USING E-CASH IN THE NEW ECONOMY: AN ECONOMIC ANALYSIS OF MICROPAYMENT SYSTEMS

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ABSTRACT

The growth of electronic commerce is dependent upon the emergence of effective electronic payment systems. Whilst payments for large purchases can be made relatively easily using credit/debit cards, small-scale electronic commerce is constrained by the limited nature of existing e-cash (or 'micropayments') systems. This paper outlines the evolution of electronic payment systems, leading to an analysis of the essential characteristics of e-cash, and microeconomic / macroeconomic implications of the development of e-cash. Finally, the key characteristics of successful electronic payment innovations are analysed using binary dependent variable estimation techniques on data derived from the Electronic Payments Systems Observatory (ePSO) database.

Keywords: e-cash, micro-payment systems, e-commerce

1. Introduction

Electronic commerce is growing at an increasing pace and financial instruments are adapting to the increased volume of spending taking place over the Internet (Economides, 2001). Until now, most buyers have used credit arrangements or checking accounts as the principle means of paying for Internet purchases. There is however, a 'price umbrella' underneath credit-card transactions that makes them an excessively costly financial instrument for low-value purchases (Rivest, 1998). Given the transactions costs involved with card transactions, the opportunity gap that remains in terms of e-money products lies in developing a popular alternative to conventional cash as a convenient way to make small payments ('micropayments'[1]). For many Internet transactions, electronic cash (e-cash) could provide a potentially superior substitute for conventional monetary instruments.

Most existing electronic small payments schemes are in essence account-based systems mediated by middle-people, in practice in much the same way as a bank or credit institution acts as a financial intermediary. Accounts-based payment mechanisms lack some of the key characteristics of conventional cash, e.g. complete anonymity and low transactions costs. Financial cryptographers are attempting to harness the lower computational and/or administrative transactions costs of electronic payments schemes in order to devise an efficient electronic micro-payments scheme whilst retaining in electronic cash the virtues of conventional cash (e.g. in terms of security and anonymity) and some of the computational and technical difficulties have been overcome (van Someren, 2001, van Someren *et al.*, 2003). But attempts at a practical implementation of e-cash systems have met with limited success because logistical problems remain; to some, the widespread adoption of e-cash systems seems to be a distant prospect (Odlyzko, 2003).

This paper begins with an analysis of ideas about the evolution of money, applied to modern forms of electronic money systems. Then the characteristics of electronic cash relative to conventional money and other electronic payment systems are outlined followed by an examination of the potential microeconomic and macroeconomic implications of e-cash systems. The evolution of electronic payment systems within the real world is analysed using data derived from the Electronic Payments Systems Observatory (ePSO), which is run by the European Central Bank (ECB) as part of its monitoring role. These data are used in a binary dependent variable analysis of the characteristics of successful electronic payment services. The paper concludes with the observation that whilst e-cash systems have the potential to change monetary systems by directly matching buyers and sellers in exchange, there is still a long way to go in developing effective and extensive e-cash systems. And the further evolution of widely accepted systems will require the co-operation of governments, central banks and business.

[1] Micro-payments systems are defined as e-payment solutions that allow for payments up to 5 Euros (Carat, 2002).

2. Definitions of electronic money

In understanding the evolution of electronic money, it is useful first to define electronic money and then to examine some of the specific characteristics of e-money in general and e-cash in particular. Fullenkamp and Nsouli (2004) argue that one of the 'puzzles' surrounding the evolution of electronic money has emerged because of confusions over terminology and definitions. This point is recognised by the Basel Committee of the Bank for International Settlements (BIS): electronic money is difficult to define because it blends particular technological and economic characteristics (Basel Committee, 1998; BIS, 1996). In addition, different e-money schemes will vary according to their technical implementation, the institutional arrangements required to support them, the way in which value is transferred, the recording of transactions and the currency of denomination (BIS, 1996). This means that several definitions of electronic money have evolved over time.

In broad terms, electronic money can be defined as monetary value stored on an electronic device issued on receipt of funds or accepted as a means of payments (Carat, 2002, p. 11). This mirrors the official definitions published by ECB and BIS in focussing on the stored value aspect of electronic money (e.g. BIS 1996, Basel Committee, 1998). The ECB (1998, 2000), following the first official definition issued by the European Monetary Institute (EMI, 1996), define electronic money in the following terms:

> 'Electronic money is broadly defined as an electronic store of monetary value on a technical device that may be widely used for making payments to undertakings other than the issuer without necessarily involving bank accounts in the transactions, but acting as a prepaid bearer instrument.'

Again, the focus in this definition is on the pre-paid aspect of electronic money. The Basel Committee (1998) further divides types of electronic money into the categories of electronic purses (hardware or card based) and digital cash (software, network based). But whether these instruments are 'balance-based' (i.e. account based) or 'token-based' (i.e. involving the expenditure of electronic tokens), the essential characteristic is their pre-paid nature. For this reason, credit cards and debit cards are regarded as access products or electronic payment systems, rather than as electronic money (BIS, 1996; Basel Committee, 1998).

3. Characteristics of electronic money

3.1 The Evolution of Money[2]

In analysing whether or not electronic cash can evolve as an efficient and flexible facilitator of exchange in the Internet economy, it is useful to revise theories about why and how conventional money has evolved over time. Money plays a number of roles in economic activity: it is a unit of account, a means of deferred payment, a store of value and a medium of exchange. According to a Mengerian view, the evolution of money has taken place in a context of economising on time, effort and scarce resources (Menger, 1892; Alvarez, 2002). All economic exchanges, including the exchange of money for goods and services, involve transaction costs and these hinder the trading of goods and services. Economists regard transactions costs as a form of economic friction: if economic friction is reduced, more productive potential will be released. The Mengerian view asserts that money has evolved over the centuries to minimise the friction of transactions costs that are involved in mediating exchange.

The process can be seen from the development of the very first monetary products. Conducting economic transactions in barter economies was uneconomical: a double coincidence of wants between buyers and sellers was the necessary pre-condition for exchange. Transactions costs were considerable because a lot of time and effort was involved in finding a suitable barter partner. At first glance it may appear that e-cash is the opposite – having the potential to lead the monetary system to an even higher evolutionary point. To a non-technician, the transactions costs involved in e-cash may seem to be almost zero whilst the benefits are much the same as conventional cash. But the picture is in fact more complex.

Another element in the evolution of money was the need for divisibility and fungibility. Limits on the divisibility of goods and services created problems: if a loaf of bread is worth a tenth of a goat, what's the solution? The advent of commodity money made the process of transacting more economical by allowing people to specialise in production according to their strengths and by enabling monetary authorities to mint coins in convenient denominations, creating divisibility and fungibility: when people withdrew coins from a bank they did not have to withdraw the same coins that they deposited because all coins of a particular denomination were homogenous and standardised. This reduced the complexity of exchange.

As for the role of government, within a commodity money system a monetary authority is not essential. As long as people believe that their commodities or coins represent purchasing power then the commodity is its own

[2] For analyses of the nature and evolution of money, including electronic money, see Davies, 2002 and Solomon, 1997; Baddeley and Fontana, 2004.

guarantor. But government usually has a key role in legitimising coinage by affixing a stamp to guarantee that a coin contained a given amount of precious metal. Nonetheless, risks of counterfeiting and debasement remained. Also, using commodity money whether based upon gold, other metals, or cigarettes, meant either that extra resources were devoted to producing more of the commodity; or that limitations had to be imposed on the use of the commodity for non-monetary purposes. Also, costs were incurred in storing, holding and carrying commodity monies. An early solution came via token money: with trusted goldsmiths issuing transferable certificates to register gold reserves, commodity money could survive without the need to carry around the commodity itself.

Gradually, the issuing of notes by private banks was supplanted by central bank control of cash in the economy. Initially, central banks issued convertible paper currencies e.g. the gold standard or dollarisation. The development of convertible paper currencies allowed a decrease in the costs involved in the production, storage and use of money. The average cost of printing and storing a bank note or coin are far less than the value of that note or coin. It is likely that electronic money will have the capacity further to reduce these production and holding costs, though the role of government is likely to be constrained.

Another distinctive characteristic of conventional money over electronic money is the importance of fiat money: money that is declared by government fiat to be legal tender with people being obliged to accept it as such. It seems unlikely that governments will be willing or able to declare similar fiats with respect to electronic money. This is the essence of the problem with any form of non-commodity money: why would a person hold something inherently worthless as a store of value or medium of exchange? They hold it because they believe in it; using fiat money as a medium of exchange is vitally dependent upon a social convention. This is the essence of the Chartalist view, popularised by Knapp (1924), of money as a social relation. Whilst there are still risks of forgery and fraud associated with fiat money, the most important advantage that fiat monies have is that they are cheap. They are cheap because they are based upon a social convention supported by trusted institutions and a legal system. Credibility is crux of the system; fiat money cannot work if people are not prepared to use their tokens as a medium of exchange. And for people to be prepared to use tokens in exchange, the tokens must be legal tender or at least almost universally acceptable. This is one of the key problems for e-cash: encouraging people to adopt the convention. For conventional money, reliable monetary institutions support the fiat; modern central bankers focus on the interactions between monetary policy, inflation and purchasing power. It follows that the private production of money must be illegal: if anyone can produce monetary tokens, central banks would not be prepared to guarantee the value of money and the social convention would collapse. But for electronic cash, the private producers are the innovators and monetary authorities have had little direct impact on the various e-cash alternatives available.

So history shows that all money has evolved to meet a set of essential requirements including wide acceptability; low production/carrying/storage costs; fungibility, divisibility; and resistance to forgery.[3] For future developments in electronic money, there is no doubt that technology has evolved to a stage at which e-cash systems will be able to supplant conventional cash systems in terms of some of these characteristics. Conventional token or fiat monies do incur production, storage, carrying and handling costs which, whilst less substantial than those involved in commodity money systems, are still likely to be greater than the costs of effective e-cash systems. In addition, if systems can be devised to limit on-line processing costs, e-cash systems have the potential to be more secure than conventional cash systems. However, many barriers remain if e-cash systems are to replicate the liquidity, ubiquity and anonymity of conventional cash, particularly as ease of access to conventional cash has increased with the proliferation of ATMs (The Economist, 2000*a*, p. 21).

3.2 Constraints on the evolution of e-cash

Some of the constraints on the effect evolution of e-cash systems emerge in designing instruments that are able easily to mimic some of the essential characteristics of conventional cash, e.g. in terms of efficiency, wide acceptability, security, anonymity**,** easy transferability (including an ability to support multiple payments).

Efficiency: The costs involved in producing and storing electronic cash are likely to be lower than those involved with printing, storing and carrying conventional cash. These cost savings will create some gains in terms of economic efficiency if the use of e-cash becomes more widespread. However, the costs involved in <u>exchanging</u> e-cash are relatively high in comparison with the costs involved in exchanging conventional cash. The current technology used in security protocols involves relatively high transactions costs and is not economical for 'micro-payment' systems' (Foo, 1997). Innovations such as NetCard can support micro-payments by incorporating a digital signature into a whole stick of coins that can then be spent individually (with a given merchant). This system allows a reduction in computational complexity for series of low value payments to given merchants but is not particularly helpful for customers who want to spend their coins at a number of different sites (Anderson, 2000).

[3] For a more exhaustive summary of the desirable properties of e-cash, see Neumann and Medvinsky, 1998; Choi, Stahl and Whinston, 1997.

Another way of reducing the transactions costs involved in digital payment systems is via de-coupling the various tasks that characterise the exchange of goods and money thereby making the system more suitable for low value transactions (Kravitz, 1998). Voucher schemes, lottery ticket and coin-flipping protocols all have the potential to minimise the number of messages involved in each transaction (Rivest, 1997; Foo, 1997; Lipton and Ostrovsky, 1998). Foo's method also transfers the processing burden onto banks, which may be appropriate if banks have the specialist skills and technology to be able efficiently to mediate financial transactions. In addition, electronic vouchers can be transferable but the problem remains that they cannot mimic conventional cash because direct exchange between buyers and sellers is not possible - financial intermediaries are still involved and this will increase the transactions costs of exchange. In addition, coin-flipping and lottery ticket protocols are based upon the assumption that economic agents are risk-neutral and will be satisfied with fair bets. It does not address the issue of risk-averse economic agents who prefer guaranteed sums of money to fair bets.

Acceptability: No existing e-cash is universally acceptable; most are not even widely acceptable. Existing e-cash systems are forms of 'inside' money (available to a select group of insiders) and this is particularly true for vendor-specific schemes. If an e-cash system is to be successfully adopted, it will have to attract a wide constituency, i.e. to become ‘outside’ money. It is because current e-cash schemes are not widely accepted that they must piggyback on the non-cash money supply i.e. bank deposits and credit accounts. This implies that e-cash is just a means of re-distributing 'IOU money' (i.e. based on deposit and credit accounts) and financial intermediaries must necessarily be involved in its exchange. This contributes to the overall transactions costs involved in the exchange of deposit-based electronic cash systems.

In conventional cash systems, there is a simple bilateral interaction between buyers and sellers; the fact that no middle-people are involved means that the transactions costs are lower. This bilateral exchange works because it is based upon a trusted social convention: cheap bits of paper/metal represent value. The backing of powerful institutions is required to support this sort of fragile social convention. What are the implications for effective virtual cash systems? Some observers may believe that we will come to live in a world of 'Disney dollars and Virgin pounds' (Birch and McEvoy, 1997). However, most people are too risk-averse to trust their fortunes to the fate of a single private enterprise; history has shown that even the most successful multi-national companies do not necessarily prosper forever. If an e-cash is to survive as a true cash system, then it requires the backing of trustworthy, stable institutions such as central banks – these could implement common protocols and act as unifying institutions. The development of e-cash as a form of outside money seems unlikely if e-cash systems do not receive this sort of government backing.

Security and Anonymity: Hypothetically, the potential security of virtual money is greater than that of conventional money given the sophisticated printing and counterfeiting methods used for conventional cash. For e-money however, adoption of widely available technologies that are tamper-resistant is limited by the US government's regulation of ‘strong’ cryptography, including export limits on ‘long’ (i.e. complex) keys. It is only in practice and because of governmental constraints that the security and privacy of e-cash systems is limited (Swire, 1997). Many existing e-cash systems, particularly those that can be used with a number of different merchants, are not completely anonymous because the monitoring of their use is actually essential to the proper operation of these systems in order to prevent the double spending of virtual coins. This monitoring may be very costly requiring collusion between institutions. The use of a conventional cash system allows direct interaction between buyer and seller and so it is not possible to monitor transactions taking place mediated using conventional cash. Anonymity is ensured. Conventional cash will be preferred by those involved with criminal activities as long as criminals and tax evaders believe that electronic transactions will always leave some trace (Goodhart, 2000). It can be argued that complete anonymity is not desirable from a social welfare point-of-view (de Solages and Traore, 1998). In theory, a system of anonymity that is only revoked by some trusted authority when criminal activities take place would mean that criminal activity could be more effectively monitored and punished in a world of e-cash. But, in practice, the whole point is that criminals would not use a system that they believe allows effective monitoring and punishment. Even with such a system, until complete anonymity can be assured electronic cash cannot substitute completely for conventional cash for illicit transactions and there will always be a demand for conventional cash, whether or not agents admit their real reasons for holding it.

Partial / complete transferability and multiple payment systems: Within any system of e-cash, there are difficult trade-offs to manage between anonymity/privacy and security/reliability. These trade-offs surface in assessing the desirability of easy transferability of e-cash. Sander and Ta-Shma argue that non-transferability is an important feature for e-cash systems as it imposes limits on criminal abuses (Sander and Ta-Shma, 1997). However, whilst limiting transferability will reduce the potential for fraud, non-transferable e-cash systems will be less flexible and more costly. Assuming that double spending of electronic cash can be prevented, an e-cash system that allows multiple-payments is likely to lower the monetary costs of transactions. However, for many e-cash systems devised so far (e.g. lottery ticket and voucher systems) each unit of e-cash can only be spent once, even if the tickets/tokens/vouchers are transferable before use (Rivest, 1997; Foo, 1997). So each unit of currency is only partially transferable, i.e. it is transferable only until it is spent. In contrast, conventional cash is spent many times by many different people; it is completely transferable. In response to this problem, some multiple-payment schemes have been suggested (Pagnia and Jansen, 1997). In multiple payment systems, the costs of issuing electronic cash will be greatly reduced as long as there is an effective mechanism to allow a given unit of currency to be transferred easily between many buyers and sellers. If this transferability is possible and a token can be spent many times, then the average cost per transaction of issuing a given unit of currency will tend towards zero.

The use of methods such as Chaum's blind signature scheme (BSS) have some potential to promote transferability if a central-bank can issue signed coins and release its public signature key to all traders and consumers so that they can authenticate e-cash received (Chaum, 1992). Concerns about crime and fraud can also be addressed within such schemes, i.e. by using fair BSS in which trusted authorities have the power to monitor suspect transactions (de Solages and Traore, 1998). However, the problem remains that large databases of past transactions must be maintained in BSSs in order to prevent double spending. This requirement adds to the costs and limits the scalability of such systems. Transactions costs are reduced in systems such as NetCash because only outstanding tokens are monitored (Neumann and Medvinsky, 1998). However, these tokens are still not perfectly transferable because the holders of digital tokens/coins do not have to relinquish ownership of the digital coin when they spend it and the prevention of double-spending requires processing time even if this is reduced in comparison with other BSSs. In contrast, for conventional notes and coins, holders relinquish ownership of a physical entity when they spend a conventional note or coin and so the monitoring of double spending is not necessary.

3.3 Constraints on e-cash: some real world examples

Whilst e-cash systems may in theory have the potential to provide advantages not provided by conventional cash systems, as outlined above, designers of effective e-cash systems have the task of exploiting the efficiency gains of electronic transfer whilst mimicking desirable characteristics of conventional cash in terms of widespread acceptability, security, anonymity and easy transferability. But many early electronic cash innovative e-cash products have not stood the test of time, for example schemes such as DigiCash and CyberCash (The Economist, 2000*b*, p.77-9). Can this failure to develop e-cash systems in the real world be explained in terms of the characteristics outlined above? What underlies the success (or lack of success) of real-world e-cash systems?

Paypal is generally held to be the most successful example of an electronic cash system. The essence of its success lies in the fact that it is relatively widely accepted, being the preferred payment system for the widely popular e-Bay auction site (and it was bought-up by e-Bay in 2003). In addition, the verification systems and buyer insurance instruments used by PayPal reassure customers about the relative security of the system. Anonymity is not a characteristic of PayPal, however, and easy transferability only applies to people who want to re-spend their money within the system; it is more difficult to extract money out of the system than to set up an account in the first place. Nonetheless, PayPal does seem to have captured some first-mover advantages in the implementation of an effective micropayments system and its customer base has grown rapidly from about 185,000 in 2000 to over 45 million by 2004 (Sources: The Economist 2000*b*, http://www.paypal.com/). It also has relatively low transactions costs (http://www.wired.com/news/ebiz). The links between PayPal and e-bay has been an ingredient for success as it has helped to ensure relatively wide acceptability. And it is generally true that barter exchange payment systems designed complement some sort of virtual marketplace (e.g. Barter Trust, BigVine, LassoBucks) have been relatively successful (Economist 2000*b*, p. 78).

Other real-world micropayment systems have been less successful. DigiCash was designed to mimic the anonymity of conventional cash but ran into problems of limited acceptability, a problem that was exacerbated not only by the multiplicity of alternative, incompatible systems but also by the limited capital financing available for the project. In addition, the process of transferring money into an electronic 'mint' then to be spent in purchasing digital coins was relatively complicated (http://news.com.com/). CyberCash's CyberCoins system ran into similar problems.

PayDirect offers systems with low costs of entry, which are secure from a merchant's point of view but do not address the problem of merchant fraud. The initial accounts based system is relatively widely accepted but its interface with user accounts means that, in principle, spending is not anonymous and can be monitored. In 2003 PayDirect introduced its World Card – a stored value card that can be used to access local currency via ATMs. To an extent this may promote easy transferability but users of the World Card have to be identified when the cards are purchased.

Ultimately the real constraint is an economic or institutional constraint rather than a technological constraint and lies in generating widespread acceptability and this is the problem that has been overcome most effectively by PayPal. Given the increasing dominance of PayPal within the electronic marketplace, its first-mover advantage will be difficult to reverse even if efficient technological solutions were designed to mimic all the other conventional cash characteristics outlined above.

3.4 The advantages of e-cash over other forms of electronic payment

Evidence suggests that on-line consumers are dissatisfied with the way they spend money on-line and analysts predict that the use of credit cards to fund on-line transactions will decline significantly in the near future (*Economist*, 2000*b*). Quite apart from the constraints outlined above, does e-cash bestow any advantages relative to other forms of electronic payment? Electronic payments via credit card still dominate the market and, as explained above, many e-cash systems have not stood the test of time. Do we need a system of electronic cash when most people currently purchase goods and services over the Internet using credit cards? One of the main challenges confronting e-cash suppliers is providing effective micro-payments systems, whereby small amounts of money can be used electronically. Checks and credit/debit cards do not suit small purchases; the key problem for checks and credit-card systems is that they are not necessarily effective for micro-payments because of the costs involved in interactions between financial institutions (Neumann and Medvinsky, 1998). Using credit cards and checks involves financial intermediaries thus adding to the transactions costs involved in on-line purchases. If credit-card payments incur additional interest costs and other charges upon buyers this will also add to the costs involved with using credit cards.

Another shortcoming emerges because credit-card purchases on the Internet are not anonymous and a person's spending patterns can be tracked using credit-card records. The same is true for mechanisms using electronic checks. There is also an increased danger of fraudulent use of credit-card numbers by third parties. Using ATM cards/machines to access conventional cash is not susceptible to the same level of fraud because dedicated physical devices and anonymous PINs are essential to such transactions. It is costly to tap into telephone networks but it is relatively easy to collect databases of credit card numbers over the Internet because it is easy to intercept information (MacKie-Mason and Varian, 1998). So the use of credit cards to buy goods and services over the phone is not as susceptible to fraud as the use of credit-cards numbers over the Internet. Whilst e-cash may well suffer from the same shortcomings as other forms of electronic payment, the financial risks for individual consumers are reduced. If a consumer is only risking the loss of a not-particularly-valuable electronic coin, he/she is far more likely to conduct transactions over the Internet than if he/she risks an enormous credit-card bill emerging because someone has illicitly intercepted his/her credit-card number. Electronic cash therefore has financial potential that is not matched by alternative electronic financial instruments.

4. Some macroeconomic implications

4.1 Macroeconomic policy: the control of risk

Birch and McEvoy (1997) argue that devolving responsibilities for issuing of money away from governments and central banks will remove a ‘single point of failure’ in the economic nexus between government, financial institutions, business and consumers.[4] This is not an unusual view and many conservative commentators would herald a privately-based e-cash system as a potential triumph for laissez-faire capitalism, for example the Cato Institute (Dorn, 1997). However this view is an over-simplification because, as outlined above, cash works as a social convention and people will only use e-cash if they believe that trustworthy, long-lasting and powerful institutions are supporting it. Goodhart (2000) argues that the impacts of electronic money for government policy control will be limited. The government will still have control of interest rates and it will still play a key role as the government’s bank. But central banks’ supervisory roles will be important whether money is physical or electronic. Government policy must focus on overseeing and supervising the issuers of electronic money. In addition, it seems unlikely that virtual money will ever completely replace conventional money, so central banks will be needed to maintain the convertibility between real and virtual cash.

As far as the monitoring function is concerned, as the number of innovative electronic payment systems has increased over the years, BIS began, in 1996, to monitor and survey electronic money developments, recognising that central banks’ functions may need to be tailored in response to the electronification of finance (BIS 2000, 2001, 2004). The emphasis of BIS strategy has been on surveying electronic money developments to gain a better understanding of how the market is developing. Furthermore, BIS has recognised that central banks’ oversight functions will be particularly important given the risks that accompany the use of innovative electronic money products. These risks will have implications for policy makers because of the potential for disruption to the financial system overall (BIS 1996, 2004). For example, the Basel Committee (1998) emphasised that electronic payment systems are crucial to the increasing efficiency of electronic commerce but these payment systems carry risks as

[4] Single points of failure increase the vulnerability of electronic payment systems because illicit attacks can be targeted more easily.

well as providing benefits - with key risks emerging in the areas of operational risk (associated with security breaches, inefficient implementation of electronic systems and misuse by consumers); 'reputational' risks, legal risks and credit / liquidity / interest rate risks. One of the key implications for macroeconomic policy making institutions will be in moderating these risks whilst encouraging innovative activity in the design of new electronic payment instruments. These issues will be of particular importance given the increasing globalisation allowed by the development of electronic commerce. In particular, cross-border issues of regulation in moderating risk are likely to introduce particular complexity into the management of the risks emerging from the electronification of money (Basel Committee, 1998). Similarly, the ECB sees its role in overseeing and promoting the efficiency and security of electronic payment instruments and systems but it also sees itself as a catalyst for innovation and improved co-ordination (ECB, 2003). In these senses, effective government institutions are more likely to **reduce** than increase the single point of failure problem identified by Birch and McEvoy (1997).

4.2 Cyclical effects

Money supply is defined as the volume of bank deposits and cash. As outlined above, existing rudimentary e-cash systems in essence piggyback upon the financial services provided by banks and other financial institutions. Also, current e-cash systems account for only a small proportion of transactions. So, all other things being equal, the direct implications of current systems for control of the money supply are limited because central bank regulation of financial institutions remains unchanged. However, there is likely to be an indirect effect if the availability of e-cash systems enables consumers to buy more goods and services than they would otherwise consume. Electronic payment systems make the process of buying and selling easier because the transactions costs involved in using them are lower. People do not have to make the effort to go along to their bank or ATM.

This assumes that spending is not constrained by income and that rises in consumption are being funded by borrowings. The key issue here is the availability of credit: if a consumption boom is encouraged by credit-funded electronic commerce then the stock of consumer debt will increase. As the stock of debt increases, financial institutions will impose limits on the issue of credit but the unsustainable increase in consumption will have created financial fragility and encouraged unstable cycles of boom and bust.[5] In this way, the easy use of electronic payment systems may contribute to volatility if easier access to credit allows excessive (if temporary) growth in consumption. What are the implications for micro-payments systems specifically? Within current systems, credit and deposit transactions substitute for conventional notes and cash. In a world in which e-cash can mimic the properties of conventional cash (i.e. in a world in which e-cash is issued by a central institution and used as legal tender), rises in consumer spending and money demand will be magnified. If people have acquired their e-cash directly from someone else then they will not incur the transactions costs involved with using a financial intermediary and e-cash will substitute directly for conventional notes and coins. Either way, the money multiplier will rise with falls in the demand for the conventional notes and coins that constitute the monetary base. This implies that government control of the money supply will loosen as electronic forms of payment become more common and this could make effective government management of the business cycle more difficult. On the other side of the coin: it also means that the potential for seigniorage (value of real resources acquired from an ability to print money) will be reduced. But if governments and central banks want to retain control of the money supply, then they will become increasingly interested in controlling e-cash systems. They will do this either by issuing e-cash themselves or by manipulating the interest rate in order to (try to) control the additional fluctuations in money demand that emerge from increased use of e-cash.

Assuming that governments and central banks were to take control of issuing e-cash, another consequence for macroeconomic policy would emerge in terms of the decreased velocity of money, reducing the number of times a given unit of currency is spent in the economy. This follows from a simple analysis of the quantity theory of money: $MV=PY$ where M is the stock of money; V is the velocity of money, P is the price level and Y is the volume of output. Given $V>1$, i.e. if each coin is spent more than once, then it follows that the stock of money will be a fraction of the real spending within an economy (PY) because a given unit of currency can be spent repeatedly. This may seem like a trivial observation but the implication is that the stock of money will increase and more e-cash notes and coins will be issued compared with current issues of conventional notes and coins. Until e-cash systems are devised which can allow the repeated spending of electronic notes and coins (in the same way that conventional currency can be spent and re-spent) the average velocity of money will be reduced as e-cash enters the system. This implies that with a simple single-payment e-cash system, the lowered costs of issuing e-cash (relative to the costs of printing conventional cash) are going to be partially counter-balanced by the need to issue a greater volume of e-cash cf. conventional cash.

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[5] Further research could focus on developing ideas outlined in Minsky (1978, 1986) about the endogeneity of money, financial fragility and their implications for cyclical stability.

5. Microeconomic implications of e-cash systems

As explained above, e-cash has potential advantages not only over conventional cash systems but also over alternative virtual financial instruments. Reduced transactions costs allow increases in productivity as more resources become available for actual production. Some more specific microeconomic advantages that will emerge with an effective e-cash system include network effects, impacts on consumers in terms of reducing network congestion and promoting efficient markets for information; and impacts for producers in terms of their innovative investments.

5.1 Network effects

In understanding the evolution of electronic payment systems, it is important to recognise that these systems are networked goods: their utility emerges from the fact that they are accessed within a network of other users. Shy (2001) explains that networked goods are affected by a number of distinctive but related characteristics including complementarities, externalities, switching costs, lock-in and economies of scale. Complementarities emerge because networked products have little value in isolation (Katz and Shapiro, 1994; Economides, 1996). Consumers of electronic money products will be looking for a system that supports their electronic payments and so compatibility and operating standards are important. Network externalities emerge because the utility derived from consumption of networked goods increases with the number of agents consuming that good (Katz and Shapiro, 1985; Economides, 1996).[6] These externalities take a particular form for the financial services sector because of liquidity effects - liquidity will increase with expansion of the firm (Economides, 1993, 2001). But negative network externalities will also emerge because key players in the network will have an incentive to report the prices of financial products inaccurately (Economides, 1993). The utility derived from the use of an electronic payment system by a given consumer is dependent upon the fact that other consumers are using the same system: if other consumers are not using the same payment system, then the value of the system will be reduced accordingly. In a dynamic context, this means that multiple equilibria can exist in which a producer will have all the potential consumers within the network - or none of them. In the example described above: PayPal is an example of a system which attracts many consumers just because other consumers are using it; DigiCash is an example of a system which attracted few consumers and so could not reach the critical mass required for it to survive. As electronic payment networks grow, the utility derived by each consumer will grow with the growing acceptability of the system. Switching cost and lock-in may apply if existing a payment system is relatively more costly than entering it (Shapiro and Varian, 1999) which, as explained above, is a characteristic that applies to an extent to PayPal because it is easier to set up an account with PayPal than to get money out. Finally, economies of scale will mean that whilst there are high sunk or fixed costs involved in developing an electronic payments infrastructure, the marginal costs of copying and distributing electronic payment devices or tokens will be low. This generates a natural monopoly in which the average cost function declines sharply and limits the operation of competitive forces. These limits are likely to be more important for electronic payment system producers if the costs of developing new infrastructure are borne by private institutions. However, a number of the electronic payment systems described above are exploiting infrastructure already in existence (i.e. the Internet), which suggests that the focus of microeconomic policy should be on developing effective systems of access pricing. This is particularly important given the problem of network congestion, as explained below.

5.2 Network congestion

From consumers' point-of-view, when a network such as the Internet is uncongested, it exhibits all the key characteristics of a public good (Hallgren and McAdams, 1998), i.e. non-depletability, non-rivalry and non-excludability in consumption. This means that the provision of a good or service does not diminish because of consumption by an additional person; consumption by one person does not preclude consumption by others; and no one can be prevented from consuming the good. As a public good, an uncongested Internet is susceptible to the free-rider problem: consumers are able to free ride on the benefits without incurring any of the costs. However, for the Internet, the marginal cost involved in including additional users, whilst very small, is nonetheless non-zero. If the influx of users is dramatic enough, then the non-depletability characteristic of the Internet will disappear. Technological solutions to this problem have emerged (e.g. Broadband) but how long will these solutions last and can they be further developed as congestion increases further? As increasing numbers of people use the Internet for electronic commerce transactions, congestion charging is an obvious solution to the problem but whilst imposing charges is one thing, collecting the money is another. The computational costs involved in monitoring congestion and negotiating with users about congestion charging seem significant enough but if an additional nexus of interaction between financial intermediaries, congestion chargers and Internet users is added to all of this, then the

[6] See Liebowitz and Margolis (1994) for a discussion of the absence of network externalities.

network of interactions becomes very complicated indeed. It is analogous to a congested car-park: if the car-park becomes full not only of drivers and cars, as well as a ticket collector but also of the drivers' bank-managers (and **their** cars) and the bank manager of the ticket-collector etc. etc., then result is inevitable grid-lock. Also, the value of access to additional users of the Internet is generally very small and so the costs involved in using credit/check payment systems are not easily justifiable. With a low-cost unmediated micro-payments system, congestion charging would become far more straightforward.

An effective e-cash system for micro-payments may reduce problems of congestion when congestion is exacerbated by large numbers of different consumers using the Internet for a range of tasks. Internet congestion reflects not only electronic commerce transactions but also information searches. The marginal value of information to consumers may be quite small and a financial gap exists between the buyers and sellers of information on the Internet. Again, this gap cannot be easily filled by account-based transactions involving financial intermediaries because the **financial** transactions are too costly relative to the value gained from the exchange of information. The costs of using credit and checking payment mechanisms are not justifiable. There's a potential exchange opportunity but existing payment mechanisms cannot easily adapt to facilitate exchange (buying 10p worth of information using a credit card is like buying a 10p banana with a credit card; it is wasteful even if the seller agrees to accept the credit card). Micropayment schemes will be the way of the future in the market for information because of the 'price umbrella' problem mentioned above; credit cards are an excessively costly way to purchase low-value information (Rivest, 1998).

At the moment, the funding of Internet information exchanges is addressed partially via the ubiquitous advertising that takes place on the Internet. However, this advertising contributes to congestion because it increases capacity demands. Nonetheless, buyers of information on the Internet have access to free information. If we think about shopping malls: if all the goods in shops were free, we would find that shopping malls were heavily congested not because people wanted to hang-out in shopping malls (necessarily) but because they wanted to be in the shops taking the goods. Similarly, the problem of congestion on the Internet has its source in the fact that the information provided by the Internet is free. An effective e-cash system would partially solve the problem because people could be asked to pay a reasonable price (without using costly payment mechanisms) for information. The demand for Internet information would decrease accordingly and congestion would probably be reduced.

In addition, with an effective system of micro-payments, information providers would be financially rewarded for providing information that they might just provide at the moment as a public relations exercise. If they could effectively charge a price for selling information as well, that would increase their incentive to supply accurate and accessible information. Overall, the financial gap between the sellers and buyers of Internet information would be bridged and the market would become more disciplined.

5.3 Production implications

Some of the key impacts on producers emerge because of the additional adjustment costs imposed by investing in new technologies. Assuming two producers of electronic money – one of electronic money exchanged via the Internet (Internet money); one of electronic money exchanged using mobile technology (Mobile money). Assuming Cobb-Douglas production technology, the production functions can be described as follows:

$$Y_i = AK_i^{\alpha} L^{1-\alpha}$$

$$Y_m = AK_m^{\alpha} L^{1-\alpha}$$

Y is output, K is capital, L is labour, α is the elasticity of output with respect to capital, A represents the autonomous components of output, and the subscripts *i* and *m* differentiate output and capital in internet money versus mobile money respectively. Labour is assumed to be invariant with respect to the type of money production.

The cost functions can be described as a combination of labour, capital and adjustment costs. The real cost of labour is the real wage rate (*w*). Assuming that there is no change in the value of capital goods, the real cost of capital is the sum of the real interest rate (*r*) and the depreciation rate (∂). The analysis is simplified to a one period analysis and by allowing that I in each period is equal to K (i.e. assuming 100% depreciation gives $K_{t-1}=0$; therefore $I_t=\Delta K_t=K_t-K_{t-1}= K_t$). With $\partial = 1$, the real cost of capital is r+1. The real wage rate and real cost of capital are assumed to be invariant with respect to technology type.

Following a simplified version of Abel (1983), adjustment costs internal to the firm are incorporated into the firm's decision problem. Simplifying to allow that investment and capital are equal in any given period (as explained above), adjustment costs will be a proportion of investment / capital stock. Adjustment costs are assumed to be quadratic in form and will be greater for newer technologies because of the additional 'bolting-down', training, managerial and administrative costs involved in more innovative forms of production. As the innovations associated with mobile money are newer than those associated with internet money, it is assumed that the adjustment costs are higher for mobile money producers: if the adjustment cost for investment in the production of electronic money is γ then for mobile money it will be ϕ where $0 < \gamma < \phi < 1$. Thus the cost functions are of the following form:

$$C_i = wL + (r+1)K_i + \gamma^2 K_i$$
$$C_m = wL + (r+1)K_m + \phi^2 K_m$$

The profits functions for the two producers will be as follows:

$$\prod_i = AK_i^{\alpha} L^{1-\alpha} - \left(wL + (r+1)K_i + \gamma^2 K_i\right)$$
$$\prod_m = AK_m^{\alpha} L^{1-\alpha} - \left(wL + (r+1)K_m + \phi^2 K_m\right)$$

The marginal profitability of capital investment for the two different forms of production will differ as follows:

$$\frac{d\prod_i}{dK_i} = \alpha AK_i^{\alpha-1} L^{1-\alpha} - (r+1) - \gamma^2 = \alpha \frac{Y_i}{K_i} - (r+1) - \gamma^2$$
$$\frac{d\prod_m}{dK_m} = \alpha AK_m^{\alpha-1} L^{1-\alpha} - (r+1) - \phi^2 = \alpha \frac{Y_m}{K_m} - (r+1) - \phi^2$$

Assuming constant output-capital ratios across the two different forms of money production and given $0 < \gamma < \phi < 1$ it follows that $\frac{d\prod_i}{dK_i} > \frac{d\prod_m}{dK_m}$

This implies that the marginal profitability in Internet money production will be greater than the marginal profitability in mobile money production; mobile money production is more innovative and therefore involves the higher adjustment costs. (The validity of this assumption will be tested in the empirical section.) It may be that some firms may want to embark on joint production of Internet money and mobile money. In this case, the additional adjustment costs will impose further constraints of profitability. This effect can be shown by assuming $Y = Y_i + Y_m$, $K = K_i + K_m$ which gives a profits function of the following form:

$$\prod_j = \prod_i + \prod_m = A(K_i + K_m)^{\alpha} L^{1-\alpha} - \left[\left(wL + (r+1)(K_i + K_m) + (\gamma+\phi)^2 (K_i + K_m)\right)\right]$$
$$\prod_j = AK^{\alpha} L^{1-\alpha} - \left[\left(wL + (r+1)(K) + (\gamma+\phi)^2 K\right)\right]$$

Assuming a homogenous capital stock and constant capital-output ratios across the different types of electronic money production, it follows that:

$$\frac{d\prod_j}{dK_j} = \alpha AK^{\alpha-1} L^{1-\alpha} - \left[\left((r+1) + (\gamma+\phi)^2\right)\right]$$
$$\therefore \frac{d\prod_j}{dK_j} = \alpha \frac{Y}{K} - (r+1) - (\gamma+\phi)^2$$

Assuming that the different sources of adjustment cost are independent of each other, it follows from $0 < \gamma < \phi < \gamma + \phi < 1$ that:

$$\frac{d\prod_i}{dK_i} > \frac{d\prod_m}{dK_m} > \frac{d\prod_j}{dK_j}$$

The marginal profitability from joint production will be less than the marginal profitability from specialising in either Internet money or mobile money because of the increments to adjustment costs. It follows that the ranking in terms of marginal profitability is as following: specialising is more profitable than diversification in this one period analysis.

In a dynamic context, however, the prospects might be different because the benefits from carefully investigating new money innovations may be fostered from first-mover advantages - for example diversified firms will be in a better position slowly to develop the relatively innovative forms of money if they have a loyal customer/merchant base established from Internet money production. And when adjustment costs start to fall, these companies will be well placed to take advantage of the increasingly profitable new market opportunity. These hypotheses are tested using the econometric analysis outlined in the following section.

6. An empirical analysis

In assessing the future for electronic micropayment systems as a future alternative to conventional cash systems, an empirical analysis was conducted using data derived from the Electronic Payment Systems Observatory (ePSO) database. These data are concentrated on EU activity. All data was derived from the ePSO database by assembling together the characteristics of organisations involved in the electronic payments industry. A preliminary analysis of these data revealed that, underlying the trend growth in the number of institutions offering electronic payment systems, there has been considerable volatility in the growth of institutions offering micropayments systems in particular.

Figure 1 shows the number of new institutions offering all electronic payment systems from 1983-2002, as recorded in the ePSO database. These data reveal that there has been a sustained growth in electronic payment systems, mirrored by commensurate rises in institutions offering electronic money services as well as micropayment services.

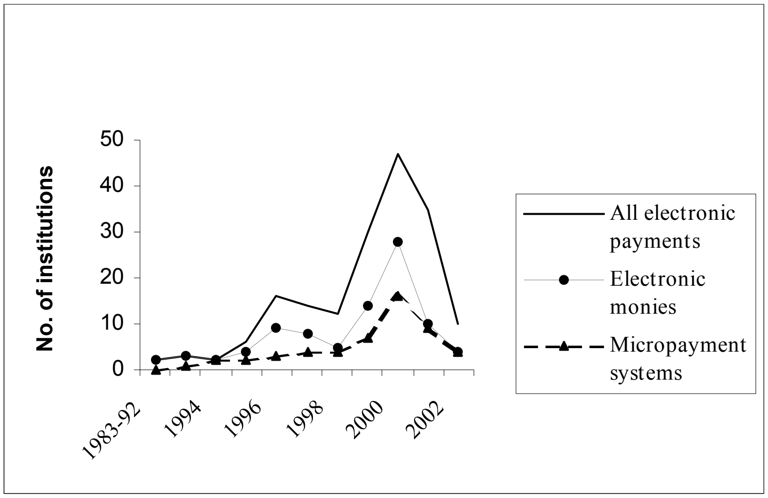

Figure 1: The growth of electronic payment institutions, 1983 to 2002

Figure 2 shows the evolution of micropayments systems as a percentage of all electronic payments and these data reveal that there has been considerable volatility in the advent of new institutions offering micropayment schemes: in comparison with all electronic payment schemes, 100% of new formed companies in 1994 were offering micropayment services, peaking again to 100% in 2002. In the intervening period, the innovative companies in the electronic payments sector concentrated their activities in other areas. During this period of time innovations were concentrated in the area of mobile telecommunications and the juxtaposition of mobile technologies and micropayments schemes (e.g. via ‘mobile wallets’ accessed using mobile phones) became a focus of new production.

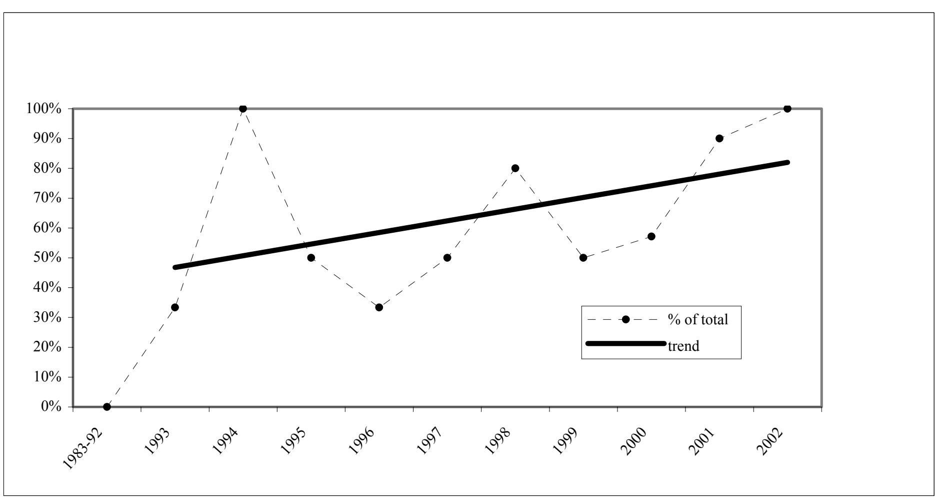

Figure 2: Micropayments systems as percentage of all electronic payments systems

In analysing these trends, the conditions for the commercial success of companies offering e-payments products was assessed using the following model:

P(y=1|A,LM,MOB,MPS,EM)

where y=1 if a firm is no longer operating; y=0 when the firm is still operating. The estimate of the probability that a firm will survive is conditioned upon its market dominance with LM (the natural log of the number of merchants using the system) as the conditioning variable. To capture the influence of technological choice, the dummy variables MOB, MPS and EM are included (equal to one if mobile technologies, micropayment systems and electronic money systems respectively are offered and equal to zero if not).[7]

The conditional probability of business survival was estimated using binary dependent variable techniques. The probability of survival of a firm for the sample as a whole was 82.4% and thus the distribution is skewed. Given this skew in the distribution and the accompanying increased probability of Type I error, extreme value binary estimations techniques were used and compared with the results from Probit estimations. The size and signs of the estimated parameters from both sets of regressions were broadly coincident although efficiency gains in estimation were seen in the extreme value results, as expected, so only the extreme value estimations are reported here in Tables 1 and 2.[8] The results recorded in Table 1 indicate that the probability of survival of firms in the electronic payment industry is raised if the firm's products have a relatively wide coverage, i.e. there is a positive relationship between survival and number of merchants using a system. This is an unsurprising result particularly as one of the essential characteristics of an effective monetary instrument is that it be widely acceptable. More interesting are the technological characteristics of the survivors: the probability of survival is, on average, higher for electronic money in general, lower for mobile money and higher if micro-payments services are offered. As hypothesised above, this could reflect the erosion of profits with the greater adjustment costs accompanying mobile technologies. It might also reflect the fact that the use of mobile money is not yet widespread.

Table 1: Extreme Value Estimation: Survival of Firms Offering Electronic Payment Services

Dependent Variable: Did the firm survive? (Yes=1; No=0)
Estimation technique: Maximum Likelihood
Sample size: 57 observations

Variable	*Estimated Parameter*	*z-Statistic*	*P value (H_0: parameter = 0)*
Number of merchants	0.843	2.21	0.027
Mobile technology?	-0.921	-1.11	0.266
Micro-payments?	0.985	1.58	0.114
Electronic money?	0.783	1.36	0.175

Akaike information criterion = 0.700 Schwarz criterion = 0.843

In assessing the theoretical models developed in the preceding section, Table 2 records the results from extreme value estimation of a model that controls for joint production, J – where J=1 if a firm is offering mobile services as well as electronic money. The estimated parameter on J was insignificantly different from zero, with a *p* value approximately equal to one so the results from these regressions were not particularly informative/reliable. This result may have emerged because of multicollinearity or micronumerosity. Future research will concentrate on building a larger and more comprehensive database in order more effectively to capture the effects of joint production on firm survival.

[7] In addition, estimations were run using the market share to assess the predominance of each firm. The parameters on this variable were insignificantly different from zero with p values of around 0.60. In addition, the inclusion of this variable compromised the significance of the number of merchants variable, perhaps reflecting a multicollinearity problem between the two variables. As the number of merchants variables seems to be capturing the impacts of market dominance more effectively and significantly, this variable is retained in the estimations reported below though results from estimations including market share are available from the author.
[8] The Probit results are available from the author.

Table 2: Extreme Value Estimation: Controlled for Joint Production

Dependent Variable: Did the firm survive? (Yes=1; No=0)			
Estimation technique: Maximum Likelihood			
Sample size: 57 observations			
Variable	*Estimated Parameter*	*z-Statistic*	*P value (H_0: parameter = 0)*
Joint production dummy	41.7	5.48E-08	1.00
Number of merchants	0.887	2.26	0.0237
Mobile technology?	-1.57	-1.70	0.0883
Micro-payments?	1.19	1.79	0.0727
Electronic money?	0.405	0.693	0.488
Akaike information criterion = 0.687 Schwarz criterion = 0.867			

7. Conclusion

Developing innovative electronic financial instruments has the potential to transform economic activity by promoting the development of the Internet to facilitate low-cost exchange. If an effective e-cash system can be developed then it will have the potential to address many of the limitations inherent to conventional cash systems (for example in its capacity to limit fraud and money-laundering). This paper has outlined some of the key characteristics of e-cash systems as well as presenting an empirical analysis of the factors that underlie innovative success in the commercial e-cash systems. However, an effective, widely accepted electronic cash system has yet to be developed and many important characteristics of conventional cash must be incorporated into current e-cash protocols if e-cash is to act as an effective substitute for other forms of money. Also, there are many trade-offs (such as the trade-off between privacy and policing) that must be negotiated during the next stages of cash-evolution. As was seen from the history of conventional cash systems, cash is based upon a social convention and therefore trusted central banks and governments must play a key role in promoting the development of effective and popular forms of electronic cash.

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