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Research Department
26.10.1998

The Market for Electronic Cash Cards

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The Market for Electronic Cash Cards

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Abstract

We develop a theoretical framework aimed to model the pricing of electronic money (electronic cash cards) and the market domain in which it will be used. We first calculate the fee structures of electronic cash- and charge-card industries for the monopoly and competitive cases. We show that the different market structures do not affect the domain of electronic cash cards and the displacement of currency in daily transactions. We provide a welfare analysis to determine whether a market equilibrium generates an underutilization or overutilization of the electronic cash cards relative to currency. Finally, we evaluate the threshold investment costs, both general and POS-specific, which would prevent the emergence of this industry.

Keywords: Electronic Money, Smart Cards, Displacement of currency

JEL Classification Numbers: E40, G20

Elektronisen korttirahan markkinat

Suomen Pankin keskustelualoitteita 21/98

Oz Shy

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Tiivistelmä

Tutkimuksessa kehitetään elektronisen rahan hinnoittelua ja käyttöalaa selittävä teoreettinen malli. Sen avulla esitetään rahakorttien ja perinteisten maksukorttien hinnoittelurakenne sekä kilpailullisessa että monopolina toimivan korttiyhtiön tapauksessa. Hinnoittelua koskevien tulosten perusteella osoitetaan, että rahakorttien käyttöala muodostuu samaksi riippumatta korttitoimialan kilpailullisuuden asteesta. Taloudellisen tehokkuuden näkökulmasta selvitetään, tuottaako markkinoiden toiminta käteisrahan liiallisen vai riittämättömän korvautumisen korttirahalla. Tutkimuksen lopussa arvioidaan, kuinka suuret yleiset tai maksupistekohtaiset investoinnit rahakorttijärjestelmä voi vaatia ilman, että nämä kustannukset estäisivät järjestelmän syntymisen kaupalliselta pohjalta.

Asiasanat: elektroninen raha, rahakortti, käteisen syrjäytyminen

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1 Introduction

Modern economies use a wide variety of means of payments. The most widely used payment instruments today are currency, payment orders, checks, debit cards and credit cards. Among these means of payments only currency, which is legal tender, provides for an immediate final settlement of the transaction in which it is used. The others are linked to the payers' bank accounts or credit lines extended by the card issuers. All these prevailing means of payment suffer from major weaknesses stemming from their high handling costs. In the case of currency these costs are generated by the physical handling and storing of notes and coins. In the case of account-linked instruments the costs are generated by the credit verification, bookkeeping and communication with the central operators of the system. Due to the cost structure, currency is still the dominating means of payment in small transactions, whereas the account-based instruments are used mainly for medium-sized and large transactions.

We are now facing an era when a new payment instrument is being introduced, namely the electronic cash card. Just as checks and charge and credit cards, the electronic cash cards are introduced by the private sector and the degree to which electronic cash cards will replace other means of payments depends on the choices made by consumers and merchants. The new payment system intends to combine the strengths of the older systems while reducing handling costs. Just like currency, electronic cash cards carry purchasing power which is valid independently of holders' bank account; thus they avoid verification and bookkeeping costs associated with checks and credit cards, for example. On the other hand, due to the electronic technology, they also avoid the physical handling costs associated with currency.

The purpose of this paper is to theoretically characterize the equilibrium fees imposed on electronic cash card transactions and their consequences on the degree of displacement of currency and other cards by this new payment medium.

1.1 Description of the electronic cash card technology

We define electronic cash as means of payment with the following characteristics, see European Central Bank (1998). First, payments made with it at the POS (point-of-sale) are electronically settled and not manually performed and second, they do not involve significant bookkeeping or verification costs in any central registry. The first characteristic is analogous to credit and debit card transactions, whereas the second characteristic is analogous to currency transactions.

Electronic cash eliminates major costs associated with currency transactions at the POS, but it also reduces verification and bookkeeping costs which characterize conventional card-based transactions. From this cost saving it could appear that e-cash would dominate all other means of payments. However, the benefits of electronic cash constitute mainly of reduced marginal costs, are counterbalanced by investment costs (fixed and possibly sunk) which are high for the electronic cash system. In addition, electronic cash bears certain holding costs (accidental loss, foregone interest, and magnetic failure). These

fixed and holding costs provide a possible explanation why electronic cash card may not eliminate other payment instruments at least not completely.

In this paper we abstract from transaction-specific verification costs of electronic cash cards completely, since we believe that the absence of verification costs is the *major* characteristic which distinguishes the electronic cash card from the traditional types of cards. In most of experimental electronic cash cards that have been implemented so far, verification has not been entirely eliminated. However, we conjecture that without virtually eliminating verification, electronic cash cards do not have any major cost advantage over the traditional cards. In this case, electronic cash cards is not likely to achieve commercial success, and moreover, would not constitute a genuine new payment instrument.

Electronic money is commonly thought of as a payment instrument to be used for purchases of low value goods and services which include purchases at vending machines, in public transportation, newsstands, etc., see e.g. Weninger and Laster, 1995. This idea reflects a basic intuition that the cost benefits are the greatest at small transactions, in which case electronic cash card compete directly with currency and not with the traditional cards.

A variety of electronic cash systems have been introduced in Europe and later in the US. The development these systems began with single-purpose prepaid cards (such as phone cards and public transportation cards widely used in Japan and in Europe). These earlier cards often used the magnetic stripe technology which are not safe enough for storing high values or general-purpose purchasing power. The 1980s saw the development of the integrated circuit (IC) cards with imbedded microprocessors in them. This new technology created a safer payment instrument which also opened the possibility of reloading purchasing power onto the cards. This is what is sometimes referred to as the “electronic purse.” Such cards are available from various issuers, such as Visa Cash which began experimenting in 1995.

On the production side, microcircuit cards are already inexpensive to produce which is why then can be used as a payment instrument for small transactions. The cost of a chip has run between \$1 to \$1.2 to buy and between 50¢ and \$2 for assembling and printing a card, see Lynch and Lundquist (1996). In the future, electronic cash cards may be integrated with a multipurpose cards serving also as ID and social security cards. This will make the card system even more economical.

At least countries like Austria, Belgium, Denmark, Finland, Germany, Israel, Italy, Netherlands, Norway, Portugal, Spain, and Switzerland are in the stage of piloting the distribution of such cards, and in Finland these cards are already used in buses, phones, and some fast-food restaurants, see Hitachi Research Institute (1997) and Hatakka (1998).

In addition to the card-based “electronic purse” applications, there are now several payment systems on the Internet which use circulating bearer instruments as means of payments, which resemble electronic cash stored on cards. These systems are intended to replace credit cards in electronic commerce to achieve anonymity and greater security. The difference from card-based electronic cash lies in the fact that the Internet “cyber money” is not used at POS transactions, and therefore does not compete with currency. Most of cy-

ber money systems use the existing banking system to make final settlements, see Lynch and Lundquist (1996), Neuman and Medvinsky (1997) and Choi, Stahl, and Whinston (1997) for detailed description of Internet-based payment services. Internet payment services are not analyzed in the present paper.

1.2 Coexistence of different payment media

In all economies several means of payment coexist in parallel to each other. However, typically each payment instrument dominates a particular transaction size or type. This is what is called the *transaction domain* of a payment instrument. The analysis of coexistence of several payment media and the corresponding transaction domains requires a detailed analysis of the market places and the particular transaction costs associated with each instrument.

The use of currency as a means of payment provides lots of advantages and a few disadvantages. First, currency is circulated freely and is the legal tender so it must be accepted everywhere in a given economy. Second, it is transferable in both directions between consumers and retailers. Third, the use of currency implies an immediate settlement since no banks are involved, and no clearing via banks is needed. Fourth, it is usually difficult to forge. Fifth, it preserves anonymity and privacy of the transacting agents.

The disadvantages of using currency include first the inconvenience of sending it to remote places. Most mail carriers do not insure envelopes valued beyond \$100. Second, currency value cannot be divided. That is, a \$50 bill cannot be split into units of \$10 unless an exchange or a transaction is performed in order to get change. As often happens, stores, restaurants and even vending machines are unable to deal with large-denomination notes. Third, storage and sorting the notes impose a great cost on consumers, retailers and banks. For these reasons banks always impose higher fees on the exchange of different national official currency notes compared to deposit money.

In the analysis of transaction costs associated with the payment activity, one has to compare the different payment instruments according to three criteria:

1. **Cost to consumers** stemming from having to pay for the good/service in the particular payment instrument. These costs are composed of two different costs:
 - (a) *Physical costs* consisting of costs associated with the time and effort the consumer puts into the actual paying process (for example, the time and effort it takes to roll out the coins from the wallet, sorting them, and receiving change), as well as holding costs due to theft, magnetic loss, etc..
 - (b) *Monetary cost* payable to the bank or the card issuer in the forms of fees and margins levied by each. These include fixed initial connection/equipment fees, per-transaction fees, and could also depend on the transaction size. In addition, consumers may incur foregone interest cost depending on the type of instrument used.

2. **Cost to the merchant** (say a store) resulting from having to receive a payment in a particular form. Again, just like the costs to the consumer, the sellers' cost is composed of *physical costs* and the *monetary costs* listed above.
3. **Profit to the issuer of the payment instrument** generated by the collection of fees and margins imposed on consumers and merchants after accounting for costs incurred in building and operating the particular payment system. These profits are composed of:
 - (a) *Direct fees* in the form of fixed connection/installation/equipment fees, per-transaction fees, and fees for different transaction sizes; and
 - (b) *Float income* which mirrors the interest foregone by consumers and merchants.
 - (c) *Issuers' costs* consisting of basic investment and equipment costs (printing money for the case of money, constructing computer systems, connecting and supplying card readers and cards to users). In addition, there are variable operating costs in payment systems where transaction-specific verification and bookkeeping by the issuer is required.

Items (a) and (b) correspond to the monetary costs to consumers and merchants (above).

Most of the literature on the coexistence of different payment instruments focused on the different positive or negative rates of return associated with holding on the different payment media. Several empirical studies have documented international differences in payment systems, see Humphrey, Pulley, and Vesala (1996), and Hatakka (1998).

The theoretical literature on the coexistence of different traditional payment instruments goes back to the *transaction demand for money* argument, see for example Baumol (1952) and Tobin (1956). Over the years, this 'portfolio' approach has been extended to include the demand for checks, charge and credit cards, Santomero (1979) and Whitesell (1989, 1992) and their references. A more general extension to include an arbitrary number of payment instruments is given in Santomero and Seater (1996). General equilibrium approaches to coexistence are given in Romer (1986) and Prescott (1987).

In this paper we wish to contribute to this literature by focusing on the electronic cash card as a substitute for currency and small debit and credit card transactions. We will therefore utilize an optimization approach and focus on fee structure implemented by card issuers. We deliberately abstract from checks in this paper despite the fact that checks are widely used in the US for example. There are two reasons why we chose to ignore checks in our model. First, even in the US, checks are used mostly to pay bills (utilities, subscriptions, and rents) and salaries. Since bills and salaries constitute relatively large amounts, there are more likely to be paid if not by checks then by electronic transfers and are therefore unlikely to be paid via an electronic cash card which is the subject of the present paper. Second, the economics

of checks in POS transactions is almost identical to paper-based debit cards transactions. Since charge cards are incorporated in the present model, adding checks would not influence our results in any interesting way.

1.3 Organization of the paper

Section 2 introduces an economy in which transactions can take place with currency, charge cards, or electronic cash cards. Section 3 solves for the equilibrium fees set by monopoly and competitive card issuing industries, respectively, and the resulting transaction domains of electronic cash cards, currency, and charge cards in the transaction space. Section 4 analyzes the market failure associated with overutilization of currency payments in various transaction sizes. Section 5 extends the model by considering merchant-specific connection costs incurred by card issuers such as the installation of card readers at retail stores and vending machines. Section 6 incorporates general system construction costs and investigates their implications for our results. Section 7 summarizes insights gained in the paper.

2 A model of electronic cash cards, currency, and charge cards

Consider an economy in which a wide variety of POS transactions are made in a given period. The transactions vary in value, i.e., some are small in value such as buying a newspaper from a newspaper stand or a machine and some are larger, say filling up a gas tank, buying an electrical appliance and so forth.

In order for electronic cash cards to be widely adopted as a means of payment, it will need to offer enough features of value to its three constituencies: buyers, merchants, and the card issuers. For this reason, in our model there are four types of interacting agents: (1) *Buyers* (consumers) who wish to buy goods and services from merchants. (2) *Merchants* who can be identified as stores, vending-machine owners, and basically all commercial service providers doing POS business. Actually, we expect that vending machines and other unattended service providers could play a major role in electronic cash card transactions. (3) *Electronic cash card issuer(s)* who can supply electronic cash card equipment and transaction services to buyers and merchants. (4) *Charge card issuer(s)* who issue charge cards and provide the related services.

In this paper we analyze the various card issuing industries using three different market structures: perfectly competitive, pure monopoly, and conclude with the analysis of contestable monopoly in the case of increasing returns to scale in the electronic cash card industry.

2.1 Merchants and buyers

We denote by p , $p > 0$, a particular transaction value which is the price (amount of money) transferred from a buyer to a merchant during the purchase. We assume that each merchant specializes in one size of transaction only. Thus, we refer a merchant specializing in selling goods valued at p as a type- p

merchant. Let $m(p)$ denote the density of merchants over the p -axis, which is interpreted as describing the “number” of merchants performing transactions valued each at p . For example, $m(35¢)$ is the “number” of points selling the daily newspaper (assuming that no other good is priced at 35¢).

On the buyers’ side, let $b(p)$ denote the density of buyers over the p -axis, which, again, is interpreted as describing the total “number” of consumers who access all merchants of type p and ‘pay’ for a good or a service valued at p .

Our analysis is based on the following assumptions.

ASSUMPTION 1

1. *The functions $b(p)$ and $m(p)$ are continuously differentiable, and $b(p) \geq m(p) \geq 0$ for all p .*
2. *The number of consumers wishing to transact declines with the value (price) of the transactions. Formally, $b(p)$ declines in p .*
3. *The number of merchants declines with the value of the transaction. Formally, $m(p)$ declines in p .*
4. *The number of transactions per merchant declines in p . Formally,*

$$\frac{d \left[\frac{b(p)}{m(p)} \right]}{dp} < 0.$$

5. *Buyers’ density function is unaffected by the physical costs of maintaining all forms of money and the fees imposed by card issuers.*

Part 4 of Assumption 1 implies that the number of transactions per merchant declines with the transaction size. The basic intuition behind this assumption is that there are typically more consumers patronizing a merchant selling, say, soft drinks than those patronizing a car dealership. We believe that this assumption is realistic for small transaction markets in which electronic cash transactions will take place.

Part 5 of Assumption 1 will be crucial for our results since it allows first degree price discrimination in the case of monopoly card issuers. We believe that this assumption is a fair approximation of reality since although transaction costs will have an effect on the choice of the means of payment, they will not have a significant effect on the buying decision or the selling decision.

2.2 Electronic cash card issuer

In this section, we ignore all costs facing the electronic cash card issuers. Note that electronic cash card issuers do not incur any significant per transaction cost. In this respect, electronic cash card issuers resemble central banks which are not directly involved in transactions performed with notes and coins. The effects of a large system setup cost and merchant-specific connection costs are analyzed in sections 5 and 6.

2.3 Charge card issuers

In contrast to electronic cash-card transaction, a charge card transaction is costly to the issuer since it requires a credit verification of the buyer with the card issuer's main computer system and perhaps the buyer's bank. Therefore, we assume that the issuer of a charge card bears a *per-transaction* cost of V^C . Notice that this cost is per transaction and is therefore independent on the size of the transaction since the transaction size is irrelevant for the cost of credit verification. We believe that this per-transaction cost plays a crucial role in the introduction of e-money and the maintenance of currency as it makes charge card payments unprofitable for small transactions. Again, as in the case of the electronic cash card, we ignore in this section fixed costs to the issuer and costs of connecting merchants to the system, which are analyzed in section 5 and 6.

2.4 Merchants

A merchant selling a product valued at p is faced by $b(p)/m(p)$ identical customers. The merchant must accept currency if the buyer offers it, since currency is the (only) legal tender in this economy. In addition, each merchant has the option of accepting electronic cash cards and charge cards if they find it profitable to do so.

In what follows, we make some assumptions on the nonfee costs merchants must bear when accepting each medium of payment. In addition to these costs, noncurrency transactions are also subject to fees collected by the various card issuers.

Currency: Accepting currency for the trade subjects the merchant to three types of costs:

1. Loss of time, denoted by T^M , which is the value of time associated with accepting currency notes and coins, counting it, checking for fraud, and returning change to the customer.
2. Expected loss with probability $0 \leq \lambda^M \leq 1$ (which includes robbery and misplacement).
3. Foregone interest, $i p$, for the time which a merchant keeps the currency in his possession (usually, one day in practice), where i is the exogeneously determined market interest rate.

Altogether, a merchant who is engaged in a transaction size p and uses currency will face a per-transaction cost of

$$T^M + (\lambda^M + i)p. \quad (1)$$

Electronic cash cards: We assume that in the absence of fees charged by card issuers, no physical costs are associated with electronic cash card transactions. This basically assumes that both, electronic cash card and charge card transactions are instantaneous. However, just as in the case of currency, merchants incur foregone interest cost. Altogether, a size p merchant's cost from each electronic cash card transaction is $i p$.

Charge cards: We capture the essence of a charge card transaction by assuming that merchants are operating on-line hence debit and credit entries are instantaneously updated. Thus, no foregone interest is created, and there are no physical costs either.

2.5 Buyers

The buyers in our model are shoppers who purchase goods and services from merchants. A buyer can always use currency to pay for the transaction, and may use electronic cash card or a charge card only if the merchants agrees to accept these cards. The nonfee per transaction buyers' costs for each means of payment are:

Currency:

1. The value of lost time, denoted by T^B associated with sorting out notes and coins, handing them out at the cashier, lifting fallen coins from the floor, and sorting out the change.
2. Loss of money with probability λ^B .
3. Foregone interest costs denoted by $(vi)p$, where i is the market interest rate and v is the length of the holding period of currency relative to merchants.

Altogether, the per-transaction cost facing a buyer engaging in a transaction of size p using currency is:

$$T^B + (\lambda^B + vi)p. \quad (2)$$

Electronic cash card: Electronic cash cards save buyers a substantial amount of time associated with currency transactions. Therefore, we will assume that electronic card transactions are instantaneous. However, buyers using electronic cash cards still face some other costs.

1. Loss of the card with probability λ^B (same probability as losing currency).
2. Loss of e-cash due to magnetic errors resulting in a loss of reading capability, with probability of γ^B . This cost highlights the limitation of the electronic cash card technology. On the one hand electronic cash cards allow anonymity as once the cash is loaded the transaction cannot be traced. On the other hand, it is precisely because of the anonymity the loss of cash cannot be recovered if the chip on the card exhibits magnetic errors.
3. Foregone interest loss, similar to currency, once the card is loaded with currency the holder loses potential interest earnings.

Altogether, the per-transaction cost facing a buyer engaging in a transaction of size p using an electronic cash card is:

$$(\lambda^B + \gamma^B + vi)p. \quad (3)$$

Equations (2) and (3) reveal that currency and electronic cash card share a common loss probability, λ^B , as a person who loses his or her purse will lose it all. In contrast, electronic cash cards can lose their value in case of magnetic errors, whereas currency cannot be erased.

Charge cards: We assume that charge cards do not impose any physical costs on buyers. This assumption is motivated by the fact that most buyers are secured against theft (say within 24 hours of notification). We also assume that the charge card transactions are instantaneous. Again, here we abstract from the fact that credit verification is time consuming for merchants and buyers in addition to the card issuers. Therefore, from consumers' point of view, charge cards are the least costly means of payment. Just as merchants, the buyers also do not incur foregone interest cost in charge card transactions.

2.6 Fees set by card issuers

We confine our analysis to three types of fees which can be imposed by the various card issuers on each participating merchant. This tariff "menu" is sufficient until we reach section 6 where we refer to more general tariff structures.

Fixed fee (participation fee): The issuer charges f_0 as a fixed connection fee which includes the cost of leasing the necessary equipment.

Transaction fee: The merchant is charged a fixed fee of f_1 for every transaction regardless of the transaction value.

Percentage fee (ad valorem): The merchant is charged f_2 per unit of value of the transaction. That is, on a transaction value of p , the merchant pays the issuer $f_2 p$.

We will be using f_0^E , f_1^E , and f_2^E to denote the fees imposed by the electronic cash card issuer on merchants; and by f_0^C , f_1^C , and f_2^C to denote the fees imposed by the charge card issuer.

3 Multiple payment media and equilibrium card fees

We now calculate the transaction domains of the different payment instruments and demonstrate how to calculate the fees imposed by electronic cash card and charge card issuers under monopoly and under competition in the two card industries.

We consider systems where card issuers impose fees only on merchants (hence, buyers obtain all cards' services without paying any fees). Although this appears to be the prevalent practice in the real world, we occasionally comment on the consequences of relaxing this assumption. It is widely observed that most cards are issued by commercial banks which compete for customers in providing banking services that are not necessarily related to payments.

This competition leads banks to subsidize the cards and to waive the issuing fees imposed by the card issuers, see Tarkka (1995) for an analysis of cross subsidies in the banking industry.

3.1 Transaction sizes and payment methods

We start out by searching for the credit card transactions domain. Since currency is the legal tender, the buyer who finds it beneficial to pay currency can dictate it to the merchant. However, buyers always prefer charge cards over all other payment instruments since they are costless to the buyers, whereas all other payment instruments involve nonzero transaction costs as was explained in subsection 2.5. It follows that charge cards will always be used when merchants accept them. Therefore, the transaction domain for charge cards is determined by the merchants' cost comparisons.

By the assumptions given in subsection 2.4 merchants prefer accepting charge cards over currency whenever

$$T^M + (\lambda^M + i)p > f_1^C + f_2^C p, \quad \text{or} \quad p > \frac{f_1^C - T^M}{\lambda^M + i - f_2^C}. \quad (4)$$

This condition has been derived for $f_0^C = 0$ which will be proven in subsubsection 3.2.2 to be part of the equilibrium fee structure for both monopoly and competitive charge card industry.

We now proceed with searching for the electronic cash card transaction domain. Subsection 2.4 reveals that in the absence of connection costs merchants always prefer accepting electronic cash cards. However, since currency is the legal tender, a buyer who finds it beneficial to pay with currency can dictate it to the merchant. Hence, the transactions in which buyers will insist on paying with currency are found by

$$T^B + (\lambda^B + v i)p < (\lambda^B + \gamma^B + v i)p, \quad \text{or} \quad p > \frac{T^B}{\gamma^B}. \quad (5)$$

Under the following condition, this economy maintains a strictly positive domain for currency transactions:

$$\frac{T^B}{\gamma^B} < \frac{f_1^C - T^M}{\lambda^M + i - f_2^C}.$$

In this case, which is in agreement with prevailing views in the card industries, the transaction domains of the different payment instruments will be arranged as illustrated in of Figure 1.

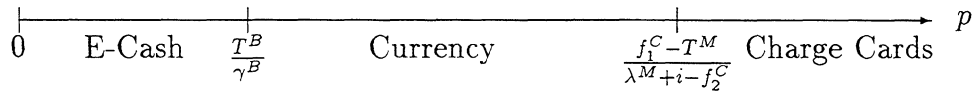


Figure 1: Transaction sizes and the use of payment instruments.

In order to have a complete analysis of how the transaction domains are determined the equilibrium tariffs must be determined.

3.2 Card pricing

We will consider two extreme cases for the two card industries: monopoly and competition. As it turns out, the method which we use to calculate issuers' profit-maximizing fees under monopoly and competition is quite simple. For the monopoly case if issuers manage to extract the entire surplus from merchants who otherwise will accept currency, then we know that the issuers indeed utilize a profit-maximizing two part tariff fee structure. The reason why the monopoly fee calculations tend out to be so simple is a direct consequence of Assumption 1.5 which separates purchase decisions from consumers' choice of payment instruments. This allows for first degree price discrimination (no incentive effects in the payment behavior) in the model and thus saves us from complicated elasticity calculations that are associated with the calculations of conventional consumption pricing under two-part tariffs (e.g., Berg and Tschirhart 1988 (Ch.4), or Wilson 1993).

3.2.1 The electronic cash card industry

Under the assumption that electronic cash card issuers do not face any cost (connection and investment costs are analyzed in section 5 and 6 below), fee competition eliminates all fees imposed on merchants. In contrast, a profit-maximizing monopoly electronic cash card issuer is able to extract the entire surplus from merchants by setting a two part tariff (fee per transaction plus an ad-valorem fee) equal to

$$f_0^E = 0, \quad f_1^E = T^M \quad \text{and} \quad f_2^E = \lambda^M. \quad (6)$$

At this two-part fee structure all merchants are indifferent between accepting electronic cash cards and currency. The reason why a monopoly sets $f_0^E = 0$ is that a two part tariff exactly extracts the entire surplus of merchants, which is the difference in costs between accepting currency and electronic cash cards. Setting $f_0^E > 0$ would produce a tariff that could not be made equal to the surplus of all merchant types.

An important thing to realize is:

Proposition 1 *In the absence of fees imposed on buyers, the market structure in the electronic card issuing industry has no effect on the transaction domain of electronic cash cards.*

Proposition 1 follows directly from (5) or from Figure 1, which shows that the determination of the electronic cash card transaction domain is independent of fees imposed on merchants. Since the monopoly can extract the entire surplus from merchants, and since buyers can always refuse to pay with electronic cash card, competitive and monopoly electronic card issuing industries yield identical market share in the payment space.

3.2.2 The charge card industry

We now proceed with analyzing the charge card issuing industry. In the absence of connection cost of linking a participating merchant to the system there are no fixed costs to issuers. However, a charge card issuer faces one special cost which is associated with the verification of the buyer's credit for each transaction.

Thus, a competitive charge card issuing industry will set a per-transaction fee of $f_1^C = V^C$ and no proportional fee and no fixed fee either, $f_0^C = f_2^C = 0$. From (4), the minimum transaction size for which a merchant will find it profitable to accept a charge card instead of currency is: $p = (V^C - T^M)/(\lambda^M + i)$.

In contrast, a profit-maximizing monopoly charge card industry will extract all surplus from merchants by setting a two-part tariff (f_1^C per transaction and an ad-valorem component of f_2^C per unit of transaction value) given by

$$f_0^C = 0, \quad f_1^C = T^M \quad \text{and} \quad f_2^C = \lambda^M + i. \quad (7)$$

Since this two-part tariff is sufficient to extract all possible surplus from merchants, the fixed connection (membership) fee is not applied.

However, since the monopoly card issuer faces a per transaction credit verification cost, V^C , small transactions are not profitable. Hence, a monopoly charge card issuer sets a *minimum transaction size* determined by a nonnegative profit condition given by

$$V^C \leq T^M + (\lambda^M + i)p, \quad \text{or} \quad p \geq \frac{V^C - T^M}{\lambda^M + i},$$

which is the same cutoff point as between currency and charge card transactions under competition. Again, the market structure does not have a real effect on the transactions domain of charge cards.

We summarize our results with the following proposition.

Proposition 2

1. *A necessary condition for currency not to be eliminated by the introduction of electronic cash cards is that the holding cost differential over currency, here identified with the probability of magnetic loss, is positive ($\gamma^B > 0$).*
2. *A necessary condition for having currency not eliminated by charge cards is that the economic cost of verifying the credit of a buyer exceeds the value of the time a merchant spends on a currency transaction ($V^C > T^M$).*

The first part of the proposition shows the crucial role which holding costs play in the present model. The reason why currency may survive is that the electronic cash card bears a specific holding costs in which currency does not. We identify this cost differential with probability of magnetic loss.

4 Is there a market failure?

In this section we analyze some of the welfare properties of this multiple means of payments economy. Our goal is to analyze which means of payments are over- or under-utilized for the various transactions.

Clearly, the most intuitive *social* goal would be to minimize physical costs associated with each payment medium (fees and foregone interest are irrelevant as they constitute gross transfers only; fees and the float on electronic cash are transfers from buyers and merchants to card issuers, whereas the float on currency is a transfer to the currency issuer which is assumed to redistribute its income in a lump sum fashion to the buyers). Hence, electronic cash card is socially preferred over currency in transactions of size p if

$$(\lambda^B + \gamma^B)p \leq T^B + T^M + (\lambda^B + \lambda^M)p, \quad \text{or} \quad p \leq \frac{T^B + T^M}{\gamma^B - \lambda^M}. \quad (8)$$

In view of Figure 1, Electronic cash card is ‘underutilized’ from a social view point if

$$\frac{T^B}{\gamma^B} < \frac{T^B + T^M}{\gamma^B - \lambda^M}. \quad (9)$$

Note that this condition applies for $\gamma^B > \lambda^M$, meaning buyers’ magnetic loss probability of electronic cash exceeds merchants’ probability of losing currency. In the reverse case, electronic cash is always socially preferred over currency at every transaction size, p .

Next, charge cards are socially preferred over currency if

$$V^C < T^B + T^M + (\lambda^B + \lambda^M)p, \quad \text{or} \quad p > \frac{V^C - (T^B + T^M)}{\lambda^B + \lambda^M}.$$

Hence, charge cards are ‘underutilized’ from a social view point whenever the following condition holds

$$\frac{V^C - T^M}{\lambda^M + i} > \frac{V^C - T^B - T^M}{\lambda^B + \lambda^M}, \quad \text{or} \quad (\lambda^B - i)(V^C - T^M) + (\lambda^M + i)T^B > 0. \quad (10)$$

Figure 2 compares the market allocation of payment instruments to the socially optimal allocation in the transaction space.

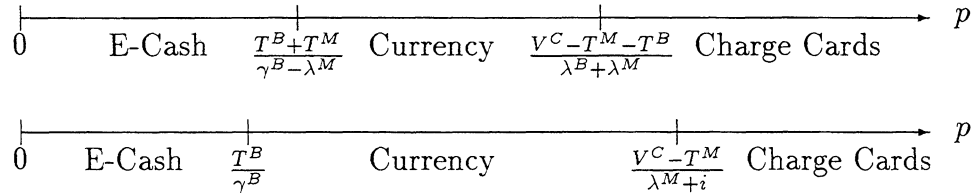


Figure 2: **Payment domains: social optimum versus equilibrium.** Above: Socially optimal domains. Below: The market allocation

We summarize our welfare results with the following proposition.

Proposition 3

1. *Market failure occurs since currency is overutilized in comparison to electronic cash.*
2. *Charge cards are underutilized if (10) holds, and overutilized if (10) is strictly reversed.*
3. *These market failures are independent of the market structure.*

Note that these welfare results are not yet taking into account the effects of introducing connection costs of linking merchants to the card systems.

Proposition 3 needs some explanations. The market failure in this economy occurs since cutoff points between the various payment instruments take into account the value of time lost in currency transactions of either the buyer or the merchant, but not both. Thus, the market failure occurs due to the fact that in economies with legal tender the market solutions are not determined by the economy-wide sum of transaction costs associated with currency. The third part of the proposition highlights the fact that market failure occurs with all types of market structures.

Altogether, the overutilization of currency from a social viewpoint occurs since the division between electronic cash card and currency transactions is determined by buyers, thereby neglecting to take into account merchants' value of time loss associated with currency transactions (T^M and λ^M). Similarly, the division between currency and charge card transactions is determined on the basis of merchants' costs only, and therefore neglects to take into account buyers' costs associated with currency transactions (T^B and λ^B).

5 Merchant specific fixed costs: Who will pay for the connection?

Card issuers face two types of fixed costs. There are general system construction investment costs composed of location, computer system, telephone lines etc., as well as the minimum return that must be paid to investors. We denote investment costs incurred by an electronic cash card issuer by I^E . Analyzing the consequences of investment costs in the electronic cash card industries is deferred to section 6. In this section we ignore the general system investment cost and assume that $I^E = 0$.

The second type of fixed cost borne by card issuers is generated by each merchant joining the card system. These costs are separable in the sense that they can be attributed to each merchant individually. For example, they consist of the equipment needed to be installed at the location of each merchant subscribing to the card network system. We call these costs merchant-specific connection costs and denote them by E^E ; "E" is for equipment, and superscript "E" is for electronic cash card. Given that this equipment is durable (i.e., lasts for several billing periods), we will treat the parameter E^E as the rental cost of a merchant's connection cost per billing period.

We now analyze how the introduction of these connection costs affects the fees imposed on merchants, and its effect on the transaction domain of

electronic cash cards. The issue revolves mainly around the question whether the connection costs will be borne by the card issuers, by the merchants, or shared.

5.1 Monopoly card issuers

Under a monopoly case, in view of (6), a monopoly card issuer manages to extract the entire surplus from merchants, so the introduction of connection cost must place the burden entirely on card issuers. A monopoly issuer, however, may find some merchants to be unprofitable if they turn out to have a small number of customers. Thus, a monopoly electronic cash card issuer will provide ‘free connection’ (i.e., $f_0^E = 0$) only to those merchants on the distribution where

$$\left[f_1^E + f_2^E p\right] \frac{b(p)}{m(p)} = \left[T^M + \lambda^M p\right] \frac{b(p)}{m(p)} \geq E^E. \quad (11)$$

The merchants for whom condition (11) is not satisfied will be excluded by the card issuer either by imposing a connection fee for these merchants or simply by imposing a minimum turnover requirement. The possible exclusion of various merchant types depends on the distribution of buyers, $b(p)$, as well as of the stores, $m(p)$.

Under certain conditions, the transaction domain in p of electronic cash cards will consist of a single interval $(0, \bar{p}]$, where \bar{p} is the maximal transaction size paid with electronic cash. Formally, for such a unique interval domain to exist, it is sufficient that the elasticity of number of transactions per merchant with respect to the transaction size p will be sufficiently low. More precisely,

$$\frac{d \ln \left[\frac{b(p)}{m(p)} \right]}{d \ln p} < \frac{-\lambda^M p}{T^M + p}. \quad (12)$$

Subsection 5.4 demonstrates the implications of this condition on the determination of transaction domain of electronic cash cards.

\bar{p} is determined by the minimum of two conditions. The first one is set by the card issuer (11) and the second one is buyers’ acceptance criterion for electronic cash (5). In case that the first condition is the binding one, \bar{p} is solved from

$$\frac{b(\bar{p})}{m(\bar{p})} = \frac{E^E}{T^M + \lambda^M \bar{p}}. \quad (13)$$

5.2 Competitive card issuers

Under fee competition, all fees drop down to issuers’ costs. Thus, a competitive electronic cash card industry will set only a connection fee; so, $f_0^E = E^E$ and $f_1^E = f_2^E = 0$. Given this fee structure, (merchants pay for connection only) only merchants for whom $\left[T^M + \lambda^M p\right] \left[b(p)/m(p)\right] \geq E^E$ will adopt electronic cash, which is exactly those merchants that are not excluded by the monopoly card issuer. Of course, the buyers’ acceptance criterion (5) applies as well so that the transaction domain in the competitive case coincides with the monopoly case.

5.3 Comparing monopoly and competitive card industries

An important lesson to be learned from these simple fee calculations in the presence of connection (participation) costs, is that by looking at the fee structure, one can infer whether the card industries are competitive or monopoly structured. In general, it is hard to infer whether an industry is monopolistic or competitive by just looking at prices firms in the industry charge. This makes antitrust investigation extremely hard since given that costs are not observed, markups cannot be calculated and therefore industry structure cannot be detected. However, in the case of electronic money, it turns out that the observed fees can hint the type of market structure in the card issuing industry.

The interesting conclusion that comes out of our analysis is that monopolistic and competitive industries set completely different fee structures. By completely different we mean that the two industry types impose fees that differ not only by the scale of pricing. Hence,

Proposition 4

1. *For the merchants participating in the electronic cash system, a monopoly card industry will not impose a connection fee, f_0^E , whereas a competitive card industry will charge for the full connection cost.*
2. *The monopoly market structure and the competitive market structure will result in the same transaction domain of electronic cash cards.*

The intuition behind this result is quite simple. A monopoly card industry can extract entire surplus from merchants by setting the fees just slightly lower than merchants' cost of handling currency. The cost of a currency transaction involves only per transaction and an ad-valorem component. Hence, since a monopoly card issuing industry cannot extract any additional surplus, it will have to bear the entire connection costs. Otherwise, imposing fees on equipment will cause dealers to switch to currency transactions. In contrast, a competitive industry does not extract the entire surplus from merchants, so given that the issuers make only normal profits, any equipment costs must be borne by merchants only.

Altogether, the competitive and the monopoly electronic cash card issuing industries yield the same adoption of electronic cash, but differ only in how the surplus is divided between card issuers and merchants. Therefore, the two market structures are equally efficient. Ordinarily, monopolies tend to reduce output compared with the perfectly-competitive market structure. This is not the case however when there is perfect (first-degree) price discrimination such as in the present model.

5.4 Some particular cases

We now illustrate the effect of introducing connection costs on merchants' adoption of electronic cash cards. As noted above, condition (5) imposes a buyers' upper bound on electronic cash card transactions, which stems from a strictly positive probability for magnetic errors in which cards lose their value. The following illustrations assume that T^B/γ^B in condition (5) is sufficiently

high so that the upper bound on the usage of electronic cash cards is effectively imposed by merchants only.

Merchants' upper bound on electronic cash card transactions, given in (11), depends on the behavior of the ratio of buyers' density and merchants' density functions, $b(p)/m(p)$. From (13) we know that electronic cash cards will be adopted in the region where the number of transactions per merchant, $b(p)/m(p)$, exceeds the connection costs divided by the merchant's costs of a currency transaction, $E^E/(T^M + \lambda^M p)$.

We believe that typically the number of transactions per merchant indeed declines with the size of purchase. In this case the transaction domain for electronic cash could be determined as in Figure 3. This figure assumes that $b(p)/m(p)$ declines sufficiently fast so that (12) is satisfied.

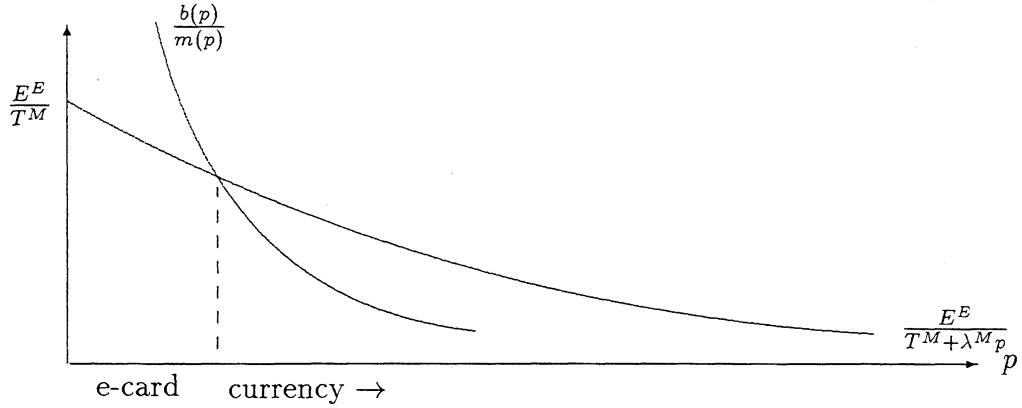


Figure 3: The division between electronic card and currency transactions assuming that condition (12) holds

Figure 4 departs from the declining turnover property and assumes a U-shaped ratio of density functions. In this case, electronic cash cards are used for

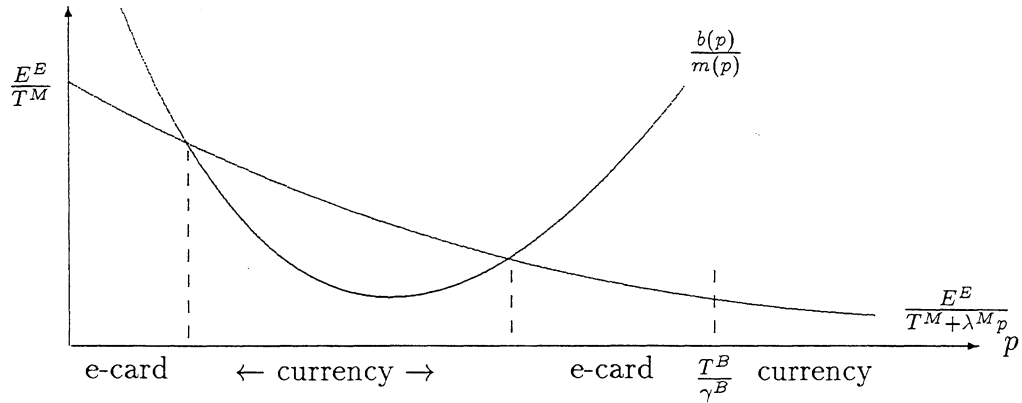


Figure 4: The division between electronic card and currency transactions assuming U-shaped locus of per merchant transactions

extremely small transactions (with a large turnover), such as vending machines, and then for medium size transactions such as grocery stores food purchases. For some transaction sizes falling between the two mentioned above, currency

would be used. Finally, in transactions larger than the maximum electronic cash transaction acceptable to buyers, T^B/γ^B , currency again would dominate as determined by (5).

Note that in Figures 3 and 4, the ratio of the connection cost to currency transaction cost approaches E^E/T^M as transaction value, p , gets smaller. In the case where the number of transactions per merchant never exceeds this ratio, electronic cash cards will not be adopted, as illustrated in Figure 5.

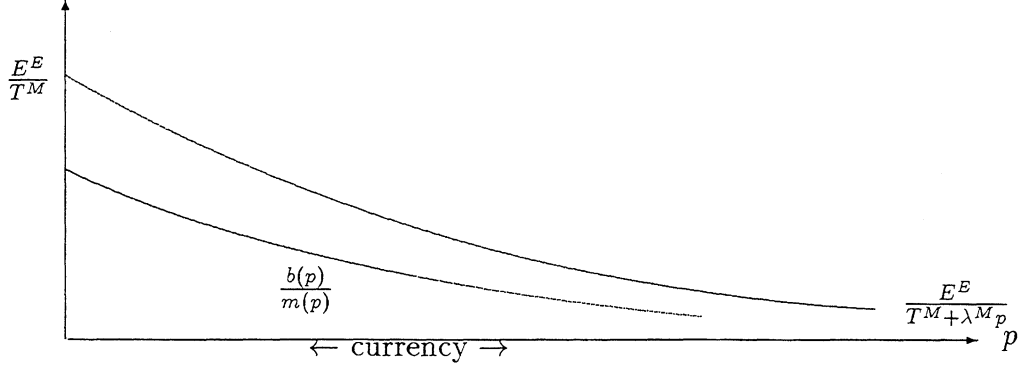


Figure 5: **Prohibitive connection costs: Electronic cash cards are not introduced**

Comparing Figures 3 and 5 demonstrates how a decline in connection costs can trigger the emergence of a transaction domain for electronic cash cards, for example as a result of cost reducing innovations.

5.5 General welfare analysis

In section 4 we identified potential market failure associated with the adoption of electronic cash cards. We now extend this analysis to include connection fees.

Analogously to (8), it is socially optimal to have a merchant type p accepting electronic cash cards instead of currency if

$$E^E + \frac{b(p)}{m(p)} [\lambda^B + \gamma^B] p \leq \frac{b(p)}{m(p)} [T^B + T^M + (\lambda^M + \lambda^B) p].$$

Hence, from a social welfare viewpoint, the maximal transaction size paid for by electronic cash cards, denoted by p^* , is implicitly determined by

$$E^E = [T^B + T^M + (\lambda^M - \gamma^B) p^*] \frac{b(p^*)}{m(p^*)}. \quad (14)$$

To find whether there exists a market failure in the adoption of the electronic cash card in the presence of connection costs, we have to compare the equilibrium marginal electronic card transaction determined in (13) with socially optimal (14). Hence, if $\bar{p} < p^*$, the electronic cash card is *underutilized* compared with currency, whereas if $\bar{p} > p^*$, the electronic cash card is *overutilized*.

From (14), we define the function

$$f(p) \stackrel{\text{def}}{=} \left[T^B + T^M + (\lambda^M - \gamma^B) p \right] \frac{b(p)}{m(p)} \quad \text{so} \quad f(p^*) = E^E.$$

From (13), we define the function

$$g(p) \stackrel{\text{def}}{=} \left[T^M + \lambda^M p \right] \frac{b(p)}{m(p)}, \quad \text{so} \quad g(\bar{p}) = E^E.$$

From condition (12), we know that $g(p)$ is decreasing in p . It is readily verified that $f(p) = g(p)$ if and only if $p = T^B/\gamma^B$, which, by Proposition 5, is precisely the equilibrium cutoff transaction size when connection costs are absent, see equation (5) and Figure 1. The functions f and g are plotted in Figure 6. Since as $p \rightarrow 0$, $f(p) \rightarrow T^B + T^M$ and $g(p) \rightarrow T^M$. Hence, for

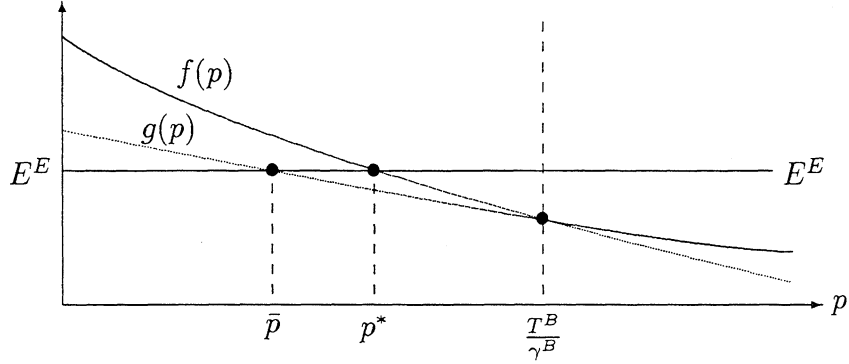


Figure 6: **Equilibrium versus socially optimal maximal electronic transaction size**

sufficiently small values of p , $f(p) > g(p)$. Given the unique intersection of f and g , have it that $f(p) > g(p)$ for all $0 < p < T^B/\gamma^B$. The above arguments imply the following proposition.

Proposition 5 *In equilibrium, the transaction domain of the electronic cash cards is smaller or equal to the socially optimal domain.*

The equality of the socially optimal domain and the equilibrium domain for the electronic cash cards occurs in the special case when $\bar{p} = T^B/\gamma^B$.

6 Investment in the electronic cash card system

So far, our analysis has ignored the general investment considerations associated with the introduction of electronic cash cards. More precisely, our analysis has so far focused on the pricing and transaction domain of an already existing system. However, in practice, the electronic cash card industry involves large investment costs which cannot be attributed to any single user. Still, these costs must be recovered from fees and margins imposed on users of these cards. We are interested in the implications of both the competitive and the monopoly market structures in the card issuing industries.

6.1 The pure monopolist's investment decision

In the monopoly case, the pricing and the transaction domain of electronic cash cards will not be altered by the presence of fixed cost since we have shown that all surplus is extracted from merchants in any case, provided that the surplus is sufficiently high to cover the fixed cost and to allow for the establishment of the system. A key question is under which conditions the electronic cash card industry will emerge. It turns out that the relationship between fixed costs and the potential merchants' surpluses is the factor determining the profitability of constructing the system. The monopolist's total profit is given by the sum of fee income from all merchants in accordance with (6) minus connection costs multiplied by the number of merchants. From this, the monopoly card issuer must deduct the investment cost, I^E . Hence,

$$\pi^{\text{monop}} = \int_0^{\bar{p}} [(T^M + \lambda^M p)b(p) - m(p)E^E] dp - I^E, \quad (15)$$

where \bar{p} is solved from (13). Hence, under the pure monopoly market structure, the system will be built when (15) is nonnegative. Obviously, a decline of either the connection cost, E^E , or the investment cost, I^E , or both as a result of technological advance can trigger the construction of the system.

6.2 A Contestable Electronic-Cash Card Industry

In contrast to the monopoly case, analysis of competition is fundamentally changed when fixed costs are taken into account, for the simple reason that the classical competitive equilibrium no longer exists. However, the nearest alternative which is applicable to analyzing industries with large fixed costs is the *contestable market* equilibrium, see Baumol, Panzar, and Willig (1982). In a contestable market structure, an incumbent card issuer sets its fee structure so that no other potential card issuer can undercut the incumbent's fees while still generating a sufficient amount of revenue to recover the necessary investment and connection costs. In absence of entry barriers, contestability leads to zero profit for the incumbent which means that monopoly power will be utilized only to the extent necessary to cover the connection and investment costs. Contestable equilibria will emerge in environments where a costless hit-and-run entry is possible i.e., when fixed costs are not sunk. Typically, contestable market equilibria are socially optimal under the constraint that the industry must be self financing.

In order to analyze the contestable market equilibrium, we can take the pure monopoly equilibrium as a starting point and see what are the effects of introducing a threat of entry into the model. The impact of the threat of entry is that the equilibrium prices applied by the monopolist will no longer be determined by simple profit maximization subject to the demand constraint. Instead, the equilibrium prices will have to satisfy certain equilibrium conditions, such as

Feasibility: the equilibrium prices must generate revenue which is sufficient to cover the total costs of the monopolist.

Sustainability: It be impossible for a potential entrant to devise a fee structure which would enable it to enter and obtain enough revenue to cover its total costs.

In the case of no entry barriers, the conditions of feasibility and sustainability imply that the equilibrium prices will result in zero profits for the incumbent monopolist; the conditions also imply that the revenue generated from any subset of the monopolist's clientele will not exceed the stand-alone costs of serving this subset (i.e., total costs of the hypothetical entrant which would serve only this subset of customers). This implies that there are no cross subsidies in the contestable equilibrium.

Turning now to the case of the electronic cash industry, recall that in the pure monopoly equilibrium, the monopolist will be able to extract all of the merchants' surplus. Introducing contestability will lead the monopolist to lower the fees charged to some of the merchants compared to the pure monopoly equilibrium.¹ Fees decrease until the total revenues of the contestable monopolist equal its total costs. However, the following proposition shows that these reductions in fees are such that they do not influence the merchants' decisions regarding the adoption of the electronic cash system.

Proposition 6 *Under contestable monopoly, the transaction domain of electronic cash will be exactly the same as in the pure monopoly case.*

The proof of Proposition 6 follows from the following arguments. First, observe that introducing contestability cannot reduce the transaction domain of electronic cash cards. In the model, it is impossible to extract from any merchant type higher fees than those set by the pure monopoly, simply because under pure monopoly, the electronic cash card issuer already extracts the entire surplus from all merchants. Attempting to raise fees would therefore lead to the switching from electronic cash to the use of currency by all merchants to which these higher fees would be applied. This switching would generate loss of revenue which would not be possible to compensate for by adjusting fees imposed on other merchants. Therefore, the contestable monopolist will not exclude any merchant served by a pure monopolist.

Second, introducing contestability cannot increase the transaction domain of the electronic cash cards, either. This is because if a pure monopolist practicing perfect first-degree price discrimination does not find a merchant of type p to be profitable to serve, then no issuer in any other market structure will make a profit by serving this type. With the zero-profit constraint in force, serving merchants which are not served in the pure monopoly case would mean that serving these unprofitable merchants would require extracting a positive net profit from the rest. However, such extraction is inconsistent with in a contestable market equilibrium because it would make entry profitable.

On the basis of the above results, we know that the only effect which contestability has on the electronic cash issuing monopoly is that it will lead to lower fees imposed on some of the merchants, compared to the pure monopoly equilibrium. However, it is impossible to determine a unique equilibrium fee

¹Clearly, in the borderline case where a pure monopoly would happen to break even prior to the threat of entry, fees would not be affected.

structure. This is because the monopolist is obviously indifferent with respect to the way in which it will allocate the burden of its fixed (investment) costs to its customers, as long as their participation constraint is not violated. Any fee structure satisfying both the participation constraint and the zero-profit constraint will be both feasible and sustainable - i.e., it will be a contestable market equilibrium.

Some things can be inferred about the equilibrium fee structure under contestable monopoly. First, the total revenue extracted from the marginal merchants (those who are indifferent between adopting the electronic cash cards and using currency) is E^E . Second, the three-part tariff used in the previous sections is no longer generally relevant.

However, the partial indeterminacy of the fee structure in a contestable equilibrium does not imply the indeterminacy of the transactions domain. In fact, we have shown that the transaction domain of electronic cash cards is the same under a contestable monopoly as in the pure monopoly case.

Finally, note that as is in all contestable markets with no entry barriers there no difference between the pure monopoly and the contestable monopoly cases regarding the question whether the electronic cash system will be established at all. This is because the contestable monopoly would be able to break even whenever a pure monopoly makes a nonnegative profit.

7 Conclusion

Electronic cash cards can displace currency at least for small transactions. Assuming away transition and adjustment costs, the introduction of the electronic cash card technology is socially welfare improving since buyers and merchants' aggregate cost of acquiring, holding, maintaining, and transacting with currency is reduced.

Under the assumption that the volume of transactions per merchant is declining sufficiently fast with the transaction size typical to the merchant, the transaction domains of the different payment instruments are as follows. The smallest transactions will be paid for with electronic cash cards. The medium-sized transactions will be paid for with currency, although under certain parameter range currency may vanish entirely. The largest transactions will be paid for with charge cards or, more generally, account-based media such as checks. Perhaps the most striking result concerning transaction domains is that these domains are invariant with respect to the market structure of the card industry.

The pricing of electronic cash card services depends on (a) the market structure (monopoly versus several competing card issuers), and (b) most importantly, on the cost of transacting with the alternative means of payments (currency and charge cards).

Our model implies that a monopoly electronic cash card issuer can extract from merchants all surplus generated to them by this new technology with relatively very little information about the merchants' characteristics.

Under a competitive market structure, fees on electronic cash card transactions will drop to zero, or the connection costs, when these are taken into

account.

Our welfare analysis reveals an overutilization of currency over electronic cash card transactions. The existence of an inherent market failure follows from the fact that the cutoff transaction size is determined by either buyers' or merchants' payment transaction but not both. Therefore, the entire costs associated with currency transactions are not taken into account.

When connection and investment costs are included, the transaction domain of electronic cash cards may be reduced. Characterization of the contestable market equilibrium reveals that the transaction domain of electronic cash cards is independent of the investment cost provided that the system is established. The maximal investment cost which still permits the construction of this new medium depends on how many buyers and merchants are interacting in the various size classes of payments, on the cost of extending the service to a point of sale, and on the cost of handling currency.

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