CAN CASH HOLD ITS OWN ? INTERNATIONAL COMPARISONS: THEORY AND EVIDENCE

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Abstract:

A number of papers predict the imminent demise of currency use in transactions while some make a case for its continued use due to its distinctive feature of anonymity. Notwithstanding the latter, this paper shows on both theoretical and empirical grounds, that cash use is sustainable for the foreseeable future because of the cost competitiveness of ATM networked cash to the consumer relative to electronic POS card substitutes. Indeed, since the mid-1990s, Finland, Canada and France which are countries in the vanguard of EFTPOS development, have experienced a resurgence of ATM cash use as measured by its expenditure share.
JEL Codes: E41; E50; G2.

Key Words: Payments network ; ATM Cash; Electronic POS media.

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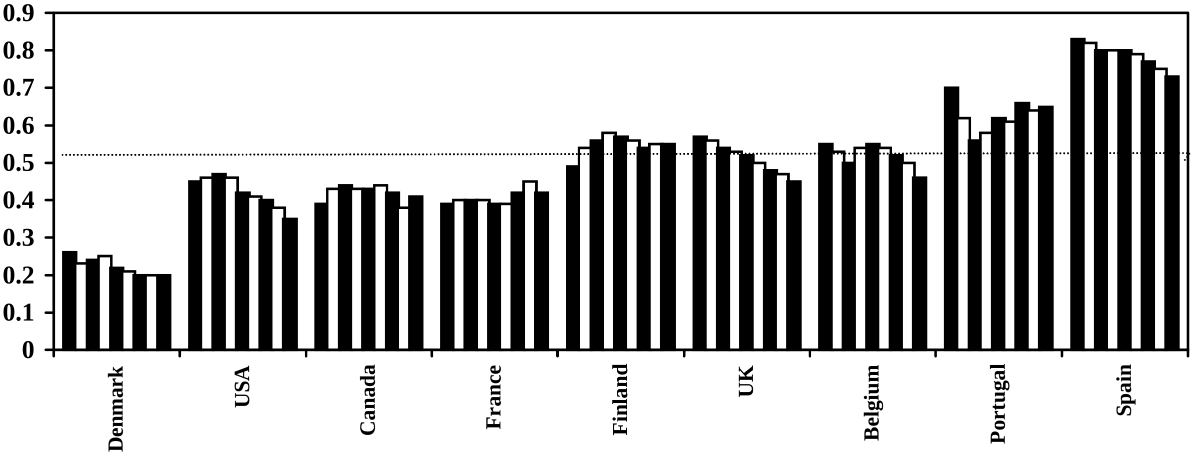
INTRODUCTION

An interesting aspect of this study on the recent developments in payments system is that it is underpinned by the proliferation of an electronic technology that has enhanced *both* cash dispensation via ATM (Automated Teller Machine) networks as well as the use of electronic payment media like debit and credit cards at point of sale. The primary feature of the new EFTPOS media (Electronic Fund Transfer at Point of Sale) is that by forging direct links to consumers' bank balances it can bypass the costs and problems associated with the verification of payors' funds that has historically maintained cash-in-advance as the cheapest means of payment guarantee. Electronic POS instruments and the use of cheques as cash substitutes in the payment system share the property that bank accounts with depository institutions are merely debited or credited and net liquidity within depository institutions remains unchanged. However, despite the bank guarantee card, cheques never became prominent in retail expenditures to rival the use of cash[1]. Further, the expansion of ATM networks by banks has enhanced the convenience yield of cash and also reduced shoe leather costs by increasing accessibility to cash closer to point of sale. This has historically, for the first time, reduced the transaction costs of cash use in payments. Thus, despite an overall trend toward an increasing proportion of card financed purchases to that by cash (Humphreys et al.,1996, and Markose and Loke, 2000a) what primarily emerges from this study is that the cost effectiveness of ATM cash dispensation has enabled cash to maintain its competitiveness vis-à-vis EFTPOS instruments such as credit cards and debit cards. Indeed, what is original to this paper and has not yet been highlighted in the studies undertaken so far on trends in cashlessness is the following somewhat surprising evidence that among the early developers in EFTPOS networks viz. USA, Denmark, Canada, France and Finland**,** the latter three have experienced a resurgence of ATM cash use. This can be observed from Figure 1 that plots the proportion of ATM cash financed expenditure, ω, with total networked expenditure (ATM cash plus EFTPOS card networked purchases). For Canada, France and Finland, the bar charts rise as compared to the marked downward trend in ω for other countries.

FIGURE 1: PROPORTION OF CASH FINANCED EXPENDITURE (ω) IN SELECTED COUNTRIES: 1990-1998

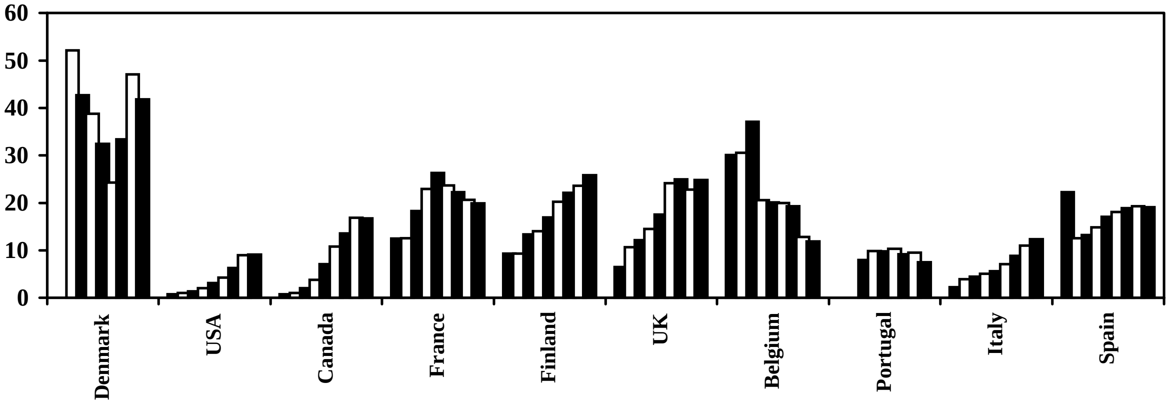


Note: From left to right: The "black" bar refers to 1990,1992,1994,1996,1998 and the "white" bar refers to 1991,1993,1995,1997.

Source: EUROPEAN MONETARY INSTITUTE. (1994,1996,2000). Payment Systems in the European Union. Frankfurt. BANK FOR INTERNATIONAL SETTLEMENTS. (1994, 1996, 2000). Payment Systems in the G10 countries. Basle.

Figure 2 highlights some other competitive aspects of cash and card networks in payment systems. Figure 2 which gives the relative network densities of EFTPOS to ATM terminals (per person) from 1990-98 shows a typical profile for selected countries. With the exception of Belgium and Denmark, in the early part of the last decade, clearly the ATM networks had a head start while towards the middle of the 1990's EFTPOS terminals have been increasing at a faster rate. The flattening of the bar charts in Figure 2 in the late 1990s, indicates converging growth rates in ATM and EFTPOS networks in most countries. This coextensiveness of ATM provision of cash and the EFTPOS card type media yields evidence that they compete keenly on cost criterion relating to accessibility that encourages the consumer to use both instruments in their retail purchases. Thirdly, despite the significant trend towards non-cash retail payments, it is estimated that 70%-90% of the volume of retail transactions remain cash financed. In other words, cash purchases are high in volume and low in value compared to card transactions. Fourthly, we note that in recent years the growth of debit card transactions has outstripped that of credit cards, indicating that non-cash POS instruments are primarily used as a cheap means of fund transfer rather than for credit purposes[2].

FIGURE 2: PER CAPITA RATIO OF EFTPOS TO ATM TERMINALS: 1990-1998



Note: Data for Portugal 1992 -1998. From left to right: The " black" bar refers to 1990,1992,1994,1996 and 1998 and the "white" bar refers to 1991,1993,1995 and 1997.

Source: EUROPEAN MONETARY INSTITUTE. (1994,1996,2000). Payment Systems in the European Union. Frankfurt. BANK FOR INTERNATIONAL SETTLEMENTS. (1994, 1996, 2000). Payment Systems in the G10 countries. Basle.

Each of the four above features on the two competing media, cash and card, will be explicitly addressed in the model on the microstructure of the retail payments system and the mechanics by which substitution between cash and POS type cards takes place. The crucial determinant of the latter will be found to be the extent of EFTPOS network coverage. We provide a means of estimating this. The networked POS cash substitutes materially alter the traditional transactions demand for money equation as well as the dynamics of the interest rate elasticity of the demand for cash. Once an economy becomes highly EFTPOS linked with low interest rate regimes, we find these conditions correlate with low cost of ATM use to the consumer enabling cash to hold its own.

This paper aims to remedy the gap in the literature highlighted by Hancock and Humphrey (1998, p.1574-1575) that "…although the popular press is full of references on the potential use of new types of payment arrangements- from the effect of ATMs and smart cards on cash use to the potential for electronic payments over the Internet to replace cheques or credit cards for bill payments- *little theoretical (and even less empirical) work* *has been done in this area*" (italics added). Literature in this area is either outdated with little factual basis on the core strategic and technology driven nature of networked POS innovations or has fast forwarded into futurology. In a number of theoretical papers (Schreft and Smith, 2000; Woodford,1998 and Ireland, 1994) that analyse recent trends in cashlessness, despite preliminary remarks made on the significance of the new electronic cash substitutes, the explicit models in these papers are based on the premise that the economization of cash is achieved by a credit instrument with all the attendant banking and risk issues rather than the fact that it is mainly due to POS type debit card media. The latter are simply a means of fund transfer necessary in payments and do not entail loans. Thus, for instance, in Schreft and Smith (2000) the demand for cash is determined by random relocations of agents to strange places where the use of credit is not viable. Further, in Schreft and Smith (2000) preference parameters of risk aversion rather than the evolution of available technology of competing media appear to drive the economies of cash use in payments. Woodford (1998, p.180) postulates a distance function between the buyer and the seller and when this exceeds a certain bound, a relevant fraction of goods can only be purchased by cash. The latter is then formally set to be arbitrarily small to obtain the cashless limit with no reference to the strategic or technological process that brings this about.

A number of papers that verge on futurology predict the imminent disappearance of monetary base and hence raise concerns on the potency of monetary policy ((Dowd, 1990; King, 1999; and Friedman, 1999). Others assume the end of cash use in transactions and focus solely on monetary policy implications arising from reserve management demand for monetary base (Henckel et al., 1999, and Woodford, 2000). In contrast, (Goodhart, 2000, and Goodhart and Krueger, 2001) are sceptical of the prediction on the demise of cash use in transactions and believe in its sustainability due to the distinctive feature of anonymity of currency use. The black economy and categories of 'bad behaviour' such as a visit to the brothel, Drehmann et al. (2001) naturally highlight a preference for cash use due to its anonymity. Notwithstanding the latter, this paper underscores the view on the continuance of ATM cash use in transactions for the foreseeable future due to its cost competitiveness in relation to electronic POS card substitutes.

Large denomination notes are associated with the more nefarious activities in the black economy, Rogoff (1998). As ATMs do not dispense large denomination notes, it is plausible that in terms of the network effects of ATM cash and its EFTPOS cash substitute, consumers view these as perfect substitutes. Hence, in an equilibrium in which consumers use both media, their network costs must be equal at the margin under conditions of optimal money management. The theoretical model of this paper that can explain trends in the use of ATM cash and its substitution by POS media, thus, not only incorporates a means to measure the rate of adoption of the electronic POS technology but also stringently imposes a condition of cost competitiveness of ATM cash which secures its continued use. Dutta and Weale (2001) conduct an econometric analysis of a consumption payments model with non-cash payment innovations. It is the only paper to date, other than Markose and Loke (2001) and this one, that has estimated the rate of growth of the latter in the UK.

The rest of the paper is organized as follows. In Section I, a simple Nash game is developed to model the adoption of a new EFTPOS card payment media given that cash is dispensed by a competitive ATM network. The reaction functions of the representative consumer and merchant, respectively, depend on the expected card network coverage, π^k, and the proportion of card financed expenditure, $(1-\omega)$. The Nash equilibria in the game involving mutual adoption of a new payments media by the representative merchant and consumer have strategic features similar to those in the case of the Susan B. Anthony dollar coin, Caskey and St. Laurent (1994), as well as the search theoretic issue raised in Kiyotaki and Wright (1993) and Berentsen (1997). However in the latter, the consumer's demand for the two payments media with network externalities is not integrated into the game involving both merchant and consumer. Further, to correctly equate the marginal network costs to the consumer of cash and card use, it is necessary to consider the annual flow effects of per capita cash and card financed disbursements. This framework provides a means to estimate the volume of cash purchases as there is a paucity of historical records on cash use due to its anonymity. In Section II, by calibrating the theoretical model using the payments data from BIS and ECB/EMI for the selected EU and G10 countries[3], we estimate the unobserved card network coverage, π^k, and the cost per unit of ATM transactions, $T_c^{\#}$, for each of the countries. These estimates are used to compare the speed of development and competitiveness of cash-card networks in these countries between 1990-1998.

Countries are grouped into early, medium and late developers in payment networks. In Section III(a), using panel data analysis, we test for the statistical significance of the new model generated values for the variables π^k and $T_c^{\#}$ in a panel regression framework for the explanation of the trends in the proportion of ATM cash financed expenditures, ω. Finally, in Section III(b), we turn to the observed phenomena that countries in the vanguard of EFTPOS developments have experienced a resurgence of ATM cash use. The theoretical proposition, that early developers with little scope for further improvements in EFTPOS networks will have lost the impetus for more cash economization and then experience a resurgence of ATM cash use with low interest rates and low unit ATM costs, is borne out by the panel regression analysis.

I. MICROSTRUCTURE OF CASH-CARD NETWORKS

As explicit costs of cash management are needed, we extend the Baumol (1952)–Tobin (1956) model for transactions demand for cash. Unlike the traditional assumption that 100% of the value of expenditures is cash financed, on including the possibility of substitution by card payments, the transactions demand for cash balances is reduced by a factor of $\sqrt{\omega}$, the square root of the proportion of cash financed expenditures. The smaller is ω, the larger the substitution away from cash in payments.

The Nash equilibria being selected are ones in which *both* payments media coexist when an appropriate measure of costs in cash and card use are equal. The series of Nash equilibria over time are taken to be outcomes of a formally identical one shot game between the representative consumer and merchant which yields a unique relationship between the historically observed per capita proportion of ATM cash financed expenditures ω, interest rates and the implied Baumol-Tobin unit costs of cash, on one hand, and the extent of π^k or card network density for the economy, on the other.

(a) Costs of ATM Cash Use

At the beginning of a period, the representative consumer receives a fixed income, α and the income is expended at regular intervals to buy a fixed volume, V, of goods and services. The proportion of cash financed retail expenditures is given by $\omega = \alpha_c / \alpha$ and V_c denotes the volume of cash purchases. The proportion of card financed expenditures is given by $(1-\omega)=\alpha_k/\alpha$ with V_k denoting the volume of card financed purchases. Note, $\alpha=\alpha_c+\alpha_k$ and $V=V_c+V_k$.

The costs of cash network use include the standard opportunity cost of holding cash balances which arises from foregoing interest income, *r*, the shoe leather cost of going to the nearest ATM , and thirdly the cost of using an incompatible ATM. The latter two will be simply denoted by $T_c^{\#}$. These costs apply to each ATM cash withdrawal. The total number of the latter is denoted by W_c. The total costs, T_c, to a consumer of using cash payments for a per capita amount α_c of annual retail expenditures and W_c, withdrawals is given by,

$$T_c = W_c T_c^{\#} + \frac{r\,\omega\alpha}{2W_c} \,. \tag{1}$$

The second term in (1) is the interest rate cost on average per capita transaction balances. Following Baumol (1952) and Tobin (1956), we obtain the so called square root rule for optimal number of cash withdrawals,

$$W_c^* = \sqrt{\frac{r\ \omega\alpha}{2T_c^{\#}}} \,. \qquad (2)^4$$

On setting the optimal W_c^* to equal the historical per capita number of ATM cash withdrawals and using data on r, ω and α, using (2) we estimate the unit ATM transaction costs to the consumer as

$$T_c^{\#} = \frac{r\omega\alpha}{2{W_c}^2} \,. \tag{3}$$

The per capita optimal transaction balance is given by

$$B^* = \frac{\omega\alpha}{2W_c^*} = \sqrt{\frac{\omega\alpha T_c^{\#}}{2r}} \,. \tag{4}$$

On substitution of optimal W_c^* in (2) into (4), we get the second equality in (4). When card substitution is possible, $\omega < 1$, we note that per capita transactions balances is reduced by $\sqrt{\omega}$ relative to an economy in which 100% of expenditures is cash financed.

(b) Costs of EFTPOS card use

The cost of using card is zero in terms of interest rate losses that are incurred on idle transactions balances. However, card use will not proliferate unless consumers are confident that retailers will accept the card. Consumers, therefore, face the risk of non-acceptance of cards and they have to fall back on the time honoured way of producing cash on the nail. To a random consumer, his expectation of the probability with which a card is accepted by a retailer is equal to $E_C\pi^k$, viz. the proportion of all merchants in the economy that are EFTPOS linked. Thus, with expected probability ($1 - E_C\pi^k$) when the card is rejected, the consumer has to incur the costs of cash use, $T_c^{\#}$ (see, equation (3)). The total cost, T_k, of putting through V_k volume of card transactions is therefore,

$$T_k = V_k(1 - E_C\pi^k)T_c^{\#}. \qquad (5)$$

(c) Volume of Cash Purchases

Here we model the commonplace feature of modern payments systems that cash purchases are higher in volume but lower in value than card purchases. The latter implies that the card fund α_k which makes larger value purchases is depleted at a slower rate over the year. This results in differential flow effects of disbursements from the cash and card funds. Evaluating the present values in per dollar average value of cash and card purchases, viz. $1/V_j$, $j=c,k$, we have

$$PVE_j = \frac{1}{V_j} PV_c^u = \frac{1}{V_j} \sum_{i=1}^{V_j} \frac{1}{(1+\frac{r}{V_j})^i}, \qquad j=c,k. \qquad (6)$$

Here, PV_c^u and PV_k^u are the present discounted[5] values of a dollar worth of purchases made by cash and card, respectively. Trivially, if $V_c = V_k$, PV_k^u is the same for both streams, and $PVE_c = PVE_k$. Using simple principles of a capital budgeting problem we determine $V_c > V_k$ such that $PVE_c = PVE_k$. Thus, given that the volume of card purchases are recorded, this approach enables us to determine the volume of cash purchases for which records do not exist. The equality of present value of cash and card disbursements on a unit fund may be seen as a no arbitrage condition in the use of the two media.

The consumer equates the present value of average per dollar value of purchases over the year for the cash and card funds defined in (6), such that $V_c > V_k$. This results in

$$V_c = V_k(r|D| + 1) \quad . \qquad (7)$$

Proof, see Appendix 2.

Here, $|D|$ denotes the absolute value of the duration of the fund and $r|D|$ is the interest elasticity of the present value flow. The duration of a fund is defined as the percentage change in the present value for a 1% change in the interest rate[6]. This formula is given in the Appendix 2 (equation (A.3)). From (7), we see that the volume of cash purchases for a fixed value of the cash fund will rise considerably as the interest rate rises. This has the effect of reducing the average per dollar value of a cash purchase and hence interest rate costs by increasing the frequency of cash purchases relative to those made by card.

(d) Consumer's Reaction Function $R_C((1-\omega), E_C\,\pi^k)$

Since flow effects in disbursements over a year discussed above are important to the consumer in the use of cash and card, his profit or net return functions denoted by PVR_j , $j= c,k$, is given by,

$$PVR = PVR_k + PVR_c .$$

$$PVR_k = \left[\frac{1-\omega}{V_k}(1+r) - \left(1 - E_C\pi^k\right)T_c^{\#}\right]PV_k^u \quad . \tag{8.a}$$

$$PVR_c = \left[\frac{\omega}{V_c}(1+r) - 2\frac{W_c^*}{V_c}T_c^{\#}\right]PV_c^u . \tag{8.b}$$

In (8.a,b), the first terms are the portfolio weighted average per dollar gross return on deposit balances from the card and cash funds respectively given in (6) and the second terms are the per unit (volume) optimal cost of using the card and cash networks obtained from (5) and note (4) respectively.

The consumer's reaction function, $R_C((1-\omega),E_C\pi^k)$, in the Nash game, relates his choice of the proportion of card financed purchases ($1-\omega$) to $E_C\pi^k$ given the optimal conditions of cash management and the costs of card use over time. In the latter case, with $PVE_k= PVE_c$ in (6) to equalize flow effects of disbursements from the two funds the net revenue function in (8.a,b) simplifies to

$$PVR = \left[\frac{1}{V_k}(1+r) - \left(1 - E_C\pi^k\right)T_c^{\#}\right]PV_k^u - 2\frac{W_c^*}{V_c}T_c^{\#}PV_c^u \quad . \tag{8.c}$$

The objective function above can be shown to be a special case of a more general CES utility function for cash and card disbursements when the two payments media are taken to be perfect substitutes. This is given in Appendix 3. From (8.c) we see that the optimal ω is indeterminate which is again a generic result with a CES utility function in the case of perfect substitutes. Then, only relative costs matter and an unique reaction function $R_C((1-\omega), E_C\pi^k)$ can be shown to exist when the volume of cash and card use are such that their network costs are equalized at the margin,

$$\frac{d\left(\left(1-E_C\pi^k\right)T_c^{\#}PV_k^u\right)}{dV_k} = \frac{d\left(2\frac{W_c^*}{V_c}T_c^{\#}PV_c^u\right)}{dV_c} .$$

In an equilibrium when cash and card use coexist the above condition yields,

$$(1-E_C\,\pi^k)\,T_c^{\#}\,r|D| = 2\frac{W_c^*}{V_c}\,T_c^{\#}\,(r|D|-1) .$$

From this, the consumer's implicit reaction function $R_C((1-\omega), E_C\pi^k)$ (plotted in Figure 3) is obtained from the relationship between the expected card network density parameter, $E_C\pi^k$, and the possibility of substitution between cash and card determined by ω. Thus,

$$E_C\pi^k = 1-2\frac{W_c^*}{V_c}\frac{\left(r|D|-1\right)}{r|D|} = 1-2\sqrt{\frac{r\omega\alpha}{2V_c^2T_c^{\#}}}\frac{\left(r|D|-1\right)}{r|D|},\ 0\leq \pi^k \leq 1. \qquad (9)$$

The second equality is obtained by substituting for the optimal cash withdrawals, W_c^*, from (2). Note that in arriving at (9) the appropriate unit cost comparisons between cash and card use must entail their respective volumes, V_c and V_k. Further, the last term in (9), $\frac{\left(r|D|-1\right)}{r|D|}$, which yields the reciprocal of the ratio of the interest elasticity $r|D|$ of PVE_k in (6) and the volume elasticity of PVE_k [7], appears to be essential to get the correct trend in the values for π^k over the years. It also incorporates the relative flow effects of cash and card use.

(e) Merchant's Decision Problem

Merchants in turn, will not make the investment in the new EFTPOS machines unless they expect a large proportion of per capita retail expenditures, $(1-\omega)$, will be financed by card payments[8]. Hence, the representative merchant's reaction function $R_M(\pi^k, E_M(1-\omega))$ relates π^k with his expectation $E_M(1-\omega)$. The profit function of the representative merchant is given as:

$$P = (1-\pi^k)[E_M\omega\alpha - T_c - T_c^M] + \pi^k[E_M(1-\omega)(\alpha - T_k^M) + E_M\omega(\alpha - T_c^M) - T_c - F]. \qquad (10)$$

Here, the first term denotes the net revenue from cash transactions in the case when with probability $(1-\pi^k)$ a merchant has not installed the EFTPOS. In this situation, the merchant gets a gross return of only the proportion $\omega\alpha$ of cash expenditures, less an amount T_c which equals the total cost of cash transactions incurred by the consumer and the total cost to the merchant of T_c^M for cash handling. The second term in (10) denotes the net revenue to the merchant in the case when with probability π^k a merchant has installed EFTPOS. In this case, the representative merchant effectively gets the full α of annual per capita income of the consumer less only the costs of card and cash handling T_k^M and T_c^M and the costs to the consumer for using cash T_c. Finally, a fixed cost F has to be incurred for the installation of an EFTPOS connection.

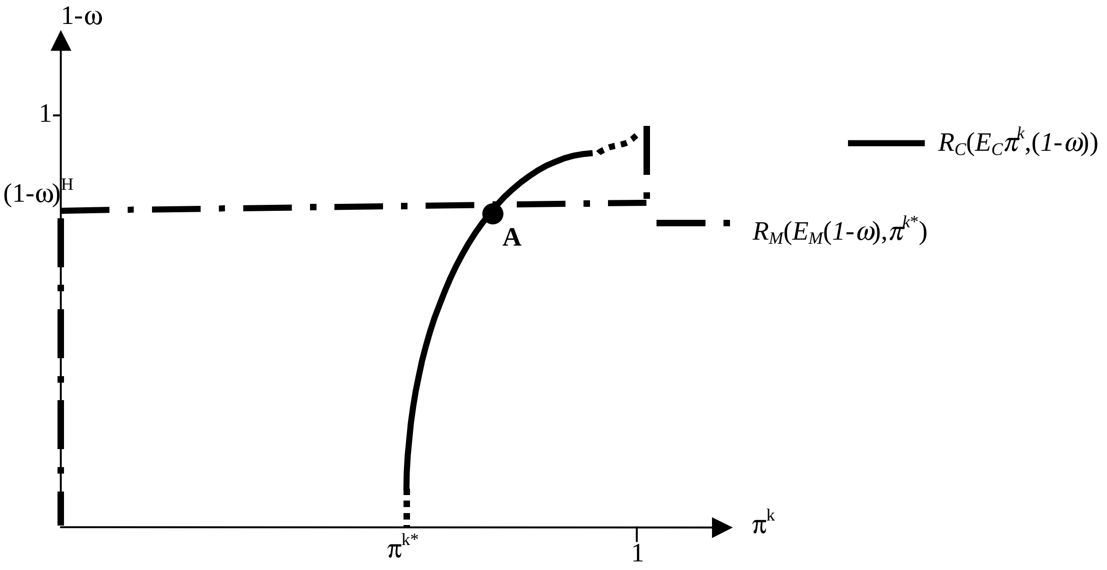
Optimizing (10) with respect to π^k yields the decision rules for the merchant,

$$E_M(1-\omega)\begin{cases} > & \Rightarrow \quad \pi^k = 1 \\ = \dfrac{F}{\alpha + (T_c^M - T_k^M)} & \Rightarrow \quad 0 < \pi^k < 1 \\ < & \Rightarrow \quad \pi^k = 0. \end{cases} \qquad (11)$$

The first term on the R.H.S of (11) gives the ratio of the fixed cost, F, with the consumer's income α and the cost difference of handling cash transactions and card transactions. Equation (11) states that if the merchant's expectation of the proportion of consumer's card expenditures, $E_M(1-\omega)$, is greater (>) than the cost factors in the first term on the R.H.S of (11) then he will invest in EFTPOS. In the absence of heterogeneous expectations, this also implies that there is full EFTPOS coverage with $\pi^k = 1$. When there is equality in equation (11), the relevant section of the merchant's reaction function is horizontal in the $(\pi^k, (1-\omega))$ plane, see Figure 3, and the economy can have any π^k, $0 < \pi^k < 1$, consistent with the per capita value for $(1-\omega)$ given by the reaction function in (9). Finally, if $E_M(1-\omega)$ is less than the cost factors in (11), no merchant will invest in EFTPOS and the economy has zero EFTPOS.

(f) Nash Equilibrium

FIGURE 3: REACTION FUNCTIONS OF CONSUMER AND MERCHANT: NASH EQUILIBRIUM



In Figure 2, we plot the consumer's reaction function, $R_C(E\pi^k, (1\text{-}\omega))$ from equation (9) with that of the merchant, $R_M(E_M(1\text{-}\omega), \pi^k)$ given in (11). As specified in (11), the merchant's reaction function R_M has three segments. The Nash equilibrium points in the $(\pi^k,(1\text{-}\omega))$ plane are at the intersection between the R_C curve and the horizontal segment of the R_M curve. Thus, as shown in Figure 3, as $R_C(E\pi^k, (1\text{-}\omega))$ exists strictly for, $0 <(1\text{-}\omega) < 1$, viz. only for cases when both cash and card are in use by the consumer, the R_C curve cannot intersect at the points where $\pi^k=1$ and the horizontal axis where $(1\text{-}\omega) =0$.

In the Nash equilibrium, the merchant's expectation $E_M(1\text{-}\omega)$ has to equal the historically observed per capita $(1\text{-} \omega)^H$ for the economy. The ω consistent with this, then, determines the Nash equilibrium π^{k*} in terms of the consumer's implicit reaction function in (9). For given historical values for α, r, V_k and estimated $T_c^{\#}$, we have a unique $R_C((1\text{-}\omega)^H, E_C\pi^k)$ curve from (9) and hence a unique point A, in Figure 3, on the horizontal segment of the R_M curve which denotes the Nash equilibrium pair $((1\text{-}\omega)^H, \pi^{k*})$ for the economy.

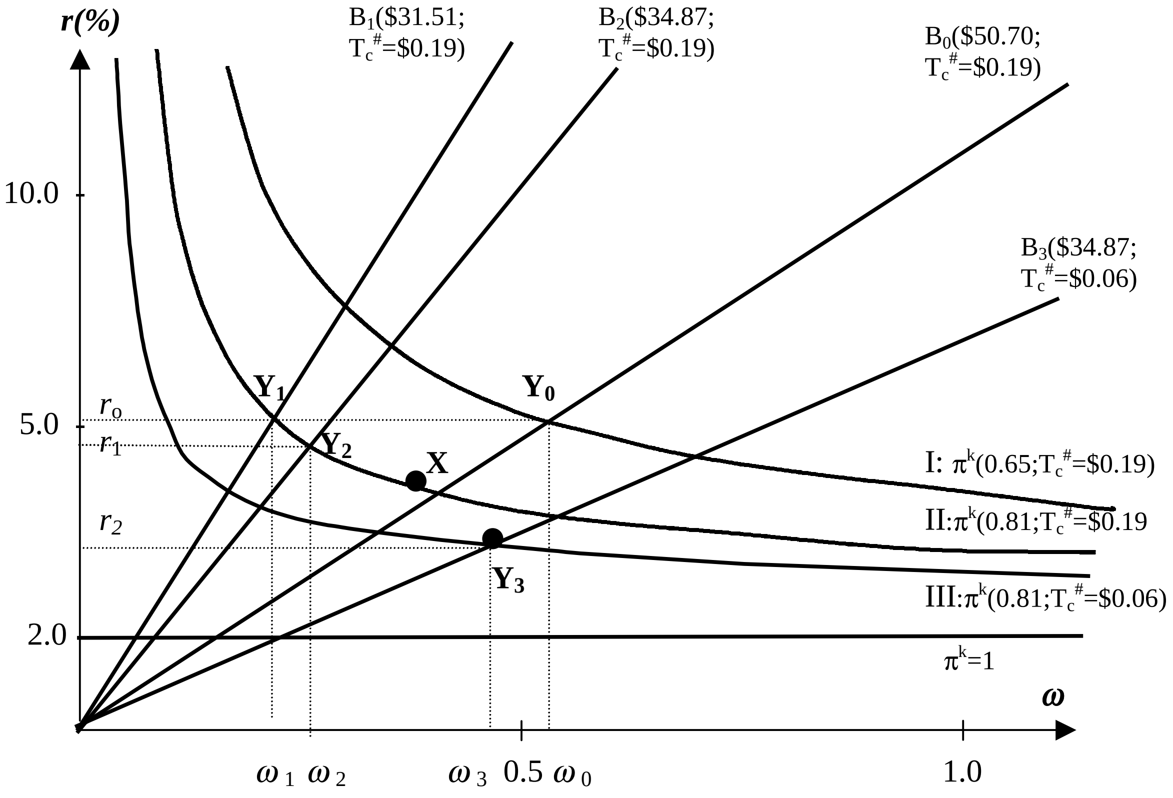
(g) Card Network Coverage and Microstructure of Cash-Card Substitution

The main thesis here is that cash-card substitution in an economy is determined primarily by the extent to which the retail nodes are EFTPOS linked. Using equation (9) and historical payments data, we can plot the combinations of (ω, r) that give the same equilibrium level of EFTPOS density, π^k, in an economy. This is referred to as the iso π^k-curves. The iso π^k-curves that can be derived for any economy with their payments data (see, Appendix 1), is the main vehicle for the explanation of international trends in ω and for the calibration of interest rate sensitivity of cash-card substitution in the different countries. Figure 4 specifically uses the payments data for France with 1997 historical values for α and estimated $T_c^{\#}$, V_c and the duration value, $|D|$, to plot the iso-π^k curves based on the equation (9). We note the following features of the iso π^k-curves in Figure 4:

- Point X gives the historical $\omega = 0.39$ and $r = 4.5\%$ for France in 1990 and the estimated level of $\pi^k = 0.79$, from equation (9). Point Y_3 gives the historical $\omega = 0.45$ and $r = 3.5\%$ for France in 1997 with estimated $\pi^k = 0.81$. This implies that 79 % and 81% of the merchants accept card payments in 1990 and 1997 respectively.
- The π^k-curve I sets $\pi^k = 0.65$ with $T_c^{\#}$ being 19 cents and α equal to the 1997 historical value ($3108.24) for France.
- The leftward shift of the π^k-curve in Figure 4 from Curve I to Curve II indicates higher levels of card network coverage from $\pi^k = 0.65$ to $\pi^k = 0.81$. Note that $T_c^{\#}$ and α remain unchanged for Curves I and II. On the other hand, π^k-curve III is identical to Curve II with $\pi^k = 0.81$, but has lower ATM costs, $T_c^{\#} = 6$ cents. Curve III corresponds precisely with the historical payments data for France in 1997.
- Downward sloping π^k-curves imply an inverse relationship between deposit interest rate, r, and proportion of cash financed expenditure, ω.

- The important point of Figure 4 is that as an economy becomes highly EFTPOS linked, along with low ATM unit costs, the flatness of the π^k-curve at low interest rates implies that cash-card substitution is highly interest rate sensitive. This has consequences for the conduct of monetary policy[9].

FIGURE 4: RESURGENCE OF CASH EXPLAINED IN HIGH π^k ECONOMIES WITH FALLING INTEREST RATE AND ATM COST



- In the limit, when there exists full card network coverage, π^k=1, the iso-π^k curve is horizontal and from equation (9) we see that there exists a critical lower bound to nominal interest rates of approximately 2%.
- Finally, to analyse the implications of payment innovations for the optimal transactions balances, B^*, and for cash-card substitution, the iso B-curve is superimposed on the (ω,r) plane in Figure 4. Note that from equation (4), with α unchanged,

$$dB(r,\omega,T_c^{\#}) = -\frac{1}{2}\frac{B}{r}dr + \frac{1}{2}\frac{B}{\omega}d\omega + \frac{1}{2}\frac{B}{T_c^{\#}}dT_c^{\#} \quad . \qquad (12)$$

From (12) with $T_c^{\#}$ unchanged, we obtain the iso *B*-curve in Figure 4 which is a straight line through the origin with slope given by $\left.\frac{dr}{d\omega}\right|_{dB=0} = \frac{r}{\omega} > 0$. The important implication of our model is that $d\omega$ that determines cash-card substitution is constrained by the equilibrium condition in (9). Thus, solving for the ω,

$$\omega = \left[\left(\frac{1-\pi^k}{2}\right)\left(\frac{r|D|}{r|D|-1}\right)\right]^2 \left(\frac{2V_c^2 T_c^\#}{\alpha r}\right).$$

With, α unchanged, cash-card substitution is determined by changes in π^k ,r and $T_c^\#$.

$$d\omega = \frac{\partial\omega}{\partial\pi^k}d\pi^k + \frac{\partial\omega}{\partial r}dr + \frac{\partial\omega}{\partial T_c^\#}dT_c^\# = -\left[\frac{2\omega}{1-\pi^k}d\pi^k + \frac{\omega}{r}\left(\frac{r|D|+1}{r|D|-1}\right)dr\right] + \frac{\omega}{T_c^\#}dT_c^\#. \quad (13)$$

The first two terms in (13) determine the impact of EFTPOS, π^k, and the interest rate on the cash-card substitution. Clearly, advancements in π^k will lead to cash economization with $d\omega < 0$, while interest rate cuts lead to $d\omega > 0$. *Ceteris paribus,* the higher the π^k, the greater is fall in ω with π^k improvements. Likewise, at low interest rates, *ceteris paribus*, (13) implies large swings in ω for changes in interest rates. With the iso π^k-curve unchanging and $dT_c^\# = 0$, we can see from equation (13) that an infinite rate of cash-card substitution (from cash to card and vice versa) can exist at the critical nominal interest rate of 2%. Finally, to isolate the impact of unit ATM costs $T_c^\#$ on the equilibrium changes in ω for a given level of π^k in the economy, we set $d\pi^k$ in (13) and dB in (12) to be zero and simultaneously solve for $d\omega$ using (12) and (13). Thus, the impact of costs of cash use which are determined by r and unit ATM costs $T_c^\#$, is given by

$$d\omega^* = -\frac{\omega}{T_c^\#}\frac{1}{r|D|}dT_c^\#. \quad (14)$$

This result shows that for high π^k economies with little scope for further π^k improvements, cash resurgence with $d\omega > 0$ follows with a reduction in ATM costs and interest rates. Further, from (14), we see that the lower the interest rate, the greater is the scope for cash use[10].

The respective impact of EFTPOS, interest rates and ATM costs on trends in the proportion, ω, of cash financed networked expenditures for an economy can be analysed graphically. Consider a point such as Y_0, in Figure 4, which characterizes a relatively low π^k economy well before card dominance ($\omega < 1/2$) features. Starting from Y_0 in Figure 4 on the B_0-curve for a given α and $T_c^\#$, the economy enjoys π^k improvements from π^k=0.65 to

0.81. The extent of cash economization, $d\omega < 0$, is given by the first term in (12). Visually, the new ω_1 is given by the B_1-curve, which intersects the $\pi^k = .81$ curve (Curve II) at point Y_1. Note that the B_1-curve yields optimal transaction balances of \$31.51, with α=\$3108.87 and $T_c^{\#}$=19 cents. However, starting from point Y_1, when an interest rate fall to r_1 is not accompanied by any change in π^k, the B-curve can only shift from B_1 to B_2, where $d\omega$ is given by the second term in (13) with $d\pi^k = 0$. Note, that the optimal transaction balances in B_2 is equal to \$34.87. Now we consider a fall in the unit ATM costs $T_c^{\#}$ to be equal to the historical fall in France from 19 cents in 1990 to 6 cents in 1997. The equilibrium $d\omega$ from Y_2 to Y_3 that corresponds to the fall $T_c^{\#}$ and interest rate is given by equation (14). Visually the new (ω_3, r_2) at Y_3 is given by the intersection of the B_3-curve and π^k curve III with transaction balances equal to \$34.87 and $T_c^{\#} = 6$ cents corresponding to the precise historical transaction balances B^* for France in 1997. This gives a theoretical explanation for resurgence of ATM cash use in economies with competitive provision of ATM cash under conditions of falling interest rates and high π^k where scope for further π^k improvements is small and the iso π^k-curve is more or less unchanging.

II. INTERNATIONAL COMPARISONS OF ESTIMATES FOR EFTPOS DENSITY (π^k) AND UNIT ATM COSTS ($T_c^{\#}$)

Using the payments data obtained from BIS and ECB/EMI for 1990-1998 (see, Appendix 1), we calibrate the theoretical model developed in Section I to estimate the card network coverage, π^k (equation 9) and cost per unit of ATM transactions, $T_c^{\#}$ (equation 3) for the selected EU and G10 countries. This is given in Table 1. The historical proportion of ATM cash financed expenditure, ω, deposit interest rates, r and the per capita ATM Baumol-Tobin transactions balances, given by $B^* = \alpha_c / (2W_c^*)$, for the respective countries are also given in Table 1. For ease of international comparisons, payments data is given in per capita terms and where appropriate is converted into US dollars.

TABLE 1: HISTORICAL DATA FOR (ω, r, B^*) AND CALIBRATED ESTIMATES FOR $T_c^\#$ AND π^k IN SELECTED COUNTRIES: 1990-1998

		DK.	USA	Can	Fra.	Fin.	U.K	Belg.	Port.	Italy	Spain	Japan	Ave
1990	ω	0.26	0.45	0.39	0.39	0.49	0.57	0.55	0.70	0.77	0.83	0.51	*0.54*
	r	7.9	8.1	12.81	4.5	7.5	12.54	6.13	13.99	6.8	10.65	3.56	*9.09*
	B^*	45.20	33.02	20.53	40.70	49.98	38.72	52.49	35.05	119.25	58.10	175.71	*49.60*
	$T_c^\#$	0.82	0.12	0.09	0.19	0.15	0.28	0.45	1.24	4.65	0.68	3.73	*0.87*
	π^k	0.92	0.84	0.80	0.79	0.81	0.74	0.76	0.63	0.52	0.09	n.a	*0.69*
1991	ω	0.23	0.46	0.43	0.40	0.54	0.56	0.53	0.62	0.77	0.82	0.55	*0.54*
	r	7.2	5.7	8.62	4.5	7.5	10.28	6.25	14.8	6.64	10.47	4.14	*8.20*
	B^*	49.83	33.52	21.74	41.34	46.14	40.64	53.72	36.57	119.61	56.89	178.25	*50.00*
	$T_c^\#$	0.74	0.08	0.06	0.17	0.11	0.23	0.42	0.97	3.44	0.64	3.07	*0.68*
	π^k	0.93	0.81	0.71	0.77	0.77	0.74	0.78	0.77	0.52	0.22	n.a	*0.70*
1992	ω	0.24	0.47	0.44	0.40	0.56	0.54	0.50	0.56	0.77	0.80	0.56	*0.53*
	r	7.5	3.52	6.67	4.5	7.5	7.46	6.25	14.59	7.11	10.43	3.35	*7.55*
	B^*	55.40	33.47	21.44	33.10	39.67	40.53	58.47	39.98	122.69	62.24	172.99	*51.70*
	$T_c^\#$	0.80	0.04	0.04	0.16	0.08	0.15	0.42	0.78	3.05	0.64	1.95	*0.62*
	π^k	0.94	0.81	0.67	0.84	0.74	0.71	0.80	0.82	0.52	0.35	n.a	*0.72*
1993	ω	0.25	0.46	0.43	0.40	0.58	0.53	0.54	0.58	0.79	0.80	0.59	*0.53*
	r	6.5	3.02	4.92	4.5	4.75	3.97	7.11	11.06	7.79	9.63	2.14	*6.32*
	B^*	54.16	35.00	20.62	38.47	29.72	35.04	57.25	33.14	98.39	51.16	193.03	*45.29*
	$T_c^\#$	0.65	0.04	0.03	0.13	0.04	0.07	0.36	0.38	2.34	0.42	1.24	*0.44*
	π^k	0.95	0.84	0.67	0.83	0.67	0.70	0.79	0.78	0.52	0.49	n.a	*0.72*
1994	ω	0.22	0.42	0.43	0.39	0.57	0.52	0.55	0.62	0.78	0.80	0.61	*0.53*
	r	3.5	4.2	5.59	4.56	3.27	3.66	4.86	8.37	6.21	6.7	1.7	*5.09*
	B^*	58.77	33.61	19.72	38.06	36.40	37.28	60.30	32.12	97.71	49.93	209.93	*46.39*
	$T_c^\#$	0.37	0.04	0.03	0.12	0.03	0.06	0.22	0.23	1.64	0.26	1.00	*0.30*
	π^k	0.96	0.81	0.70	0.83	0.75	0.73	0.76	0.82	0.41	0.38	n.a	*0.72*
1995	ω	0.21	0.41	0.44	0.39	0.56	0.50	0.54	0.61	0.76	0.79	0.61	*0.52*
	r	3.9	5.84	7.15	4.5	3.19	4.11	4.04	8.38	6.45	7.68	0.9	*5.52*
	B^*	70.79	33.85	19.31	40.67	43.12	38.61	68.91	35.32	97.24	54.73	225.32	*50.20*
	$T_c^\#$	0.48	0.05	0.03	0.12	0.03	0.06	0.19	0.21	1.47	0.29	0.53	*0.29*
	π^k	0.96	0.80	0.74	0.83	0.76	0.74	0.78	0.80	0.41	0.47	n.a	*0.73*
1996	ω	0.20	0.40	0.42	0.42	0.54	0.48	0.52	0.66	0.77	0.77	0.60	*0.52*
	r	2.8	5.3	4.33	3.67	2.35	3.05	2.66	6.32	6.49	6.12	0.3	*4.31*
	B^*	72.90	34.00	18.96	39.72	42.07	39.03	66.96	38.50	101.52	53.76	191.68	*50.74*
	$T_c^\#$	0.35	0.04	0.02	0.08	0.02	0.04	0.12	0.13	1.03	0.22	0.14	*0.21*
	π^k	0.97	0.81	0.75	0.83	0.88	0.81	0.86	0.71	0.39	0.37	n.a	*0.74*
1997	ω	0.20	0.38	0.38	0.45	0.55	0.47	0.50	0.64	0.73	0.75	0.58	*0.50*
	r	2.7	5.62	3.59	3.5	2	3.63	2.88	4.56	4.83	3.96	0.3	*3.73*
	B^*	68.19	34.16	17.84	34.87	38.10	42.23	58.97	34.23	92.35	46.35	144.33	*46.73*
	$T_c^\#$	0.30	0.05	0.01	0.06	0.02	0.05	0.11	0.07	0.62	0.12	0.09	*0.14*
	π^k	0.98	0.82	0.79	0.81	0.99	0.79	0.85	0.71	0.47	0.41	n.a	*0.76*
1998	ω	0.20	0.35	0.41	0.42	0.55	0.45	0.46	0.65	0.72	0.73	0.56	*0.49*
	r	3.1	5.47	5.03	3.21	2	4.48	3.01	3.37	3.16	2.92	0.27	*3.57*
	B^*	71.73	34.00	23.04	33.59	37.57	43.88	59.08	37.24	89.48	46.05	117.50	*47.50*
	$T_c^\#$	0.36	0.04	0.02	0.05	0.02	0.06	0.11	0.05	0.33	0.08	0.06	*0.11*
	π^k	0.97	0.84	0.77	0.84	0.99	0.79	0.87	0.75	0.58	0.54	n.a	*0.79*
Ave.	ω	*0.22*	*0.42*	*0.42*	*0.41*	*0.55*	*0.51*	*0.52*	*0.63*	*0.76*	*0.79*	*0.57*	
	r	*4.82*	*5.21*	*6.36*	*4.01*	*4.17*	*5.71*	*4.62*	*9.49*	*5.71*	*7.61*	*1.68*	
	B^*	*61.11*	*33.85*	*20.36*	*38.94*	*40.31*	*39.55*	*59.57*	*35.79*	*104.25*	*53.25*	*178.75*	
	$T_c^\#$	*0.54*	*0.06*	*0.04*	*0.12*	*0.05*	*0.11*	*0.27*	*0.45*	*2.06*	*0.37*	*1.31*	
	π^k	*0.95*	*0.82*	*0.73*	*0.82*	*0.79*	*0.75*	*0.81*	*0.75*	*0.48*	*0.37*	*n.a*	

In most countries, with the exception of Japan, the high interest rate regimes of the late 1980's and the early 1990's were a spur to the development of EFTPOS cash substitutes. From the last row in Table 1, we see that the average Japanese per capita holdings of ATM cash, B^*, for this period was about \$178 while, for example, that for USA is \$34 and that for UK is \$39. However, what is interesting is that Japan is the only country in this group that at no time in the last decade had appropriate incentives to economize on cash holdings. The low interest rates of 1990 followed by interest rates below 2% by 1994, makes it difficult to estimate the extent of card network coverage in Japan by the model proposed in this paper. Likewise for Finland, in Table 1, in 1997, when r= 2%, the equation (9) which estimates π^k will record π^k close to 1.

From the last column of Table 1, for countries excluding Japan, we see that the average π^k in these countries in 1990 was 69% growing to 79% by 1998. However, by 1998, most of the countries have achieved estimated card network densities of over 75% (π^k=0.75) and the marked changes took place in 1993-1994.

In the period leading up to high EFTPOS densities in the countries, the rate of ATM cash substitution in retail expenditures is measured by a fall in ω. From Table 1 (last column), we see that in 1990, on average, 54% of networked expenditures in the ten countries is cash financed while in 1998 this fell to 49%.

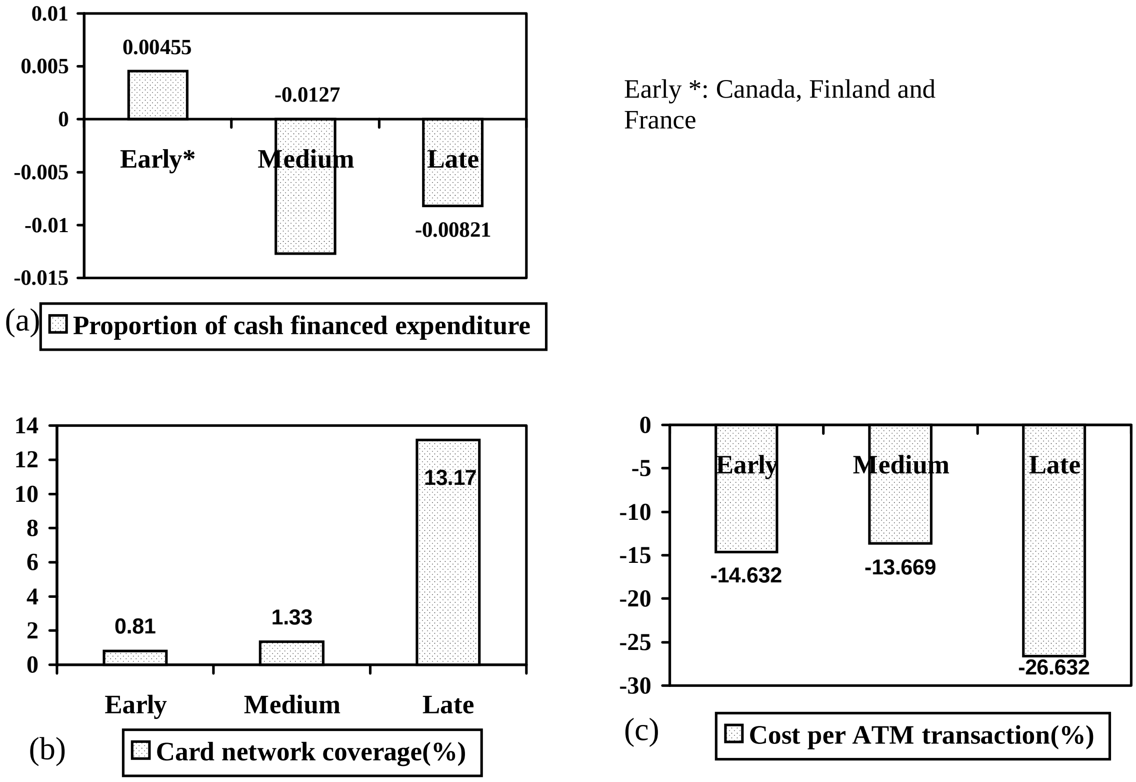
Following from Table 1 and Figure 5(a-c), on the basis of individual variations the ten countries are divided into three groups of early, medium and late developers of networked payments.

(a) The early developers are countries such as Canada, Finland, France, Denmark and USA which are in the vanguard of EFTPOS. These countries attained an above average π^k of 0.79 as early as in 1990 and their average ATM cost was 27 cents in 1990 falling to 10 cents in 1998. From Figure (5b), we see that these countries show the least scope for π^k improvements. A majority of the countries in this group (Finland, France and Canada) show signs of resurgence of cash use (see Figure 5a). In Finland, which has a high average card network density of 79% and low ATM unit costs of 5 cents, when deposit interest rates halved from an average of 7.5% in the years 1990-1992 to 4.75% in 1993, from Table 1 we find that ω jumps from 54% to 58%, implying a resurgence of ATM cash use. In France, with a π^k average of 82% and ATM costs at 12 cents, we find that the use of cash increased from ω of about 39% to over 43% against a background of gradual interest rates falls. Similarly in Canada, from low cash use of $\omega = 39\%$ in 1990, when interest rates halved by 1994, given negligible unit ATM costs of 3 cents, cash use has picked up to about 44% of networked expenditures.

(b) The medium developers are countries such as Belgium and U.K, which had achieved an average π^k of 0.75 and 36 cents in the ATM cost in 1990. From Figure (5a), it is shown that ATM cash economization is most intensive in this group of countries.

(c) The late developers are countries such as Italy, Portugal and Spain which had high ATM cost (Italy and Portugal) and low card network coverage (Italy and Spain) in 1990. The late developers show the largest fall in ATM costs, (Figure 5c) and highest increase in card network coverage (Figure 5b).

FIGURE 5: AVERAGE YEAR ON YEAR CHANGES IN PROPORTION OF CASH FINANCED EXPENDITURES, COST PER ATM TRANSACTIONS (%) AND CARD NETWORK COVERAGE (%): 1990-1998



Early *: Canada, Finland and France

III. EMPIRICAL PANEL ESTIMATION RESULTS

(a) Panel (Pooled) Data Analysis for Significance of Model Determined Variables (π^k and $T_c^{\#}$)

Here we are concerned with estimating the model for the trends in ATM cash financed expenditures measured by ω for the selected countries. The lack of proper theoretical formulations for the role of payment innovations in cash substitution and the problem with obtaining empirical data on transactions costs of competing payments media have dogged empirical work in this area. The Dutta and Weale (2001) econometric estimation of a consumption payments model is the only example of a theoretically founded model for empirical estimation of non-cash payments innovation and in its implications of interest rate semi-elasticity for the transactions demand for money. However, the feature of a highly competitive provision of ATM cash in low interest rate regimes is not properly modeled in Dutta and Weale (2001). The more traditional way of incorporating payments innovation for money demand has been to use data on the number of ATM and EFTPOS terminals in the regression equations (Trundle, 1982 and Boeschoten, 1992). We will compare the efficacy of our model generated variables, $T_c^{\#}$ and π^k, with the traditional variables for network developments.

A two way fixed effects error component model (Baltagi, 1995) is used in the estimation where the error term is made up of three components. In equation (15), λ_i represents country-specific effect which takes into account the unobserved heterogeneity, μ_t represents a time specific component and ε_{it} denotes the stochastic disturbance term with i =1,2,…10 (countries), t=1,2,…9 (years:1990-1998). There are a total of 90 observations. The empirical specification used is as follows:

Proportion of per capita cash financed expenditure(ω): Lin-log model

$$\omega_{it} = \gamma_2 + \delta_j Z_{j,it} + \lambda_i + \mu_t + \varepsilon_{it} . \tag{15}$$

Here, Z is the vector of regressors which consists of deposit interest rate (r), per capita real private consumption (RPC), per capita value of card transactions (α_k), ATM terminals per person (ATM), EFTPOS terminals per person (EFT), unit ATM cost ($T_c^{\#}$) and card network coverage (π^k) and j=1,2,…7. As a lin-log model is used, the coefficients measure the effect of a percentage change in the explanatory variables on the level change in ω.

Two specifications are used. Specification 1 will examine the relationship between the proportion of cash financed expenditure and its explanatory variables without the model determined variables, $T_c^{\#}$ and π^k. This is then compared with the analysis from Specification 2 which includes $T_c^{\#}$ and π^k. Due to simultaneous equation bias between ω and α_k, the α_k is instrumented by $\alpha_{k,t-2}$ and the value of EFTPOS transactions per person. Table 2 gives the "within" regression estimates.

TABLE 2: PANEL REGRESSION RESULTS FOR PROPORTION OF CASH FINANCED EXPENDITURE (10 COUNTRIES:1990-1998)

Deposit interest rate: r	Real private consumption: RPC	Value of card expenditure: α_k	ATM	EFTPOS	Cost per ATM transaction: $T_c^{\#}$	Card network coverage: π^k	R^2
Specification 1:							
-0.018 (-1.07)	0.019 (0.21)	-0.097 (-1.00)	0.046* (2.50)	-0.039 (-0.17)			0.5490
Specification 2:							
0.061* (2.60)	0.131 (1.25)	-0.092 (-1.18)	0.024 (1.51)	-0.011 (-0.68)	-0.070* (-2.76)	-0.044 (-1.29)	0.7007
0.05* (2.11)	0.207* (2.94)	-0.147* (-3.20)			-0.089* (-4.18)	-0.068* (-2.46)	0.7168

Note: * denotes 5% significance level and ** denotes 10% significance level. t-statistics in parenthesis.

In Specification 1, where only the traditional monetary innovation variables are used such as the number of ATM and EFTPOS terminals per person, the estimation result is poor with R^2=0.5490. Further, only the number of ATM terminals per person was found to be statistically significant for the estimation of ω. However, in Specification 2, when the model determined variables which proxies for the cost of ATM transactions and the extent of EFTPOS innovation are included, the general fitness of the model is improved with a higher R^2=0.7007. In fact, the traditional variables on the number of ATM and EFTPOS terminals per person are found to be statistically insignificant now.

On dropping the variables for EFTPOS and ATM terminals per person in Specification 2 (second row), it is found that the model generated variables, $T_c^{\#}$ and π^k clearly enhance the statistical significance of all the remaining regressors.

(b) Group Panel Estimation For The Proportion of Cash Financed Expenditure (ω)

This section aims to test for the validity of the categorization of economies as given in Section II to explain the trends in ATM cash use. The empirical specification of the model is as follows:

Proportion of per capita cash financed expenditure (ω): Lin-Log Model.

$$\omega_{it} = \beta + \delta r_{it} + \gamma RPC_{it} + \phi_n (S_n T_{c_{it}}^{\#}) + \varphi_n (S_n \pi_{it}^{k}) + \lambda_i + \mu_t + \varepsilon_{it} \qquad (16)$$

where i=1,2,…,10 (countries), t=1,2,…,9 (years from 1990-1998), n=1,2,3 (group of countries according to development of card network coverage). S represents the slope dummies for each group of countries and for the other variables, refer to equation (15).

TABLE 3: DETERMINANTS OF THE TRENDS IN THE PROPORTION OF CASH FINANCED EXPENDITURE (ω) FOR EARLY, MEDIUM AND LATE EFTPOS ECONOMIES:1990-1998 (LIN-LOG MODEL).

	Nominal Deposit Rate (r)	Real Private Cons. (RPC)	Cost ($T_c^{\#}$)			Card Network Coverage (π^k)			R^2
			Early	Medium	Late	Early	Medium	Late	
ω	-0.054** (-1.89)	-0.054 (-1.03)	-0.069* (-5.04)	0.055 (1.61)	-0.006 (-0.39)	-0.14 (-0.89)	-0.69** (-1.76)	-0.192* (-8.68)	0.8774

* denotes 5% significance level and ** denotes 10% significance level. t-statistics in parenthesis.

The resurgence of cash use discussed in Section II (g) was based on the premise that in the early developers of EFTPOS with less than 1% growth in π^k (see, Figure 5b), the increased competitiveness in the unit costs of ATM cash use, $T_c^{\#}$ (which fell by 14.63%) will dominate the EFTPOS effect. This is borne out in Table 3, where card network coverage has no significant effect on ω while $T_c^{\#}$ has a strong statistically significant effect for high π^k economies. On the other hand, the estimates for late developers in Table 3, which experienced the most significant development in π^k growth, show that the fall in ω is significantly affected by the growth in π^k.

On using the empirical estimates given above, we can predict the extent of the resurgence of cash use in Canada, Finland and France. Table 4 compares the actual with the predicted increase in ω from the lowest initial point to the peak of ω in the decade. We see that the estimated coefficients yield a very close prediction of the observed resurgence of cash use in these countries.

TABLE 4: PREDICTION OF ATM CASH RESURGENCE

	Changes in interest rate (%)	Changes in cost, $T_c^{\#}$ (%)	Actual changes in ω (level)	*Predicted changes in ω (level)*
Canada : (1990-1992)	-47.9	-55.5	0.05	*0.064*
Finland : (1990-1993)	-36.7	-73.3	0.09	*0.070*
France : (1990-1997)	-22.2	-68.4	0.06	*0.059*

Note: The calculations for the last column are reported in Appendix 4.

V. CONCLUSION

The resurgence of ATM networked cash use measured by the proportion of cash financed expenditures, ω, in the course of 1990s has been observed in countries in the vanguard of EFTPOS developments such as France, Finland and Canada. Tables 1 and 4, clearly indicate the cost competitiveness of cash for the consumer vis-à-vis card. The reduction in deposit interest rates further encourages the use of cash. This feature has been built into the theoretical model on the microstructure of the networked cash-card payments. Hence, not withstanding the attractiveness of cash transactions due to anonymity emphasized by (Goodhart, 2000, and Drehmann et al., 2001) for its sustainability, the major findings of this paper is that cash holds its own due to the competitive low costs, estimated by $T_c^{\#}$, in its provision relative to the EFTPOS card substitute. This result decisively rules against the position taken by those who predict the imminent demise of cash in transactions.

The methodology given in this paper to estimate the extent of card network coverage, π^k, for any economy yields an analytical tool in the form of iso π^k-curves (see Figure 4) which is useful to explain trends in cash-card substitution for an economy as shown in equations (12) to (14). The monetary policy implications of this are crucial and have been investigated in Markose and Loke (2001, 2002). Further, the framework of the model enables classification of countries according to the speed in the development and competitiveness of payment innovations on the basis of ω, $T_c^{\#}$ and π^k. The two model determined variables π^k and $T_c^{\#}$, were found to enhance the explanatory power of the panel regression analysis for ω in the selected countries. The grouped panel regression analysis for early, medium and late developers of payment networks, validates the fact that their different stages of development have a crucial impact on the rate of ATM cash economization. In particular, the popularly held view of a monotonic decrease in cash use is unfounded. Using coefficients from the grouped panel regression for early developers, we provide a remarkably accurate prediction of ATM cash resurgence in Canada, Finland and France.

APPENDIX 1: TABLE A1: USA PER CAPITA CASH-CARD PAYMENTS DATA: 1990 - 1998 (USD)

Year	***1990***	***1991***	***1992***	***1993***	***1994***	***1995***	***1996***	***1997***	***1998***
α_c: Value of cash purchases	1532.61	1697.67	1886.5	2033.31	2140.39	2496.58	2740.49	2779.39	2817.61
α_k: Value of card purchases	1907.96	1983.78	2156.16	2403.56	2932.11	3566.92	4066.29	4604.70	5163.52
$\alpha=\alpha_c+\alpha_k$: Total value of purchases	3440.58	3681.44	4042.66	4436.87	5072.50	6063.5	6806.78	7384.10	7981.13
$\omega=\alpha_c/\alpha$	0.45	0.46	0.47	0.46	0.42	0.41	0.40	0.38	0.35
W_c: Vol. of cash w'drawal	23	25	28	29	32	37	40	41	41
B^+: Average cash balances	33.01	33.51	33.47	35	33.61	38.84	34	34.15	34
V_k: Volume of card purchases	44	46	48	51	57	63	71	78	86
r: Interest rate	0.081	0.057	0.0352	0.0302	0.042	0.0584	0.053	0.0562	0.0547

$^+$ $B=\dfrac{\alpha_C}{2W_C}$.

Source: BANK FOR INTERNATIONAL SETTLEMENTS. (1993,1996,2000). Payment Systems in G10 Countries. Basle. INTERNATIONAL MONETARY FUND. (2000). International Financial Statistics Yearbook 1999. New York.

APPENDIX 2: PROOF FOR THE ESTIMATION OF THE VOLUME OF CASH PURCHASES, V_c.

We require that $V_c > V_k$, yet $PVE_c = PVE_k$ in (6). Starting from an initial volume of purchases equal to that of the card purchases V_k which is known, we have to determine- (i) the precise increase in the volume of purchases for the cash fund relative to the card fund, $dV_k = V_c - V_k$ and (ii) the corresponding fall in value, $d\frac{1}{V}_k < 0$, that maintains the same present value, PVE_k, as for the card fund. For fixed interest rates, the total derivative of the present value function in (6) with $j=k$, is set equal to zero. This has to be identical whether in volume, V_k, or value $\$1/V_k$ terms. Further by definition

$$\frac{1}{V_k}\, dV_k = -V_k\, d\frac{1}{V_k} \ . \tag{A1}$$

Hence, iso-PVE curve in the (PV_k^u , V_k) plane is given by

$$\frac{dPVE_k(V_k)}{PVE_k} = \frac{\frac{\partial PVE_k}{\partial V_k}}{PVE_k} dV_k + \frac{\frac{\partial PVE_k}{\partial PV_k{}^u}}{PVE_k} dPV_k{}^u = 0$$

$$= \frac{1}{V_k}(r|D| -1)dV_k + \frac{dPV_k^u}{PV_k^u} = 0 \ , \tag{A2}$$

Here, $|D|$ denotes the absolute value of the duration of the funds and $r|D|$ is the interest elasticity of the present value flow. Also note that, $(r|D|-1)$ is the volume elasticity of the present value flow, PVE. The duration of a flow value of a fund defined as the percentage change in the present value for a 1% change in the interest rate is given by the formula

$$D_j = \frac{\frac{dPVE_j}{dr_j}}{PVE_j} = -\frac{1}{V_j}\frac{1}{(1+\frac{r}{V_j})}\frac{\sum_{i=1}^{V_j}\frac{i}{(1+\frac{r}{V_j})^i}}{\sum_{i=1}^{V_j}\frac{1}{(1+\frac{r}{V_j})^i}} \ , \ j = c,k. \tag{A3}$$

From (A2), we see that the following relationships must hold for the iso-level PVE_k curve,

$$\frac{dPV_k{}^u}{PV_k^u} = \frac{1}{V_k}\ (1 - r|D|)\, dV_k \ . \tag{A4}$$

Rewriting (A4), and using (A1), we have

$$\frac{1}{V_k} dV_k = \frac{dPV_k{}^u}{PV_k^u} + \frac{1}{V_k} r|D| dV_k$$

$$= -V_k d\frac{1}{V_k} + \left[\frac{1}{V_k} r|D| dV_k + r|D| V_k d\frac{1}{V_k}\right]. \qquad \text{(A5)}$$

To satisfy (A1), in (A5) the expression in the square brackets is equal to zero. This implies that $\frac{dV_k}{d\frac{1}{V_k}} = \frac{dPV_k^u \big/ PV_k^u d\frac{1}{v_k}}{dPV_k^u \big/ PV_k^u dV_k}$. Thus,

$$dV_k = V_c \text{-} V_k = \frac{dPV_k{}^u}{PV_k^u d\frac{1}{V_k}} = V_k r|D| \qquad \text{(A6)}$$

and

$$d\frac{1}{V_k} = \frac{dPV_k{}^u}{PV_k^u dV_k} = -\frac{1}{V_k} r|D|. \qquad \text{(A7)}$$

In other words, these precise movements in volume and value are necessary to stay on the same PVE_k curve. From (A6) we derive that $V_c > V_k$ which consistent with the iso-PVE_k for a given V_k is

$$V_c = V_k(r|D| + 1).$$

APPENDIX 3: THE INDETERMINACY OF OPTIMAL EXPENDITURE SHARES

Consider the general CES utility function for cash and cards disbursements (with the coefficient ρ =1 implying cash and cards are perfect substitutes)[11]:

$$\underset{\alpha_c, \alpha_k}{Max}\, U = \left[(\alpha_c PVE_c)^\rho + (\alpha_k PVE_k)^\rho\right]$$

subject to the budget constraint: $Z \geq \alpha_c + 2W_c^* T_c^\# + \alpha_k + V_k(1 - E_c \pi^k) T_c^\#$ with PVE_j as defined in equation (6). With the constraint above being exactly met, note that the identities of the expenditure shares can be expressed as follows: $\alpha_c = q_0 Z - 2W_c^* T_c^\#$ and $\alpha_k = (1 - q_0)Z - V_k(1 - E_c \pi^k) T_c^\#$. $q_0 Z$ ((1-q_0)Z) denotes the proportion of total sum of the value of cash (card) purchases and cost of cash (card) use to the total budget. On substituting the latter identities for the expenditure shares α_c and α_k above into the CES utility function and setting ρ =1, the objective function in (8c) is obtained with the proviso that $Z \equiv (1+r)$ as α has been normalized to 1 in the model. The generic indeterminacy of optimal expenditures shares when ρ =1 where cash and cards are perfect substitutes is as follows. On using Lagrangian function, L, and solving the utility maximization problem above, we have, $\frac{\partial L / \partial \alpha_c}{\partial L / \partial \alpha_k} = \left(\frac{\alpha_c}{\alpha_k} \right)^{\rho-1} = 1 + \sqrt{\frac{r\,T_c^{\#}}{2\alpha_c}} = 1 + \frac{r}{2W_c^{*}}$ = 0, from which the required result of the indeterminacy of optimal expenditures shares follows when ρ =1.

APPENDIX 4: CALCULATION OF THE EMPIRICAL PREDICTION FOR CHANGES IN ATM CASH USE (ω)

In the lin-log model of equation (16), on dividing the statistically significant coefficients by 100 and multiplying them by the percentage changes in the regressors ($T_c^{\#}$ and r), we obtain the estimated level changes in the ω.

a. Canada (1990-1992): $\Delta\omega$ = (-0.00054 x (-47.9)) +(-0.00069 x (-55.5)) = 0.064.

b. Finland (1990-1993): $\Delta\omega$ = (-0.00054 x (-36.7)) + (-0.00069 x (-73.3)) = 0.07.

c. France (1990-1997): $\Delta\omega$ = (-0.00054 x (-22.2)) + (-0.00069 x (-68.4)) = 0.059.

NOTES

1. According to Evans and Schmalensee (1999, p.91) in the USA: "…of the personal consumption on goods and services in 1996, 57% were made by cheques, 21% with cash and 22% with payment cards. In 1984, …only 6% personal consumption spending was made with cards, compared with 58% with cheques and 36% with cash". This data suggests that the growth of card use has come largely at the expense of cash in retail payments.
2. Between 1990-1998, the average growth in the value of debit card transactions for a sample of three countries is (USA:44%; UK:34%;Canada:103%) while the average growth in the value of credit card transactions is (USA:11%; UK:10%;Canada:3%). These calculations are based on Table 12 and 13 of BIS (1993, 1996, 2000).
3. Table A1 in Appendix 1 gives the ATM and EFTPOS (card) per capita payments data for USA for 1990-1998. The same format for data sets applies to all selected countries and can be obtained from the authors.

4. On substituting the optimal cash withdrawal, W_c^* into (1), the expected optimal total cost of cash use simplifies to $T_c = 2W_c^* T_c^\#$.
1. While making disbursements from his cash and card funds, the consumer adopts an average time interval between each of the cash purchases to be $365/V_c$ while that for card purchases is $365/V_k$. This results in respective discount rates in (6) of $\beta_c = r/V_c$ and $\beta_k = r/V_k$ where r is the per annum interest rate. The flow of purchases over time are then discounted at a compounded rate equal to the frequency of purchases. This corresponds to a capital budgeting problem with multiple but fixed value coupon payments in a year.
6. Note that 1% change in the interest rate means a change from say 8% to 9% rather than 8% to 8.08%. That is, when r is 5% and $|D|= .50$, $r|D|= 5\text{x } 0.50 = 2.5$. It was found that for the volume of purchases per annum over 50, the duration value converges to close to .50 irrespective of interest rates.
7. The volume elasticity of present value PVE is given by $\frac{\partial PVE_j}{\partial V_j}\frac{V_j}{PVE_j} = (r|D| -1)$.
8. Note the model here assumes duality of membership by the merchants (i.e.merchants accept all types of cards) and also they make no distinction between offline and online transactions. Alternatively, these can be viewed as second order decisions, with the primary one being whether to accept card or only cash.
9. The tabulations of interest rate sensitivity of cash-card substitution in a partial equilibrium framework and some of its implications for monetary policy has been dealt with in Markose and Loke (2001). This analysis which focuses on changes in household payments habit is further extended in Markose and Loke (2002) to include the banking sector and the loanable funds market to get the bigger picture.
10. It is important to note that $d\omega > 0$ need not correspond to $dB>0$. Indeed, from the derivation of equations (12) and (13), there exists a specific relationship between dr and $dT_c^\#$ which determines whether dB is positive, negative or unchanged when r and $T_c^\#$ fall.
11. The version of the CES function used in Dutta and Weale (2001) incorporates the payments technology into the utility function yielding: $\max_{\alpha_c,\alpha_k}\left[\left(1-\pi^k\right)^{1-\rho}\left(\alpha_c PVE_c\right)^\rho + (\pi^k)^{1-\rho}\left(\alpha_k PVE_k\right)^\rho\right]$.

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