland, and France, the amount of currency outstanding actually shrank slightly in the early 1990s. This coincides with what we estimated to be a phase of rapid substitution of noncash payments for cash before the process started to slide into a phase of decelerating substitution. These were also years of sluggish economic growth. Thus when a phase of rapid substitution (on the S-curve) coincides with a weak income effect on currency demand, the amount of currency can actually decline generating a need to redeem currency. However, when the substitution process is in its preliminary phase or is decelerating toward maturity, the income effect (increasing sales and therefore cash purchases) outweighs the substitution effect and is the primary determinant of changes in currency stock. In Finland and France, currency stock has increased since the early 1990s providing support for this view. Moreover, in the Netherlands the growth of currency stock has recently started to decrease in line with our predicted effect from accelerating cash substitution. The other countries have not generally witnessed reductions in their currency stock, as they presently remain in the preliminary stage of the substitution process. In sum, provided that the e-cash innovation does not produce a large additional expansion in the cash substitution process, the threat of governments having to redeem currency in large amounts seems to be quite limited based on our results.

[32] Internet-money (e-money used for paying purchases on the Internet) is usually considered another facet of e-cash loaded on chip cards. It would not replace cash directly, rather it would substitute for credit cards as means of payment in electronic commerce. However, if electronic commerce replaces "physical" commerce using cash, then e-cash over the Internet would reduce cash use indirectly.

[33] Since e-cash would most likely be used for the smallest-value transactions such as vending machines, local transportation, phone calls etc., the resulting downward shift in the saturation level of the total value of cash-based POS payments may not be overly large even if it becomes polpular.

# References


BIS (1989) **Payment Systems in Eleven Developed Countries.** Bank of International Settlements, Basel.

BIS (1993) **Payment Systems in the Group of Ten Countries.** Bank of International Settlements, Basel.

BIS (1998) **Statistics on Payment Systems in the Group of Ten Countries: Figures for 1996.** Basel.

Boeschoten, W. (1991) **National Trends in Payment Systems and the Demand for Currency and Banknotes.** Research memorandum WO&E, nr 9108, De Nederlandsche Bank, March 1991.

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

EMI (1996) **Payment Systems in the European Union.** European Monetary Institute, Frankfurt am Main.

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

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

Hancock, D. - Humphrey, D. (1998) **Payment Transactions, Instruments and Systems: A Survey.** Journal of Banking and Finance, 1573-1624.

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.

Humphrey, D. – Pulley, L. – Vesala, J. (1996) **Cash, Paper and Electronic Payments: A Cross-Country Analysis.** Journal of Money, Credit and Banking 28, 4, 914–939.

Humphrey, D. – Pulley, L. – Vesala, J. (2000) **The Check's in the Mail: Why the US Lags behind in the Adoption of Cost Saving Electronic Payments.** Journal of Financial Services Research (forthcoming).

International Monetary Fund (1997) **International Financial Statistics.** Washington, D.C.

Kearney, K. (1993) **An Historical Perspective on Research and Studies on Payment Systems.** In Yamaguchi, M (1993): Payment systems – Strategic Choices for the Future, Hitachi Research Institute, Tokyo.

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.

Marquardt, J. (1994) **Payment System Policy Issues and Analysis.** In Summers, B editor, The Payment System: Design, Management and Supervision, International Monetary Fund.

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.

Niehans, J. (1978) **The Theory of Money.** John Hopkins University Press.

Paroush, J. – Ruthenberg, D. (1986) **Automated Teller Machines and the Share of Deposits in the Money Supply.** European Economic Review, 30, 1207–1215.

Santomero, A. – Seater, J. (1996) **Alternative Monies and the Demand for Media of Exchange.** Journal of Money, Credit and Banking, 28, 4, 942–964.

Snellman, J. – Vesala, J. (1999) **Changing Payment Patterns in Finland: Cash Substitution and Electrification.** Bank of Finland Discussion Paper, 8/99, Helsinki.

Shy, O. – Tarkka, J. (1998) **The Market for Electronic Cash Cards.** Bank of Finland Discussion Paper 21/98, Helsinki.

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

# Appendix 1

Table A1.1 **EFT-POS systems**

| | EFT-POS terminals | | | | EFT-POS terminals per 10 000 inhabitants | | | | EFT-POS transactions per capita | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1987 | 1990 | 1993 | 1996 | 1987 | 1990 | 1993 | 1996 | 1987 | 1990 | 1993 | 1996 |
| Belgium | 15388 | 28253 | 52984 | 81331 | 15,57 | 28,28 | 52,46 | 79,97 | 114,29 | 320,17 | 703,81 | 1413,59 |
| Denmark | 6264 | 15804 | 21778 | 41911 | 12,21 | 30,74 | 41,96 | 79,83 | 84,32 | 680,40 | 1081,21 | 2478,33 |
| Finland* | 4995 | 26500 | 42000 | 51000 | 10,13 | 53,00 | 82,84 | 99,42 | 83,85 | 1115,23 | 1149,82 | 1989,44 |
| France | 70000 | 180000 | 429000 | 546000 | 12,18 | 31,80 | 74,35 | 93,33 | 430,07 | 775,60 | 1201,84 | 1727,19 |
| Germany | 6044 | 23152 | 51806 | 115000 | 0,99 | 2,90 | 6,37 | 14,02 | 0,79 | 1,22 | 39,37 | 208,83 |
| Italy | 392 | 22185 | 77206 | 216093 | 0,07 | 3,84 | 13,50 | 37,58 | 0,22 | 10,23 | 32,26 | 115,91 |
| Netherlands | 926 | 2223 | 24549 | 96044 | 0,63 | 1,48 | 16,05 | 61,96 | 0,00 | 37,42 | 219,64 | 1078,68 |
| Sweden* | 520 | 6090 | 26630 | 67000 | 0,62 | 7,11 | 30,54 | 75,79 | 0,00 | 124,28 | 415,20 | 916,60 |
| Switzerland | 903 | 2765 | 9989 | 33018 | 1,38 | 4,10 | 14,33 | 46,44 | 3,56 | 39,38 | 201,32 | 813,19 |
| United Kingdom | 13006 | 110000 | 270000 | 550000 | 2,29 | 19,16 | 46,39 | 93,54 | 0,00 | 124,49 | 440,62 | Na |

Data sources: BIS's and EMI's statistics (various issues); Bank of Finland, Finnish Bankers Association (*).

Table A1.2 **Banks' ATM networks (both cash dispensing and payment ATMs)**

| | Number of ATMs | | | | Number of ATMs per 10 000 inhabitants | | | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1990 | 1993 | 1996 | 1987 | 1990 | 1993 | 1996 |
| Belgium | 802 | 939 | 2819 | 4207 | 0,81 | 0,94 | 2,79 | 4,14 |
| Denmark | Na | Na | 561 | 1257 | Na | Na | 1,08 | 2,39 |
| Finland* | 1557 | 2838 | 4201 | 4661 | 3,16 | 5,68 | 8,29 | 9,09 |
| France | 11500 | 14428 | 18735 | 24531 | 2,10 | 2,55 | 3,25 | 4,19 |
| Germany | 4033 | 8775 | 25000 | 37600 | 0,66 | 1,10 | 3,08 | 4,59 |
| Italy | 3705 | 9770 | 15227 | 24161 | 0,65 | 1,69 | 2,66 | 4,20 |
| Netherlands | 457 | 2700 | 4461 | 5793 | 0,31 | 1,80 | 2,92 | 3,74 |
| Sweden* | 1650 | 2102 | 2226 | 2379 | 1,96 | 2,46 | 2,55 | 2,69 |
| Switzerland | 1234 | 2262 | 3062 | 4160 | 1,89 | 3,35 | 4,39 | 5,85 |
| United Kingdom | 12507 | 17000 | 19100 | 22100 | 2,20 | 2,96 | 3,28 | 3,76 |

Data sources: BIS's and EMI's statistics (various issues) Bank of Finland, Finnish Bankers' Association (*).

Table A1.3 **ATM transactions**

| | ATM transactions per capita | | | | ATM transactions / ATMs (thousands per year) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1987 | 1990 | 1993 | 1996 | 1987 | 1990 | 1993 | 1996 |
| Belgium | 4,87 | 7,09 | 11,45 | 15,12 | 60,00 | 75,46 | 41,03 | 36,56 |
| Denmark | 1,73 | 3,01 | 5,16 | Na | Na | Na | 47,77 | Na |
| Finland* | 10,26 | 24,20 | 39,84 | 54,70 | 32,50 | 42,64 | 48,08 | 60,20 |
| France | 8,17 | 9,68 | 13,27 | 18,21 | 38,88 | 37,96 | 40,87 | 43,42 |
| Germany | 0,73 | 1,13 | Na | 15,27 | 11,06 | 10,30 | Na | 33,29 |
| Italy | 0,71 | 1,75 | 3,28 | 6,42 | 11,07 | 10,31 | 12,31 | 15,28 |
| Netherlands | 1,44 | 11,20 | 20,52 | 29,42 | 45,95 | 62,22 | 70,39 | 78,72 |
| Sweden* | 17,02 | 19,86 | 28,33 | 33,60 | 86,67 | 80,88 | 110,96 | 124,84 |
| Switzerland | 2,91 | 5,84 | 8,28 | 10,52 | 15,40 | 17,42 | 18,84 | 17,98 |
| United Kingdom | 11,88 | 17,28 | 21,34 | 27,19 | 53,97 | 58,35 | 65,03 | 72,35 |

Data sources: BIS's and EMI's statistics (various issues) Bank of Finland, Finnish Bankers' Association (*).

# Appendix 2

## Basic statistics[34]

| Variable | Mean | Standard deviation |
|---|---|---|
| ATMPOP | 0.32 | 0.18 |
| C | 312.3 | 283.9 |
| CARD | 20.5 | 25.7 |
| CARDPOP | 498 | 292 |
| CHECK | 56.1 | 72.5 |
| CURR | 22.5 | 20.2 |
| EFTPOP | 20 | 80 |
| GDP | 537 | 507 |
| POP | 30.0 | 27.3 |
| r (%) | 5.65 | 2.25 |

ATMPOP = number of ATMs/1000 people
C = value of private consumption, in billions of ECU
CARD = value of card payments, in billions of ECU
CARDPOP = number of debit and charge cards outstanding/1000 people
CHECK = value of POS checks outstanding (our approximation), in billions of ECU
CURR = total value of currency outstanding outside the banking sector, in billions of ECU
EFTPOP = number of EFT-POS terminals/1000 people
GDP = value of GDP in billions of ECU
POP = population in millions
r = nominal money market interest rate

[34] As panel data are used, statistics refer to pooled time series and cross-country data.

# Appendix 3

## Cash payment flows and shares

| | | ΔCASH | β | S |
|---|---|---|---|---|
| Belgium | 1988 | 0,03 | -0,22 | 0,66 |
| | 1989 | -0,17 | -0,34 | 0,65 |
| | 1990 | -0,55 | -0,41 | 0,65 |
| | 1991 | -0,26 | -0,49 | 0,63 |
| | 1992 | -0,68 | -0,67 | 0,62 |
| | 1993 | -1,39 | -0,92 | 0,61 |
| | 1994 | -1,70 | -1,15 | 0,59 |
| | 1995 | 0,20 | -1,33 | 0,57 |
| | 1996 | 0,19 | -1,51 | 0,57 |
| Germany | 1988 | -2,22 | 0,16 | 0,97 |
| | 1989 | -0,58 | 0,15 | 0,97 |
| | 1990 | -1,88 | 0,13 | 0,96 |
| | 1991 | -1,25 | 0,10 | 0,96 |
| | 1992 | -0,59 | 0,05 | 0,96 |
| | 1993 | -0,37 | 0,05 | 0,95 |
| | 1994 | 0,04 | 0,03 | 0,95 |
| | 1995 | 0,03 | 0,01 | 0,96 |
| | 1996 | -0,08 | -0,11 | 0,95 |
| Netherlands | 1988 | 0,68 | na | 0,96 |
| | 1989 | 0,59 | -2,12 | 0,96 |
| | 1990 | 0,02 | -2,13 | 0,96 |
| | 1991 | -0,36 | -2,13 | 0,96 |
| | 1992 | -1,70 | -2,15 | 0,96 |
| | 1993 | -2,47 | -2,26 | 0,95 |
| | 1994 | -2,52 | -2,44 | 0,94 |
| | 1995 | -3,42 | -2,75 | 0,91 |
| | 1996 | -2,66 | -3,11 | 0,89 |
| U.K. | 1988 | -0,55 | 0,10 | 0,96 |
| | 1989 | 0,52 | -0,09 | 0,96 |
| | 1990 | 0,67 | -0,22 | 0,95 |
| | 1991 | -1,87 | -0,51 | 0,95 |
| | 1992 | -2,33 | -0,54 | 0,95 |
| | 1993 | -3,16 | -0,79 | 0,95 |
| | 1994 | -2,91 | -1,08 | 0,95 |
| | 1995 | -4,91 | -1,64 | 0,95 |
| | 1996 | -2,29 | -1,79 | 0,94 |
| Sweden | 1988 | -0,22 | 0,17 | 0,84 |
| | 1989 | -0,19 | 0,10 | 0,83 |
| | 1990 | 0,17 | 0,04 | 0,86 |
| | 1991 | -0,12 | -0,03 | 0,88 |
| | 1992 | -0,10 | -0,16 | 0,88 |
| | 1993 | -0,58 | -0,46 | 0,88 |
| | 1994 | na | -0,98 | na |
| | 1995 | na | -1,12 | na |
| | 1996 | na | -1,42 | na |
| Average | 1988 | -0,52 | 0,05 | 0,90 |
| 10 countries | 1989 | 0,20 | -0,11 | 0,90 |
| | 1990 | 0,35 | -0,17 | 0,89 |
| | 1991 | -1,28 | -0,25 | 0,89 |
| | 1992 | 0,03 | -0,34 | 0,89 |
| | 1993 | -0,48 | -0,47 | 0,88 |
| | 1994 | -0,89 | -0,62 | 0,88 |
| | 1995 | -0,49 | -0,76 | 0,88 |
| | 1996 | 1,42 | -0,91 | 0,87 |

| | | ΔCASH | β | S |
|---|---|---|---|---|
| France | 1988 | 2,04 | -0,27 | 0,66 |
| | 1989 | 2,25 | -0,41 | 0,65 |
| | 1990 | 6,09 | -0,49 | 0,64 |
| | 1991 | -2,63 | -0,57 | 0,63 |
| | 1992 | 4,34 | -1,00 | 0,63 |
| | 1993 | 1,35 | -1,39 | 0,62 |
| | 1994 | 2,00 | -1,79 | 0,62 |
| | 1995 | 1,71 | -1,80 | 0,61 |
| | 1996 | 7,01 | -1,79 | 0,60 |
| Italy | 1988 | 0,41 | 0,17 | 0,96 |
| | 1989 | -1,43 | 0,15 | 0,96 |
| | 1990 | -0,65 | 0,11 | 0,96 |
| | 1991 | 0,01 | 0,02 | 0,96 |
| | 1992 | 0,18 | -0,04 | 0,96 |
| | 1993 | -0,30 | -0,10 | 0,96 |
| | 1994 | -0,22 | -0,20 | 0,96 |
| | 1995 | 0,00 | -0,38 | 0,96 |
| | 1996 | 5,52 | -0,61 | 0,95 |
| Switzerland | 1988 | -0,13 | 0,14 | 0,96 |
| | 1989 | -0,00 | 0,12 | 0,95 |
| | 1990 | 0,01 | 0,10 | 0,95 |
| | 1991 | 0,00 | 0,04 | 0,94 |
| | 1992 | 0,00 | -0,03 | 0,94 |
| | 1993 | -0,06 | -0,12 | 0,93 |
| | 1994 | 0,08 | -0,30 | 0,93 |
| | 1995 | -0,11 | -0,54 | 0,92 |
| | 1996 | 0,65 | -0,80 | 0,91 |
| Denmark | 1988 | -0,13 | -0,17 | 0,70 |
| | 1989 | -0,28 | -0,33 | 0,69 |
| | 1990 | -0,44 | -0,46 | 0,68 |
| | 1991 | -0,68 | -0,60 | 0,67 |
| | 1992 | -0,40 | -0,73 | 0,67 |
| | 1993 | -0,19 | -0,70 | 0,67 |
| | 1994 | -0,15 | -0,79 | 0,64 |
| | 1995 | -0,56 | -0,87 | 0,63 |
| | 1996 | -0,77 | -1,50 | 0,61 |
| Finland | 1988 | -0,21 | -0,30 | 0,72 |
| | 1989 | -0,10 | -0,52 | 0,67 |
| | 1990 | -0,38 | -0,93 | 0,63 |
| | 1991 | -0,27 | -1,22 | 0,62 |
| | 1992 | 0,01 | -1,44 | 0,62 |
| | 1993 | 0,20 | -1,57 | 0,62 |
| | 1994 | 0,05 | -1,81 | 0,61 |
| | 1995 | 0,39 | -1,84 | 0,60 |
| | 1996 | 0,39 | -1,92 | 0,57 |
| Euro 6 aver. | 1988 | -0,58 | 0,02 | 0,88 |
| | 1989 | 0,13 | -0,14 | 0,88 |
| | 1990 | 0,33 | -0,19 | 0,87 |
| | 1991 | -1,31 | -0,21 | 0,87 |
| | 1992 | 0,53 | -0,33 | 0,87 |
| | 1993 | -0,08 | -0,45 | 0,86 |
| | 1994 | -0,66 | -0,57 | 0,87 |
| | 1995 | 0,22 | -0,63 | 0,86 |
| | 1996 | 2,20 | -0,75 | 0,86 |

# Starting values for cash shares

The estimated changes in cash payment flows need to be translated into estimates of the share of cash in the total value of POS payments (S). Section 4 shows how estimates of the changes in cash payment flows are obtained. This estimate is translated into the share of cash payments in total POS payments using the information presented in Column 1 of Table 5 (namely, using the 1987 share of cash in total value of POS payments for six countries: Finland (77 %), France (68 %), Germany (97,7 %), the Netherlands (96 %), Sweden (85 %) and the UK (96 %)). To obtain an estimate of the starting points for the remaining four countries, we used the significant negative correlation between $S_{i87}$ and $EFTPOP_{i87}$ for the above six countries (R-squared 83 %). This is consistent with our result that EFT-POS terminals are the most important determinant of the cash substitution process. The starting points approximated this way are Belgium (67 %), Denmark (70 %), Italy (96 %), and Switzerland (96 %). In Belgium and Denmark, EFT-POS terminal density was close to that in Finland and France in 1987, and hence our approximation aligns these four countries. Italy and Switzerland were close to the Netherlands, Germany and the UK in this regard.

# Appendix 4

## Forecasted shares of cash in the value of POS-payments (S)

| | year | cash share |
|---|---|---|
| Belgium | 1997 | 0,63 |
| | 1998 | 0,60 |
| | 1999 | 0,60 |
| | 2000 | 0,60 |
| | 2001 | 0,60 |
| | 2002 | 0,60 |
| | 2003 | 0,60 |
| | 2004 | 0,60 |
| | 2005 | 0,60 |
| | 2006 | 0,60 |
| Germany | 1997 | 0,95 |
| | 1998 | 0,95 |
| | 1999 | 0,95 |
| | 2000 | 0,95 |
| | 2001 | 0,95 |
| | 2002 | 0,95 |
| | 2003 | 0,94 |
| | 2004 | 0,94 |
| | 2005 | 0,94 |
| | 2006 | 0,94 |
| Netherlands | 1997 | 0,89 |
| | 1998 | 0,88 |
| | 1999 | 0,86 |
| | 2000 | 0,85 |
| | 2001 | 0,84 |
| | 2002 | 0,82 |
| | 2003 | 0,81 |
| | 2004 | 0,80 |
| | 2005 | 0,79 |
| | 2006 | 0,77 |
| U.K. | 1997 | 0,94 |
| | 1998 | 0,94 |
| | 1999 | 0,94 |
| | 2000 | 0,94 |
| | 2001 | 0,93 |
| | 2002 | 0,93 |
| | 2003 | 0,93 |
| | 2004 | 0,93 |
| | 2005 | 0,93 |
| | 2006 | 0,92 |
| France | 1997 | 0,61 |
| | 1998 | 0,61 |
| | 1999 | 0,60 |
| | 2000 | 0,60 |
| | 2001 | 0,60 |
| | 2002 | 0,60 |
| | 2003 | 0,60 |
| | 2004 | 0,60 |
| | 2005 | 0,60 |
| | 2006 | 0,60 |
| Average | 1997 | 0,87 |
| 9 countries | 1998 | 0,87 |
| | 1999 | 0,87 |
| | 2000 | 0,87 |
| | 2001 | 0,87 |
| | 2002 | 0,86 |
| | 2003 | 0,86 |
| | 2004 | 0,86 |
| | 2005 | 0,86 |
| | 2006 | 0,86 |

| | year | cash share |
|---|---|---|
| Italy | 1997 | 0,96 |
| | 1998 | 0,96 |
| | 1999 | 0,96 |
| | 2000 | 0,96 |
| | 2001 | 0,96 |
| | 2002 | 0,96 |
| | 2003 | 0,96 |
| | 2004 | 0,96 |
| | 2005 | 0,96 |
| | 2006 | 0,96 |
| Switzerland | 1997 | 0,91 |
| | 1998 | 0,90 |
| | 1999 | 0,89 |
| | 2000 | 0,88 |
| | 2001 | 0,88 |
| | 2002 | 0,87 |
| | 2003 | 0,86 |
| | 2004 | 0,85 |
| | 2005 | 0,85 |
| | 2006 | 0,84 |
| Denmark | 1997 | 0,63 |
| | 1998 | 0,62 |
| | 1999 | 0,62 |
| | 2000 | 0,61 |
| | 2001 | 0,61 |
| | 2002 | 0,61 |
| | 2003 | 0,61 |
| | 2004 | 0,61 |
| | 2005 | 0,61 |
| | 2006 | 0,61 |
| Finland | 1997 | 0,59 |
| | 1998 | 0,59 |
| | 1999 | 0,59 |
| | 2000 | 0,59 |
| | 2001 | 0,58 |
| | 2002 | 0,58 |
| | 2003 | 0,58 |
| | 2004 | 0,58 |
| | 2005 | 0,58 |
| | 2006 | 0,58 |
| Euro 6 avg. | 1997 | 0,86 |
| | 1998 | 0,86 |
| | 1999 | 0,86 |
| | 2000 | 0,86 |
| | 2001 | 0,86 |
| | 2002 | 0,85 |
| | 2003 | 0,85 |
| | 2004 | 0,85 |
| | 2005 | 0,85 |
| | 2006 | 0,85 |

**BANK OF FINLAND DISCUSSION PAPERS**

ISSN 0785-3572, print; ISSN 1456-6184, online

1/2000 Jussi Snellman – Jukka Vesala – David Humphrey **Substitution of Noncash Payment Instruments for Cash in Europe.** 2000. 39 p. ISBN 951-686-647-6, print; ISBN 951-686-648-4, online. (TU)