# Empirical evidence on payment media costs and switch points

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## Abstract

This paper recovers micro cost schedules of consumers' payment instruments from aggregate transaction costs. We assume that only two moments of the size distribution of payments matter: the number and volume of transactions. These variables explain the transaction costs of currency and debit card payments with much precision for a representative 1998 sample of Dutch retailers. The results imply that low fixed transaction costs favor currency for small transactions, while low variable transaction costs favor debit card payments for large transactions. The switch point is 30 Euros, but including the hidden costs of currency would lower it to 13 Euros.
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## 1. Introduction

This study assesses the roles costs and fees play in the choice between currency and electronic payments in the Dutch payment system, where the relevant choice is between currency and electronic debit cards, the prevailing media of exchange in North-Western Europe (unlike the US and the UK). Using our access to a wealth of Dutch payment cost data, we are able to build upon the few cost analyses of payment systems in the academic literature.

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The distinction that drives the choice of payment mode is that between fixed and variable costs. Currency has low fixed but high variable cost and, therefore, is cost effective for small payments. Electronic payments have high fixed but low variable costs and, therefore, are cost effective for big payments. The distinction can be visualized by a pair of straight cost lines, one for currency with a low vertical intercept but a steep slope, and one for debit cards with high vertical intercept, but a flat slope.

The main contribution of this paper is the recovery of such micro cost schedules from aggregate transaction costs at the level of the retailer. The main insight is that an ordinary regression framework with a constant term for the fixed cost and a coefficient for the variable cost should *not* be imposed, but at best emerge from an analysis of a cost function at the aggregate level of the firm.

The organization of the paper is as follows. Section 2 discusses the literature. Then Section 3 sets up a general framework for payment costs and derives micro cost schedules. Section 4 discusses and implements the estimation of payment costs. Section 5 takes up the tricky yet important issue of social costs. Section 6 discusses the extension to other media of exchange, and Section 7 concludes.

## 2. Literature

Our discussion of the literature is directed towards our cost-based approach to the choice of payment instrument. For a more comprehensive review of the payment literature we refer to Hancock and Humphrey (1998).

The choice of payment instrument has been analyzed primarily from the perspective of the consumer. Daniels and Murphy (1994) find that the increased availability of new technologies, particularly, automatic teller machines, has lowered household demand for currency. Duca and Whitesell (1995) find that credit card ownership reduces checking balances and money fund balances. Boeschoten (1998) uses a number of variables to explain the choice of payment mode and finds that the amount to be paid dominates.

The aforementioned studies pay little attention to costs. There may be a good reason for this, as Hancock and Humphrey (1998, p. 1612) observe:

> Data on payment costs are fragmented and often proprietary, so no cross-section or time-series data exists on the payment costs incurred by payors, payees or banks.

Only limited information is available from surveys and, therefore, few empirical papers explore this area. Some interesting findings are reported however in Humphrey et al. (2000), who argue that electronic payment methods cost only around one third to one half as much as checks, but that the relative costs are not reflected in the prices banks charge, especially not in the US. Furthermore, analyzing Norwegian data, Humphrey et al. (2001) find that payment users are quite sensitive to the relative prices. It should be mentioned though that even in Norway the bank price-to-cost ratio varies quite a bit between payment instruments.

In this paper we attempt to replace prices or user costs with the underlying production costs. This approach does not permit us to explain observed consumers' behavior, but it does enable us to map the efficient choice of payment instrument as a function of transaction size. This insight is obviously a useful guide for retailers and policy makers in designing price and non-price instruments for the consumers' choice of payment instrument.

## 3. The theory of payment costs

We develop a general model of medium of exchange, which induces a trade-off between fixed and variable costs across transaction technologies; and is flexible enough to lend itself for estimation. We follow the framework of Whitesell (1989, 1992), but free his model of a number of restrictions. Whitesell considers a representative consumer who makes large numbers of transactions. The choice of payment medium depends only on the size (dollar value) of a transaction – not on the particular commodities purchased. In contrast, we do not focus on a consumer's rational choice of a unique payment instrument for each transaction size, but on the costs of different payment instruments for an additional transaction, given the retailer's distributions of transaction sizes (for the modes of payments). A transaction of any size, $v$, can be paid by instrument $i$, where $i$ is currency or debit card, and the numbers of these transactions are denoted by $n^i(v)$. Whitesell (1992) would let $i$ = currency, check, or credit card. [1]

The total costs associated with transactions paid through medium $i$ is in its most general form a function of the entire frequency distribution, $n^i$: $C^i(n^i)$. We assume, however, that only two moments of the distribution matter, namely the number and the volume of transactions. The *number* of transactions is $\int n^i(v)\,dv$ and the *volume* of transactions is $\int v n^i(v)\,dv$. The cost function is thus:

$$C^i(n^i) = F^i\left[\int n^i(v)\,dv, \int v n^i(v)\,dv\right]. \tag{1}$$

An important example is the linear case,

$$F^i(x,y) = \alpha^i x + \beta^i y, \tag{2}$$

which turns (1) into

$$C^i = \alpha^i \int n^i(v)\,dv + \beta^i \int v n^i(v)\,dv. \tag{3}$$

In (3) costs are additively separable with respect to transaction size. Cost minimization can, therefore, be performed pointwise (per transaction size). The linear specification encompasses that of Whitesell (1992). He fixes the frequency distribution

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[1] Notational warning: Whitesell (1992) uses no index for payment medium. He temporarily uses index $i = 1, \ldots, I$ for transaction size (taking discrete values); his $I$ is some huge number, whereas our index corresponds to the payment instrument and takes only two or three values.

Table 1
Summary of the transaction cost structure in Whitesell (1992)

| Payment medium | Cost terms $\alpha n$ | Cost terms $\beta Y$ |
|---|---|---|
| Currency | $b - an$ | $rY$ |
| Check | $fn$ | $sY$ |
| Credit card | $n$ | $0$ |

Source: Whitesell (1992, Table 1). In his terminology, cost terms $\alpha n$ and $\beta Y$ represent the transaction and holding costs, respectively, for checks and credit cards. For currency he includes term $b$ in the transaction cost. The specification involves two normalizations. (i) All transactions are measured as incremental costs, net of the time and bookkeeping cost of check writing. (ii) The incremental cost of using a credit card, including account verification delays, but net of the above time and bookkeeping cost, is normalized at unity.

by the assumption $vn^i(v) = Y$, where $Y$ is a constant, and specifies the integrands in the two terms in (3) as displayed in Table 1, where $\alpha n$ is in the first term and $\beta Y$ in the second.

Whitesell's specification of the payment frequency distribution – assuming constant sales for each size of transaction – may be convenient for theoretical tractability, but is drastic. We are able to dispense with this restriction and proceed without making a distributional assumption in Eq. (1). The trick is to differentiate costs with respect to the numbers of transactions, $n^i(v)$, and to use the chain rule. Thus, the incremental costs of a payment of size $v$ are given by

$$IC^i(v) = F_1^{i\prime}\left( \int n^i(v)\,\mathrm{d}v, \int vn^i(v)\,\mathrm{d}v \right) + F_2^{i\prime}\left( \int n^i(v)\,\mathrm{d}v, \int vn^i(v)\,\mathrm{d}v \right) \cdot v. \quad (4)$$

Here the primes and subscripts are standard notation for partial derivatives. Notice that once the transaction size is the perceived variable (rather than the frequency), the first term in (4) ($F_1^{i\prime}$) represents the *fixed* cost, whereas the second term in (4) ($F_2^{i\prime} \cdot v$) represents *variable* cost of the additional payment. In the linear case – see Eq. (2) – the fixed cost is $\alpha^i$, the unit variable cost is $\beta^i$, and (4) becomes

$$IC^i(v) = \alpha^i + \beta^i v. \quad (5)$$

For small transactions, incremental cost is minimized if the medium with the lowest fixed cost, $\alpha^i$, is used; while for large transactions, incremental cost is minimized if the medium with the lowest variable cost, $\beta^j$, is used. [2]

For illustration, when the coefficients are denoted as in Table 1, cost minimization implies that small transactions should be conducted with currency (for which $\alpha$ is negative) and large transactions with a credit card (for which $\beta$ is zero). Similarly, in the Dutch situation, where the dominant media of exchange are currency and debit cards, it would be optimal to have small transactions conducted by means of currency and large transactions by debit cards.

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[2] Strictly speaking this rule is myopic. However, in the linear case, (2), the rule is also rational.

Letting $i = 1, 2$ denote currency and debit card, respectively, we expect $\alpha^1 < \alpha^2$ and $\beta^1 > \beta^2$. The switch point, $v^*$, where currency and debit card costs are just equal, is determined by the following condition:

$$IC^1(v^*) = IC^2(v^*). \tag{6}$$

Substituting (5) into (6), we obtain the value of the switch point,

$$v^* = (\alpha^2 - \alpha^1)/(\beta^1 - \beta^2). \tag{7}$$

## 4. The estimation of payment costs

There are two ways to estimate the cost parameters. One is to confine the analysis to the consumer side of the economy, and to work with (subjectively) perceived costs. A good example is Humphrey et al. (1996). They find a negative effect of user costs on the use of giro and credit cards, but not on checks and debit cards; country variation is explained by cultural and institutional factors. Using a more micro-econometric analysis, Boeschoten (1998) finds that the choice of payment medium is dominated by the size of the transaction, but he does not estimate user costs. A fundamental difficulty with an exclusive demand approach is that cost parameters are estimated to fit demand, assuming cost minimizing behavior. As such, it is hard to draw efficiency conclusions.

The second approach to estimate cost parameters is to use supply-side data on transaction costs, which facilitates the analysis of technology shocks and of non-economic behavior (dominated by cultural and institutional factors). While most economists prefer this approach, it is difficult to obtain the needed data. Fortunately we have access to a unique dataset and can adopt the latter approach.

In the supply-side approach it is customary to use private cost data. However, it can be extended to factor in the hidden costs. In particular, currency has implicit cost components in the form of subsidies from the central bank [3] and, at least in the Netherlands and some other countries, from commercial banks as well. [4] Our framework allows us to compare market payment characteristics and optimal ones.

We estimate Eq. (3) with an additive error term by ordinary least squares. Thus, for currency and debit card payments we regress the transaction costs on the number of transactions and the volume of transactions (sales). The data used in this study have been collected by EIM (Economic Institute Middle and small-sized enterprises) from a representative sample of Dutch retailers in 1998. The data are described in Jaarsma and van Rijt-Veltman (1999) and have been kindly made available to us

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[3] Maintaining the security of notes implies the necessity of enhancing the design of new notes every several years. For example, just after redesigning its currency in 1996, the US is redesigning its currency again to try to keep ahead of counterfeiters. (The joint press release of the Board of Governors of the Federal Reserve System and the Bureau of Engraving and Printing (June 20, 2002) is posted on: http://www.federalreserve.gov/boarddocs/press/other/2002/20020620/default.htm.)

[4] Another "hidden" or social cost of currency is that it abets the underground economy, which entails social costs in the form of tax evasion and law breaking. On the other hand, currency does provide some benefits in the form of privacy.

Table 2
Average cost per transaction and average cost per sale for currency and for debit cards

| Payment medium | Average cost per 100 Euros of sales | Average cost per transaction (in Euros) |
|---|---|---|
| Currency | 0.90 | 0.09 |
| Debit cards | 0.53 | 0.14 |

Table 3
Composition of payment costs for currency and for debit cards

| | Currency[a] (%) | Debit cards (%) |
|---|---|---|
| Data communication | – | 24.7 |
| Subscription | – | 10.7 |
| Transaction fees | – | 34.8 |
| POS machines | – | 27.7 |
| Rent foregone | 2.9 | 2.1 |
| Transport | 22.3 | – |
| Depositing | 22.5 | – |
| Back-office operations | 45.2 | – |
| Theft | 7.1 | – |
| Total | 100 | 100 |

Source: ten Raa and Shestalova (2001).

[a] In this table the column "Currency" includes checks, which have a share of less than 1.5%.

in electronic form. For each retailer the data gives the annual totals on the use of each payment instrument in 1998, implying that only data on the total number of transactions, total sales, and total costs associated with the use of each payment instrument by a retailer, but no distribution of sales within each separate shop is available. Table 2 gives a comparison of the average cost per transaction and average cost per sale for the two payment media. [5] As we can see, the cost of one transaction paid by currency is on average smaller than that for a debit card transaction, while the opposite holds for the transaction cost per 100 Euros of revenue.

The transaction costs for currency pertain to cash management, transport, depositing, back-office operations, and theft. The debit card costs pertain to the installation, maintenance, and modernization of POS machines (point of sale), and rent foregone. Table 3 shows the composition of payment costs for currency and for debit cards. (Notice, however, that estimation of (3) requires no breakdown.)

Table 4 shows descriptive statistics for the original samples of 215 currency observations and the 96 debit cards observations. [6]

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[5] The reported average costs per transaction are estimated as ratios of the corresponding median values of cost and transaction number presented in Table 4. Similarly, the average costs per 100 Euros of sales are estimated as ratios of the corresponding medians from Table 4.

[6] We had to fill a gap in the information on currency. In the original dataset the information on transportation cost were available for 24 shops only. We found a nearly linear relationship between total sales and transportation costs. The results of the OLS regression were used to impute the transportation costs of the other shops in the sample. The cost of back-office was not readily available and we have computed it as the number of hours spent on back-office activities multiplied by an hourly wage rate of 13.5 Euros.

Table 4
Descriptive statistics for the original samples

|  | Mean | Median | Maximum | Minimum | Std. dev. |
|---|---|---|---|---|---|
| *Currency* | | | | | |
| Total sales (Euro) | 6,619,951 | 248,660 | 292,000,000 | 15,066 | 30,089,313 |
| Number of transactions | 535,852 | 23,760 | 30,613,200 | 36 | 2,899,342 |
| Cost (Euro) | 35,342 | 2245 | 2,118,438 | 248 | 179,116 |
| *Debit cards* | | | | | |
| Total sales (Euro) | 5,893,130 | 154,265 | 83,356,589 | 6178 | 15,271,107 |
| Number of transactions | 187,966 | 6000 | 2,499,000 | 84 | 489,387 |
| Cost (Euro) | 24,725 | 818 | 924,739 | 59 | 102,327 |

Table 5
Regression results

| Payment medium | Transactions number coefficient $\alpha$ (*t*-statistics)[a] | Sales coefficient $\beta$ (*t*-statistics) |
|---|---|---|
| Currency | 0.01915** | 0.00252** |
| ($R^2_{adj} = 0.72$) | (5.41, 1.43, 1.34) | (10.27, 3.22, 2.73) |
| Debit card | 0.05970** | 0.00117** |
| ($R^2_{adj} = 0.68$) | (5.37, 2.29, 2.07) | (3.42, 1.44, 1.33) |

[a] The first *t*-statistic is for OLS, the second for White's (1980) heteroscedasticity consistent covariance matrix estimation, and the third for Newey and West (1987) HAC consistent covariance matrix estimation.

Ten currency observations have been excluded because of incomparability (many times the size of the rest of the sample). Similarly, two extremely large debit card observations have been excluded because of incomparability of their costs per transaction. [7]

Estimating Eq. (3) using the resulting sample yields the regression results presented in Table 5. [8]

The first row in Table 5 shows that an additional private currency transaction costs around 2 Eurocents plus a quarter Eurocent per Euro. The second row in Table 5 shows that an additional debit card transaction costs around 6 Eurocents plus a tenth Eurocent per Euro. The *t*-statistics show that all these coefficients are highly significant in the OLS regressions, even at the 1% level, as indicated by the ** superscripts.

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[7] Jaarsma commented that EIM made a similar exclusion, considering the observations unreliable (Jaarsma and van Rijt-Veltman, 1999).

[8] The use of a linear specification with the restriction that the constant term is equal to zero not only agrees with theory (Table 1), but also with the data for currency, as well as for debit cards. More precisely, the estimation including a constant term reproduces the estimates reported in Table 5 up to the third digit for debit card coefficients and for the sales coefficient of currency, and up to the second digit for the transactions number coefficients of currency, which is all well within the confidence intervals. The results of the estimation of a more general cost function including second-order terms are insignificant. Even if they were significant, it would be difficult to incorporate them in the analysis, as coefficients would vary across shops and, therefore, switch 'points' would be functions of shop characteristics.
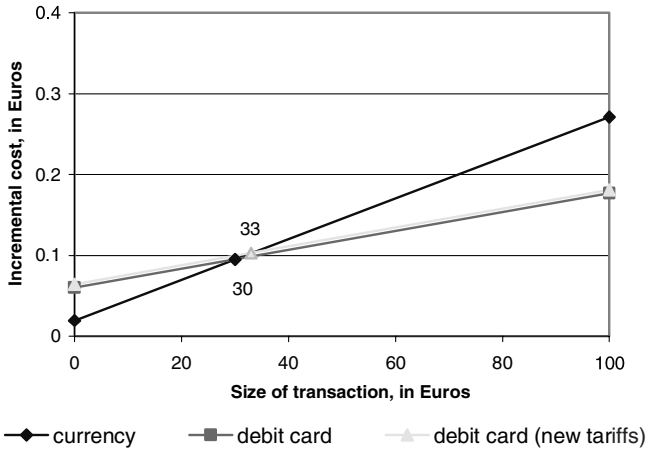
Fig. 1. Incremental private costs of a currency transaction and of a debit card transaction.

The results imply the expected trade-off between fixed and variable costs. The low fixed transaction costs of currency favor this medium for small transactions. The low variable transaction costs favor debit cards for large transactions. Substitution of the values of Table 5 in formula (7) implies that the switch point, $v^*$, is 30 Euros.

Notice that the two lines in Fig. 1 (embodying the results of Table 5) are quite flat. An upward shift of the flattest line (representing debit cards) by 0.0045 would push the intersection point to 33 Euros. This scenario illustrates the effect of an increase of the POS tariff by 0.45 Eurocent (or 1 Dutch cent), considered by the Dutch banks consortium Interpay.

## 5. Extension to social costs

Private costs of the payment system are incurred directly by sellers (retail), who eventually pass it on to the buyers (consumers). The Dutch retail costs of the currency medium amount to 0.90% of sales according to Table 2. Consumers face virtually no costs in the Netherlands, where banks fully subsidize currency withdrawals and few retailers charge a debit card fee. The extension to social costs merely involves the inclusion of commercial and central bank costs. Now Interpay (2000) claims that the Dutch fees for the use of POS are cost neutral. Hence we limit our modification of costs to the medium of currency. We also limit bank costs to the costs of ATM's (automatic teller machines). Unfortunately, the Dutch central bank has not been forthcoming with cost data and, therefore, we make use of a Norwegian proxy. The calculations are performed in Euros.
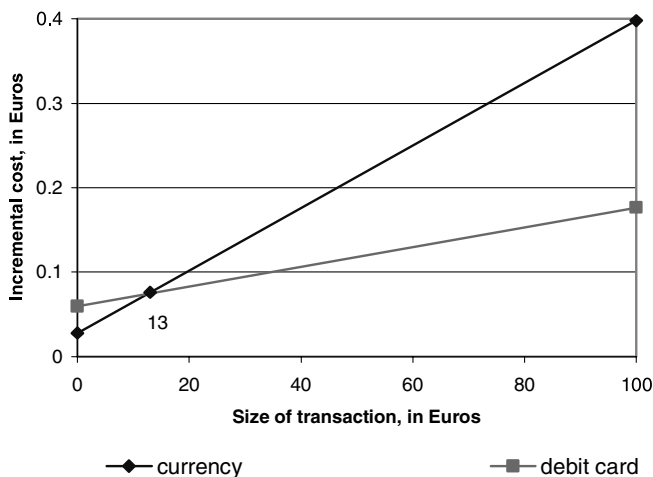
Fig. 2. Incremental social costs of a currency transaction and of a debit card transaction.

The bank costs of ATM use in Norway amount 0.43 Euro per ATM transaction according to Flatraaker and Robinson (1995). [9] On average Dutch ATM users withdraw 102 Euros per time according to Boeschoten (1998). Hence the bank costs of currency per 100 Euros can be estimated as $(100/102 \times 0.43$ Euro $=)$ 0.42 Euro or 0.42%. Adding the bank costs (0.42%) of currency use to our 0.90% retail cost estimate yields a total or social cost of currency use equal to 1.32% of sales. [10] In other words, the social costs of currency are 47% greater than the private costs (as $1.32/0.90 = 1.47$).

Accounting for social cost in Fig. 1 (that is the steeper line) makes the currency cost still steeper and, therefore, would push the intersection point leftward to 13 Euros. Fig. 2 displays the implied social costs.

From the viewpoint of private costs (Fig. 1), it is in the interest of retailers to discourage the use of debit cards for payments under 30 Euros. Some Dutch retailers charge a fee for small debit card payments indeed, but typically at the lower cut-off point of 11–13 Euros (that is Dfl 25 or 30 in the old currency). It is amazing to see how close this policy is to the socially optimal switch point of 13 Euros (see Fig. 2). Two opposite distortions thus appear to roughly offset each other, namely the implicit bank subsidies of currency and the implicit retail subsidies of debit cards.

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[9] By using this 1994 statistic, we implicitly assume that productivity improvements in ATM technology have offset any incremental costs associated with inflation between 1994 and 1998.

[10] G. Øwre of Norges Bank kindly wrote us the following on November 28, 2000. 'Given that the assumption of constant costs to scale is robust, you could say that the cost of cash is 1.87%, and if some costs are kept out, an estimate of 2% would not be too far off.' These remarks pertain to the Norwegian payment system. We have decided to use our more conservative estimate of 1.32% for the Netherlands.

## 6. Extension to other media of exchange

The newest form of payment is the electronic purse, which we have not analyzed due to a lack of data. The main Dutch retailer announced the introduction of the electronic purse on November 15, 2001. We have some observations, but not enough to obtain significant results.

What will matter is the fixed and variable cost of electronic purse payments relative to currency and debit card payments. The fixed cost will be higher than that of currency, which requires no fancy machines, but lower than that of debit cards, of which the machines must be able to telecommunicate. The use of an electronic purse is swift and safe, and thus carries less variable cost than of currency. However, it is a purse and must be filled and emptied. Eventually the variable costs will outweigh those of the debit card.

Graphically we have a third, intermediate cost line. The switch point between currency and debit card determined in the previous sections will be replaced by two new switch points, a lower one between currency and electronic purse, and a higher one between electronic purse and debit card.

In principle, these modifications apply not only to the private costs (Fig. 1), but also to the social costs (Fig. 2). However, since the social costs differ from the private costs only for currency, it is very well possible that the inclusion of social costs lifts the currency cost curve over the intersection point of the electronic purse and debit card curves. In short, the combination of the electronic purse and the introduction of bank policies that charge currency costs to the consumers (novel in the Netherlands but not elsewhere) may make cash relatively more expensive, even for small transactions. However, there are serious doubts that the electronic purse will become an important or significant payment instrument in the near future. According to Van Hove (2000), "... retailer acceptance and consumer uptake invariably fall short of expectations".

## 7. Conclusion

Transaction costs are a function of the size distribution of payments. Assuming that only two moments of this distribution matter, namely the number and the volume of payments, the partial derivatives yield the fixed and unit variable costs of payments. The approach builds upon recent applied theoretic models and is flexible enough to allow for estimation. Consistent with the literature, currency is found to have a lower fixed cost and the debit card a lower variable cost. Estimates using Dutch data indicate that currency is cost effective for small payments and debit cards for big payments. Accounting for private costs, the switch point is 30 Euros, but accounting for the hidden costs of currency, the switch point falls to 13 Euros. These Dutch estimates suggest that the use of debit card or electronic purse technology will likely displace the use of cash for larger legal transactions.

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