Reassessing the 'Threat' of E–Money: New Evidence from the Euro Area

Matthew Greenwood–Nimmo*
Leeds University Business School

Please do not quote without permission.

May 11, 2009

Abstract

The 'threat' to monetary policy posed by e–money was a high profile issue at the turn of the millennium. This paper argues that the debate surrounding this issue, although largely resolved, has diverted attention from a number of important and less fanciful issues associated with the electronification of the payments system. These include the revival of the spectre of old–fashioned bank–runs, the threats to systemic security posed by unregulated offshore issuers and issues surrounding anonymity and the right to privacy. The extent to which these issues can be considered important depends upon the degree of usage of e–money products. A comparative analysis of the Euro Area and Singapore reveals that e–money usage remains minimal in most European countries, certainly in terms of total transaction value. Furthermore, a range of forecasting exercises indicate modest growth potential in the medium–term. These results lead to either of two conclusions. The reactionist view would hold that e–money usage is not widespread and that the current regulatory framework is, therefore, sufficient. The proactive view, by contrast, would ask whether the regulatory framework may be responsible for the slow uptake of the new technology and whether it could be revised to provide stronger incentives for all parties concerned.

Keywords: Electronic Money (E–Money), Monetary Policy, Forecasting, Cross–Country Analysis.

JEL Classifications: C53, E52, G20.

*Address for correspondence: M. Greenwood–Nimmo, 3.01 Maurice Keyworth Building, Moorland Road, Leeds, UK, LS2 9JT. Tel: +44(0)113 343 8687. Email: mjgn@lubs.leeds.ac.uk. I am grateful for the helpful comments of Giuseppe Fontana, Marc Lavoie, Malcolm Sawyer and Yongcheol Shin. Any remaining errors and omissions are entirely my own.

1 Introduction

The acceleration of the process of electronification of financial markets and payments systems has generated considerable interest among both academics and practitioners. Electronification has taken many forms, from the introduction of automated telling machines and internet banking to the deployment of EFTPOS terminals and, most recently, to the development of various forms of electronic money (e–money). E–money involves the use of encrypted digital images stored either on a hardware device (e.g. a card) or on a computer network. These images may then be used in lieu of traditional means of payment at vendors equipped with the appropriate technology. In many countries, e–money usage has flourished in certain markets, including mass transport systems, parking meters and other high frequency low value transactions (e.g. newsstand purchases).

While the substitution away from physical cash toward electronic alternatives provides scope for potentially substantial efficiency gains and increased convenience, much of the early academic work in the field viewed the development of e–money as a threat to the efficacy of monetary policy. This threat, it was argued, derived from the diminution of the central bank balance sheet and the potential for economic activity to take place in isolation from the central bank (i.e. without recourse to its liabilities for payment purposes). Moreover, it was suggested that e–money schemes may evolve to offer settlement services in competition with those of the central bank. It was argued that, in such a situation, the central bank would lose its influence over the economy, becoming unable to engage in stabilising monetary policy and leaving the financial system vulnerable.

This paper argues that this extreme position relies on a flawed model of monetary policy. Furthermore, its alarmist nature has generated more heat than light in the sense that it has distracted attention from the potential efficiency gains associated with electronic payment media and has generated a general sense of mistrust. Furthermore, a number of genuine concerns about the security of e–money schemes and privacy issues have been obscured. The extent to which these concerns may be judged to be significant depends on the degree of usage of the new technology, a subject which has received relatively little attention to date.

The paper proceeds in seven sections. Section 2 redresses the lack of a consistent definition of e–money in the existing literature by updating Freedman's (2000) three–way typology. Section 3 discusses the provocative writings of Friedman (1999; 2000) and King (1999) in which e–money is treated as a threat to the efficacy of monetary policy. Having concluded that this threat is largely illusory, various more immediate regulatory issues arising from the activities of e–money issuers are discussed. However, the importance of these issues can only be judged in relation to the importance of e–money in general. Section 4 provides an overview of the degree of adoption of e–money technologies to date in the Euro Area and in Singapore. A range of forecasting exercises are carried out in Section 5, the results of which suggest that the growth of e–money in the medium–term will be no more than moderate. Section 6 discusses the longer–term prospects for e–money systems and Section 7 concludes.

2 What is 'E–Money'?

While the literature on electronic payment media is relatively recent, it has been fast growing. An unfortunate consequence of this rapid expansion has been the lack of a unified vision of the phenomena under scrutiny: simply put, the literature lacks a clear consensus about what actually constitutes electronic payment media (c.f. Fullenkamp and Nsouli, 2004). For this reason, it seems prudent to start with some rigorous definitions.

Probably the broadest term covering a wide spectrum of recent innovations in payment systems that utilise electronic devices is 'electronic payments', or 'e–payments'. The term e–money has come to be used interchangeably with e–payments although, as Allen, 2003, notes, this is somewhat misleading. Freedman (2000, p. 218) provides the following simple typology of e–payments technologies:

i. **access devices** provide access to traditional banking services through electronic means but do not represent any conceptual departure from traditional banking arrangements. A good example is internet banking.

ii. **stored value cards (SVCs)**, also known as hardware e–money, involve prepaid 'smart–cards' that employ a microchip upon which funds are stored. Freedman cites Mondex, Visa Cash and Proton as examples of contemporary international schemes. National examples include Moneo in France, Geldkarte in Germany and Edy in Japan.

iii. **network money**, also referred to as software e–money, involves the use of electronic communication networks in facilitating the transfer of funds between economic agents where the funds are stored electronically, possibly on the hard-disk of one's PC. An example of a network money system is Netcash.

Such is the speed with which e–payments technology is developing that since Freedman wrote his piece, a further category has emerged:

iv. **mobile payments, or 'm–payments',** involve the use of mobile phone technology in the transference of funds, either to facilitate access to traditional transaction facilities or, increasingly, by the addition of supplemental charges to the cost of calls, SMS or WAP/GPRS services or by spending prepaid value (Allen, 2003, pp. 430-431). Collaboration between phone manufacturers and card issuers has already resulted in the addition of credit card functionality to mobile phone handsets in many countries (examples include PayPass in the US and NTT DoCoMo's DCMX and DCMX mini platforms in Japan).

The majority of the existing literature is concerned with the impact of SVCs and network money systems on the efficacy of monetary policy and not with the use of access devices which, as noted above, do not differ conceptually from traditional bank activities[1]. Moreover, recent innovations in m–payments are yet to receive much attention in the literature because the use of the mobile phone in contemporary schemes does not represent any significant departure from the three–way typology devised by Freedman (2000). In general, the mobile phone acts either as an 'e–money access device' or as an the hardware on which e–monetary value is stored (i.e. it acts as an SVC). This would no longer be the case if contract phones were to provide non–prepaid e–money functionality. However, such developments are not currently permitted, as this would amount to the extension of a credit line by the service provider which is prohibited by law.

Allen (2003, p. 431) highlights the evolution of the term 'e–money' which originally referred to "pre–paid cards aimed at low–value transactions" but now identifies a much broader range of electronic payments services. In light of this observation, and to avoid confusion, the following terminological conventions are adopted here:

i. **e–banking** will refer to access devices;

ii. **e–purse** and **SVC** will refer interchangeably to hardware–based schemes;

iii. **network money** will refer to software–based schemes;

iv. **e–payment** will refer to all of the above; and

v. **e–money** will refer to e–purses and network money systems.

3 The 'Threat' to Monetary Policy and Financial Stability

Developments in electronic payment systems have been discussed in the literature in terms of their potential to substitute for central bank money and the 'threat' that this may pose to the efficacy of monetary policy and to the stability of the financial system. This threat, it is argued, derives from the

[1]While such innovations may reduce shoeleather costs in a Baumol–Tobin framework (Baumol, 1952; Tobin, 1956), and this may, in turn, increase both the velocity of circulation and the interest elasticity of the demand for money, such effects are not the focus of the present paper as they pose no significant threat to the efficacy of monetary policy. For a discussion including access products, the reader is referred to Fullenkamp and Nsouli (2004) in particular and also Bernkopf (1996).

reduction in demand for central bank liabilities that would result from the widespread adoption of e–money. Two extreme scenarios rooted in the work of Friedman (1999) and King (1999) have dominated discussion in the field while other, more mundane effects can be identified but have yet to receive much attention.

3.1 The Extreme Position

The early and provocative contributions of Friedman (1999) and King (1999) discuss the threat of e–money in terms of the potential of SVCs and network e–money systems to compete with central bank money. Where the central bank relies on manipulating the quantities of borrowed and non–borrowed reserves in order to achieve an operating target for its short–term interest rate, the existence of such substitutes is potentially significant. Under such systems, the central bank's position as the monopolistic supplier of base money allows it to determine the price of issuance/rate of return. Thus, it is argued that the adoption of such forms of e–money may weaken the position of a central bank operating in this way: indeed, if various forms of e–money were to eliminate the demand for central bank money entirely, such monetary policy arrangements may be rendered powerless (Woodford, 2000)[2].

The monetary base is comprised of two elements: currency and reserves. Currency refers to notes and coins in circulation and represents the bulk of money. Reserves refer to the balances maintained by commercial banks in order to facilitate their day–to–day operations. Commercial banks may be legally bound to hold a certain quantity of required reserves as in the US, although even in the absence of such requirements, or in the case that they do not bind (c.f. Bennett and Peristiani, 2002), they will voluntarily hold reserves with the central bank for use in end–of–day settlement (consider, for example, the case of Canada).

SVCs, which are often subject to purse limits and cannot take deposits or pay interest, are envisaged as a substitute for currency in small–value transactions. Network money systems, by contrast, provide an alternative vehicle for medium- and large–value transactions and, therefore, have the potential to substitute for services typically provided by depository institutions. Friedman (1999) investigates the situation in which electronic payment media come to dominate the marketplace to such an extent that the demand for currency and/or reserves at the central bank falls to negligible levels and even disappears altogether. Two distinct scenarios can be identified: firstly, that SVCs wholly displace currency for use in transactions (c.f. Costa Storti and De Grauwe, 2001) and, secondly, that network money systems develop to the extent that they offer settlement systems in competition with those of the central bank (c.f. King, 1999).

Scenario 1: SVCs wholly displace currency

If SVCs were to eliminate the demand for currency then, as currency comprises the vast majority of central bank liabilities, the central bank balance sheet would shrink substantially and its seigniorage revenue would largely disappear. In the case where final settlement still occurs on the books of the central bank, then it is immediately apparent that channel or corridor systems of monetary policy[3] remain effective, as changes in short–term interest rates are not expressly linked to balance sheet operations. Freedman (2000) and Woodford (2000, 2001) argue that, in the case of more traditional monetary policy arrangements, where the deposits are non interest–bearing and the central bank manipulates the quantities of borrowed and non–borrowed reserves in achieving its interest rate target, the monetary

[2]Fullenkamp and Nsouli (2004) make the obvious point that if the central bank were the issuer of e–money then its monopoly would remain intact. Hence, it should be clear that the extreme position is concerned with the private issuance of e–money.

[3]Also known as a Lombard facility, this refers to a system in which the central bank maintains short–term nominal interest rates within a band defined by its standing facilities: it will provide unlimited settlement balances at a fixed mark–up over its target for the overnight rate and it will pay interest on deposits at a rate set symmetrically below its target. Thus, if the rates available in the interbank market are inferior to those offered by the central bank, commercial banks will make use of the standing facilities thereby providing strong incentives to ensure that market rates remain within the 'corridor'. Such systems are in operation in Canada, New Zealand and the UK, among others. The reader is referred to Woodford (2001, pp. 31-46) for a thorough discussion of the technical aspects of the channel system and a comparison with the US system of monetary policy.

authority could continue operating in the same way that it does at present. This can be most clearly seen by reference to Figure 1, taken from Palley (2001, p. 227, fig. 1) in which R represents the supply of reserves (which adjusts passively to equate to the demand for reserves), C^d currency held by the non–bank public (which is assumed to be perfectly interest inelastic and fixed in the short–run), B^d the demand for reserves arising from commercial banks and i the central bank's policy rate. The curve $C^d + B^d$ is steeply downward sloping, indicating the short–run interest inelasticity of commercial banks' demand for reserves. Note that the mechanism underlying the diagram is consistent with the horizontalist position (Moore, 1988) as the central bank controls the interest rate and the quantity of reserves, R, responds endogenously due to the actions of commercial banks.

Should privately issued e–money eliminate the demand for currency, $\hat{C} = C^d = 0$ and the demand for reserves would decline dramatically. This would, in turn, reduce the seigniorage revenue of the central bank. However, as long as there remains a continued demand for central bank balances to facilitate gross settlement between commercial banks, a small highly inelastic demand remains. In this case, the linkage between reserves and market interest rates remains intact, and its manipulation by the central bank through open market operations remains effective. Hence, Palley (2001, p. 221) dismisses the threat to the efficacy of monetary policy arising from developments in what he calls 'e–tail money' (e–money used in retail transactions). Indeed, Woodford (2000, p. 237; 2001, pp. 23-24) argues that the elimination of currency demand would make the task of central bankers *easier* on the grounds that it would remove the feedback which currently results from the interest–sensitivity of households and firms[4].

The only major effects of a substitution by the non–bank public away from currency in favour of e–money would be the shrinkage of the central balance sheet and the reduction in its seigniorage revenue[5]. Various measures to recoup the lost seigniorage revenues have been proposed, including charging banks for services that are currently free or increasing the cost of chargeable services (Hawkins, 2001, p. 100), the issuance of interest bearing bonds by the central bank, the imposition of reserve requirements on e–money issuers and the state issuance of e–money, either competitively or monopolistically (c.f. Freedman, 2000). It is, however, difficult to imagine how private e–money could compete with riskless central bank e–money under the present legal framework where issuers are forbidden from paying interest. Presumably an appropriate risk premium would be required to induce end–users to adopt private e–money in the presence of a riskless alternative. Moreover, when one considers that central banks are not bound by the constraints of profitability or the demands of shareholders, it seems likely that they would rapidly come to dominate the SVC market should they enter it. Such an outcome is clearly incompatible with the desire to promote competition and innovation in free market economies. However, the EMI (1994) states that no European NCB has any intention of entering the e–money market in the foreseeable future, although the Monetary Authority of Singapore (MAS) will shortly begin issuing electronic legal tender (Low, 2002).

While such actions may prove effective in preventing the erosion of central bank revenues, one must question to what extent any action would be necessary at all. The central bank is under no obligation to operate with a net surplus and so a shrinkage of its balance sheet is not a cause for undue concern, beyond the extent to which its independence may suffer if it were indebted to the government.

Scenario 2: e–money provides alternative final settlement mechanisms

Friedman (1999) proposes two ways in which the settlement services offered by the central bank may become obsolete. Firstly, he argues that commercial banks could agree to settle net payments imbalances with a nominated commercial bank (i.e. a private bank that takes on the settlement role of the central bank). Secondly, he contends that an evolution of existing private interbank clearing arrangements such as CHIPS could create a situation whereby commercial banks could settle bilaterally with no element of

[4]In response to an increase in the funds rate (associated with an open market sale of securities), economic agents reduce their currency holdings and increase their deposits with banks, thereby increasing the amount of non–borrowed reserves available to banks and partly offsetting the effect of the initial OMO. This effect is not captured by Figure 1, in which the public demand for currency is assumed to be perfectly interest–inelastic for simplicity.

[5]In the US in particular and, to a lesser degree, in Europe and the UK, concerns about the reduction of domestic demand for currency are not excessively pressing due to the vast overseas holdings of these currencies as a store of value (Meyer, 2001, p. 10).

mediation provided by a central bank or any other third party[6]. Friedman notes the similarities between such a system of bilateral settlement and that of the European Union, in which NCBs settle payments imbalances directly and do not hold settlement balances with the ECB.

Referring to Figure 1, assuming that electronic substitutes eliminate the demand for settlement balances at the central bank, the overall demand for base money would not diminish greatly assuming continued demand from the non–bank public. However, it is the highly interest inelastic demand arising from the banking sector that allows relatively small open market sales and purchases of securities to affect the interest rate. If the settlement services of the central bank become redundant, then traditional US–style monetary policy arrangements will become impotent (Woodford, 2000, 2001; Palley, 2001)[7].

Goodhart (2000) suggests that the obvious course of action for a central bank faced with such a situation would be to increase the scale of its open market operations to the extent that they become significant relative to the size of the financial markets[8]. However, in order for a central bank to counterveil market sentiment in order to achieve its stabilisation goals, it seems likely that it may be forced to engage in loss–making open market operations on a potentially vast scale. While this is theoretically consistent with the objectives of a central bank, the associated costs are likely to be politically unpalatable.

Woodford (2000, 2001) provides an alternative approach. He demonstrates that the performance of monetary policy in itself is not dependent on the special role of reserves in the financial system and the inherent monopoly of the central bank in this regard. He discusses the channel system, in which the quantity of reserves plays no special role in interest rate setting (i.e. it is a residual)[9]. He shows that, in the case where the central bank provides settlement services in a (pseudo) competitive market and its settlement facilities have no specific competitive advantage, then the payment of interest on reserves would serve as a reference level for the providers of alternative settlement mechanisms. The profit–maximising motives of private entities would lead them to use whichever settlement system provided the highest return (or imposed the smallest cost). Therefore, if the central bank were to pay a positive rate of interest on reserves, then other settlement institutions would be forced to follow suit in order for their settlement services to be used. Moreover, private institutions would not pay a higher risk–adjusted rate than the central bank, as this would conflict with their own profit–maximisation objectives. Thus, the central bank may operate monetary policy using the rate of interest paid on reserves, rather than the spread, as its policy instrument. Such a system is conceptually similar to the channel system, except that the lending facility is redundant and the deposit rate is exactly equal to the overnight rate target.

The above discussion relies on the bold assumption that e–money systems evolve to the point that they can offer interbank settlement services in competition with those offered by the central bank. It seems likely that improvements in ICT will permit better forecasting of the net end–of–day positions of banks *vis–à–vis* their competitors, thereby reducing the demand for settlement balances. However, it is unlikely that this demand will be eliminated altogether, certainly in the foreseeable future.

Goodhart (2000) and Hawkins (2001) agree that there is no technological impediment to direct (bilateral) interbank gross settlement. However, this does not occur because central banks "have evolved to meet a combination of both governmental and structural needs" (Goodhart, 2000, p. 206, fn27). Among the advantages possessed by central banks, Freedman (2000) lists their risk free nature, their ability to act as lender of last resort and their historical position as the provider of settlement services. Moreover, the incentives of the central bank are, by statute, uniquely compatible with the maximisation

[6]See also King (1999) who envisages an extreme evolution of network money systems in which a centralised super–computer provides real–time gross settlement between individuals with no role for a central bank. The conceptual similarity to contemporary Local Economy Trading Systems (LETS) which are detached from the central bank is clear. Closely related to this is the work of Capie, Tsomocos, and Wood (2003) on 'e–barter'.

[7]It should be noted that, in response to the ongoing financial crisis, the Federal Reserve started paying interest on deposits on October 9^{th}, 2008. This is an important change in the policy regime, as will be made clear below. However, the operational details of the new system still seem to be subject to revision and its continuation after the resolution of the current crisis is not guaranteed. See Anderson (2008) for further details.

[8]This is a response to Friedman's (1999) observation that the scale of open market operations relative to the aggregate value of financial market transactions is very small. Such small operations are effective in steering the economy (however crudely) due to the highly inelastic reserve demand arising from banks, a point made clear in Figure 1 above and discussed by Palley (2001, p. 227).

[9]See also Sellon and Weiner (1996, 1997); Borio (1997); Henckel, Ize, and Kovanen (1999); Meyer (2001, p. 11) and Palley (2001, p. 229, fn13).

of a measure of economic welfare. This contrasts markedly with private banks, the actions of which are constrained by their responsibilities to their shareholders (Meyer, 2001).

Hawkins (2001, p. 101) elaborates on this discussion and provides the following reasons why settlement will continue to occur on the books of the central bank:

i. it is often compulsory;

ii. central banks are unique in being the only riskless counterparty;

iii. commercial banks are likely to feel uneasy about divulging detailed information to a competitor;

iv. the adoption of a new system involves commercial banks incurring migration costs;

v. the central bank offers credit to those banks with net deficits in the overnight market;

vi. the central bank acts as lender of last resort to ensure the solvency of the financial system as a whole - thus it acts as guarantor of the settlement obligations of banks; and

vii. it is within the power of governments to require that taxes and other transfers are conducted using central bank liabilities (the chartalist position).

A Rebuttal of the Extreme Position

An issue which fundamentally underlies the extreme position is the nature of the e–money value chain. In the current regulatory environment, the value chain of private e–money schemes starts with the purchase of e–monetary value using conventional financial instruments (e.g. cash, debit and credit cards, direct debits etc.). This 'charging-up' of the e–money account is necessitated by the prepaid nature of e–money products enshrined in the regulatory frameworks of most countries. Moreover, e–money issuers in the EU are required by law to redeem e–monetary value for central bank money at the request of the bearer without imposing disproportionate costs. In most other countries, such unconditional redeemability is demanded by the end–users of e–money products and is granted by service providers in order to increase both their credibility and the degree of public trust in the new technology. Finally, e–monetary value is redeemed by those merchants that have accepted it in payment for goods and services. This redemption extinguishes the e–monetary value and results in a bank transfer from the issuer to the merchant in satisfaction of the transaction. This is neatly summarised by Lanskoy (2000, p. 21) as follows:

> [Hardware based e–money] refers to the electronic units issued by the issuer and recorded in the electronic purse micro–chip. To make a payment using an electronic purse, holders transfer electronic units from their card to the sellers card. This transaction does not generate any debit/credit movement on the buyers or sellers bank account. Electronic units are converted into currency units at a later stage and the funds are transferred to the seller's account by bank transfer. Purseholders' accounts are debited when they buy the electronic units, if the transaction is carried out using bank money.

This is only technically correct in the case of non–transferable e–money and those schemes with limited transferability prior to spending. This simplification is fairly innocent because, although the technology exists to develop systems capable of multiple payments in which electronic coins may be transferred *ad infinitum*, such schemes are not widely available due to the 'double spending' problem[10], and the necessity to maintain large and costly databases tracking the usage of transferable e–money (Baddeley, 2004, pp. 242-3).

[10] It is theoretically possible to create identical copies of units of e–money and so it is feared that counterfeiting could be a major issue. Given the speed of development of the ICT industry and the increasing sophistication of personal computers, there are concerns about the security of the encryption algorithms in use. The recent announcement that the Mifare RFID microchip at the heart of the Oyster Card in London can be easily and cheaply hacked made headlines around the World (c.f. Richards, 2008).

The implication of the prepayment requirement and the demand for redeemability is that e–money issuers must hold sufficient reserves of highly liquid assets to ensure that they can meet this demand. Assuming that there is no compulsion to redeem e–money for cash (i.e. it may be redeemed by bank transfer or some alternative means) then it is possible, in theory at least, for e–money to wholly displace currency. However, to the extent that e–money issuers will hold a fraction of their outstanding float in the form of bank deposits for the purposes of redemption, the demand for reserves arising from commercial banks may actually *increase* with the increasing substitution away from currency. In this way, an ongoing demand for the liabilities of the central bank arises indirectly from the activities of e–money issuers themselves.

An interesting thought experiment is to consider the attributes that private e–money schemes would need to possess in order to eliminate reserve holding at the central bank altogether. It seems likely that the following would be necessary:

i. faith in the soundness of e–money issuers must be complete so that redeemability is no longer demanded;

ii. the liabilities of e–money issuers must be universally accepted as a means of payment and e–money systems must be fully interoperable;

iii. e–money must be fully transferable so that it is not extinguished in the process of being spent;

iv. wages must be paid in e–money so that the e–monetary value chain can exist independently of central bank money (in conjunction with point iii, the prepaid nature of e–money is effectively circumvented);

v. e–money schemes must be granted the ability to pay interest on deposits so that e–money may compete with traditional savings instruments;

vi. e–money schemes must be granted the ability to extend credit such that they can compete with depository institutions in loans markets;

vii. e–money schemes must develop settlement systems offering all of the desirable characteristics of settlement schemes managed by the central bank; and

viii. e–money must be accepted in the payment of tax debts and must be used by governments to the exclusion of central bank money.

Even if these conditions were met, e–money programmes would still have to out–compete the incumbent instruments/technologies mentioned in points v. - vii. to the extent that they would come to dominate the market. Moreover, as point viii. makes clear, e–money could only wholly displace the liabilities of the central bank with governmental support. Once these conditions have been spelled out clearly, it is understandable why many economists have dismissed the concerns of Friedman and King merely as an exercise in futurology of some theoretical interest but of little practical relevance[11].

[11] In a subsequent paper with a decidedly defensive tone, Friedman (2000) argues that it is not the complete substitution of e–money for currency or the elimination of settlement balances which poses the problem (although this would suffice), it is merely the possibility that monetary policy actions may become decoupled from real macroeconomic activity at the margin. The basis of his argument is that if some proportion of economic activity occurs through a medium of exchange which is independent of the central bank, then monetary policy is powerless to influence this section of the economy. If this proportion becomes sufficiently great, then the economic influence of the central bank may diminish. However, it is difficult to see how this argument would change the conclusions reached above. It seems unlikely that such decoupling could occur in a world where e–money is redeemable for central bank money, which will remain the case as long as there is some degree of (perceived) default risk on the part of e–money issuers.

3.2 More Mundane Effects of E–Money

The preceding section demonstrated that the two extreme outcomes envisaged by Friedman (1999; 2000) and King (1999) are not plausible threats to the efficacy of monetary policy. The interest in these two theories has diverted attention from the more mundane, but also more serious issues associated with e–money, some of which are now discussed.

Bank Runs

Palley (2001) and, to a lesser degree, Meyer (2001) suggest that the emergence of privately issued e–money which coexists with, and is redeemable in terms of, government money may revive the spectre of old–fashioned bank runs. Palley reasons that the 'herd instincts' of investors may lead them to react *en masse* to real or perceived signals from the market. Such signals may lead investors to believe either that they can make a profit through arbitraging between private e–money and government money or that their e–monetary funds are in some way unsafe: in either case the likely outcome is a massive liquidity shortage. Meyer usefully highlights the fact that if e–money issuers were depository institutions then, under US law, the discount window and Federal Deposit Insurance Corporation (FDIC) would protect the integrity of the financial system in the case of a run on a provider. However, as issuers are not required to be depository institutions under present legal arrangements, the danger of runs exists, at least in the event that e–money schemes achieve a significant market share.

A related concern frequently raised in the formal literature (especially that of the monetary authorities) is that the potential mismanagement of e–money schemes may lead to financial distress or even insolvency on the part of the issuer which could damage confidence in e–money systems and the payment system more generally. Such concerns provide the rationale for the security and soundness provisions and the prudential regulatory regimes in effect in the EU and US regulatory frameworks (among others). As long as e–money issuance is 100% backed by low risk, liquid investments, then there is no cause for concern. Presumably, such strict working capital requirements will not be lowered until regulators are satisfied that the risks associated with e–money issuance are suitably small.

Circumventive Innovation

Friedman (1999) notes another frequently overlooked aspect of the development of ICT. He asserts that the diminution of the credit market share of depository institutions is a cause for concern of central banks. He argues that recent technological advances have reduced the advantage of banks in assessing the creditworthiness of potential borrowers and that the securitisation of loans has served to further reduce the proportion of credit which is backed by deposits at the central bank (these issues have recently come to the fore in the aftermath of the subprime crisis). Although Friedman's point is that the proportion of credit backed by central bank deposits is falling and therefore that the demand for these deposits may decrease, he does not suggest that there is a particular role for e–money in this process. If, however, innovation on the part of e–money issuers were to provide a means by which they could circumvent current regulations which forbid them from extending credit, this could cause serious problems for the operation of monetary policy. Moreover, when one considers the cost advantage that non–depository institutions would derive from avoiding the requirement to hold non–interest–bearing reserve assets in proportion to their credit extension, the scope of the potential problem becomes clear. Although existing regulation limits credit provision to depository institutions, profitable opportunities provide strong incentive for circumventive innovation.

Inaccuracy of Monetary Aggregates

Another issue raised notably by central bankers and bodies related to the conduct of monetary policy is the inaccuracy of the narrow monetary aggregates which may result from the misreporting of e–money balances (see, for example, EMI, 1994). It is argued that in the absence of clear guidelines concerning the definition of e–money and its place within the payment system, it is likely to be either omitted from the relevant monetary aggregate, included in the wrong aggregate or not reported at all. To the extent that the monetary aggregates are used for modelling and as indicators in monetary policy decisions (at the ECB at least), such an outcome is undesirable. However, is should be clear that such concerns are easily allayed by the introduction of suitable regulation. Indeed, this has been achieved in the EU where Directive 2000/46/EC clearly outlines the reporting obligations of e–money issuers.

Systemic Risks Arising from Offshore Issuers

As is commonly noted in the literature (see, for example, Krueger, 2002) it is possible for a company to largely or even entirely circumvent national e–monetary regulation by basing its operations overseas. Given that many countries are yet to regulate the business of e–money issuance, it may be possible for an overseas issuer to act in a largely unregulated manner. While it is conceivable that, in the absence of effective regulation, private agencies will act in a self–policing manner in order to instill confidence in their customers, this is by no means a guarantee of the safety of such schemes. In light of such concerns, national governments may wish to explicitly extend their regulation to cover any e–money issuer operating within their borders where this is not already the case. Lee and Longe-Akindemowo (1999) call for a harmonised global regulatory framework in order to address such issues of international regulation. If offshore issuance is seen to pose a significant threat to systemic security, then there may be a role for an international agency in deploying an integrated global regulatory framework. The obvious candidate is the Bank for International Settlements.

Systemic Risks Arising from the Insolvency of Issuers

Government issued currency has the fundamental advantage that it is backed by an institution whose solvency is unimpeachable. Therefore, the default risk associated with central bank liabilities is zero (to a first approximation). In the case of any privately issued money not covered by deposit insurance (or similar arrangements), there is a risk associated with the possibility that the issuer may either refuse to honour its liabilities or, more likely, that it will be unable to do so. Given the interconnections characterising financial contracting, it is possible that the default of one issuer could have serious ramifications for the financial system as a whole. Such risks are, however, mitigated by the institutional framework. E–money schemes are targeted at low value transactions, e–money accounts are subject to relatively strict purse limits and issuers are subject to stringent asset–backing requirements. Moreover, if the default of an e–money issuer was considered likely to have substantial repercussions, it seems likely that the central bank would intervene in its role as lender of last resort even if it was not obliged to do so. Hence, the threat posed to systemic security by e–money is relatively minimal.

Social Exclusion

Van Hove (2003) raises the issue of social exclusion, reasoning that those members of society without a bank account will be unable to use the new technology. He identifies low–income consumers and the poor as those groups which are likely to become excluded from the new technology. However, this argument is not particularly persuasive as it is possible to load SVCs using cash without recourse to a bank account. Van Hove does, however, identify another reason why groups may become socially excluded. He argues that some groups within society may be unable (or unwilling) to master the new technology. The European Union e–Inclusion policy identifies five groups that may be excluded from technological innovations: those without the required skills and education, the elderly, the disabled, ethnic minorities and residents of remote areas (European Commission, 2006). Among the recommendations of the e–Inclusion policy that are likely to prove relevant in the case of e–money are the promotion of affordable solutions and the necessity to close geographical disparities.

Anonymity and the Underground Economy

Individuals and groups that wish to maintain a degree of anonymity and privacy may voluntarily exclude themselves from e–money technology. In particular, agents involved in the underground economy find the anonymity of cash particularly useful (Goodhart, 2000). This suggests that as e–money usage proliferates through the legal economy, the usage pattern of cash will shift increasingly toward the underground economy. This raises the question of whether the central bank should continue to provide a convenient and anonymous means of transacting when the demand for these properties originates largely from illicit sources (Rogoff, 1998).

The other side of the debate is the question of whether it is desirable for money to be traceable. While it is theoretically possible to provide anonymous e–money, this is not typically done in practice. Contemporary e–money leaves an electronic trail which can be tracked in a similar way to a credit or debit card transaction. The degree to which this would impinge on civil liberties in a world in which cash is wholly displaced by e–money (i.e. one in which anonymous payment is no longer possible) is unclear, but it is an important and interesting issue.

The extent to which the consequences of e–money issuance discussed above may be considered important depends on the degree to which the technology is used and its future growth prospects. These issues are addressed below.

4 The Adoption of E–Money To Date

The uptake of e–money schemes to date has been slow. They have mainly developed only where competing payment technologies are unavailable (Furche and Wrightson, 2000; Meyer, 2001; Stefanadis, 2002). Two main theories attempt to explain this limited adoption. Firstly, it is often argued that there is no convincing business case for e–money on an economy–wide scale at the present time (Furche and Wrightson, 2000, p. 41). Meyer (2001) and Krueger (2002) argue that e–money typically succeeds in limited purpose applications because it possesses attributes which make it uniquely compatible with the particular use to which it is being applied. Such attributes may include purse limits in the case of company–issued SVCs, or the ability to limit the items that may be purchased with an e–money product (Krueger, 2002, p. 20, suggests that parents could give their children allowances in such a form). By contrast, e–money fails in open systems where alternative means of payment exist because it does not possess a sufficient comparative advantage in a general setting relative to the incumbent payment systems. Indeed it may even suffer from a comparative disadvantage due to concerns over its safety (mentioned above), the first–mover advantage of the established system and the regulatory uncertainty surrounding the new technology (Furche and Wrightson, 2000, pp. 42-45). Furthermore, migration to e–money systems is costly for at least two of the three actors in the market (c.f. Van Hove, 2003, pp. 13-14). The service provider must invest in infrastructure and the merchant must invest in the appropriate terminals with which to process payments. To the extent that e–money schemes may charge a subscription fee, some cost may also be borne by the customer. In order for the three actors in the market to be willing to bear these migration costs, the new technology must offer some benefit relative to the old. It is not clear that this is the case at present.

The second explanation is rooted in the work on the diffusion and adoption of innovations. Following Rogers (2003), it is commonly argued that the uptake of innovative solutions follows a sigmoid pattern similar to that depicted in Figure 2(a) which plots the simple logistic function, $y = (1 + e^{-x})^{-1}$ for $x \in [-10, 10]$. Figure 2(b) plots the first difference of the logistic function, demonstrating the implication of the sigmoid hypothesis that the per–period rate of adoption of an innovative product will increase until some point at which the pool of non–users shrinks to a critical level. An example of the application of this approach to e–money can be found in Krueger (2002, pp. 5-6).

The proposed sigmoid pattern reflects the notion that the probability that an individual will adopt the new technology depends positively on the number (or proportion) of their friends and colleagues that already use it. Such a scenario naturally leads to nonlinearly increasing market penetration until the pool of non–users shrinks to such a point that the market becomes saturated and the adoption rate declines. Once this stage is reached, firms can no longer hope to simply attract new users and must attempt to actively win customers from their competitors if they wish to increase their market share.

The sigmoid adoption hypothesis has intuitive appeal in markets with significant network effects. Payments technology is an extreme example of a network industry which gravitates toward either a single monopoly network or an interoperable system of sub–networks (Van Hove, 1999a, 1999b). A critical feature of network technologies is that the number of potential bilateral interactions between users (or more accurately the number of nodes in the network as each user may possess multiple devices) increases quadratically with the number of terminals/cards in use. This may be most clearly seen with reference to Table 1[12].

The quadratic increase in the number of potential bilateral interactions resulting from the addition of each new node provides strong incentives for e–money service providers to strive for greater interoperability. Each service provider that subscribes to a common standard gains access to a larger network than would be the case otherwise, increasing the liquidity of their liabilities and providing stronger incentives for merchants to accept payment in this manner (i.e. the number of different transactions/uses to which the e–money device can be put increases). With this said, product differentiation becomes more difficult, making the market more competitive and squeezing profit margins.

The uptake of e–money may be interpreted within the sigmoid adoption framework. The slow initial growth of the new technology reflects the relatively high costs of adoption and the strength of the network effect in this case. The logistic curve plotted above is a highly simplistic representation of the sigmoid adoption hypothesis. In general, the shape of the curve will depend on a range of factors including cost and the importance of the network effect. Where the cost of adoption is relatively high, as is the case with e–money, the initial low adoption phase may be considerably extended. Moreover, for products with significant network effects, the rate of growth is likely to become very rapid once a critical mass of users is achieved. These issues are addressed in Section 5, in which a Gompertz curve is fitted to the data in order to test Rogers' model.

4.1 The Historical Performance of E–money at the Macro Level

Discussions of the historical performance of e–money are typically undertaken at the firm- or product–level (e.g. Van Hove, 2000; Giannopoulou, 2004) and rarely in the macro context, largely due to the lack of reliable data and the relatively short span of data where it is available. The most authoritative source of data on e–money schemes at the macro level (certainly in a global context) is the Committee on Payments and Settlements Systems (CPSS) at the Bank for International Settlements (BIS). Using figures from their annual publication *Statistics on Payment and Settlement Systems in Selected Countries* it is possible to build a picture of the nature of, and developments in, the payments infrastructure in these countries[13]. This data not only provides an interesting insight into the adoption and diffusion of innovative payment platforms, but also illuminates the nature of substitution between competing technologies.

The CPSS data on e–money is most complete for the Euro Area (EA), its member states and Singapore, with most other countries either reporting negligible activity in e–money schemes or, more often, failing to report data altogether. However, the availability of data for these two regions permits interesting comparisons, especially in light of their differing degrees of e–money adoption, their respective approaches to the regulation of the newly created innovative markets and the social attitudes prevailing toward such innovations.

Payments Systems in The Euro Area and Singapore Compared

Figure 3 plots the volume of e–money, cash and bank deposits in the EA and Singaporean economies, and their respective rates of growth[14]. Panels (a)-(c) reveal that the volume of e–money outstanding is very small relative to cash and overnight deposits (in 2006 e–money outstanding accounted for just 0.1% of cash and 0.02% of overnight deposits in the EA while the equivalent figures for Singapore were 1% and 0.4%). However, panels (d)-(f) show that e–monetary value outstanding is growing at a considerably

[12] Hardware–based e–money schemes may not conform to this model as users often cannot transfer value from one card to another directly (Mondex, among others, is an exception to this rule). However, software–based schemes may be reasonably accurately described in such a manner.

[13] A comprehensive description of the data used in this section may be found in the Appendix.

[14] The adoption of the Euro as a physical currency is responsible for the spike in 2001 in panels (b) and (e), reflecting households' desire to exchange national currencies that they had accumulated before the official transition on January 1st, 2002.

faster rate than either currency or bank deposits, averaging 35.6% p.a. in the EA and 62.3% p.a. in Singapore. These figures are somewhat exaggerated by the exceptionally rapid growth over the period 1997-8, and fall to 29.7% and 32.1% respectively if this initial period is discounted. This compares to average growth in currency of 12.2% and 5.3% and in deposit accounts of 14.6% and 10.6% in the EA and Singapore, respectively. This vibrant growth suggests that interest in e–money schemes is healthy and indicates clear scope for further development and commercialisation of e–money products.

The quantity and rate of growth of e–monetary value outstanding suggests that e–money schemes are somewhat more developed in Singapore than in the EA. This is perhaps not surprising given Singapore's reputation as a technological leader in a number of fields. Furthermore, as a small city state with a remarkably high population density (approximately 6,500 residents per square kilometre), the infrastructural costs associated with the roll–out of new technologies is very low in comparative terms. Hence, the average cost of e–money transactions is likely to be lower in Singapore than in the EA, resulting in increased demand if these costs are borne by the end–user, or in increased revenue accruing to the issuer if they are not passed on in this manner.

The greater relative importance of e–money in Singapore is underscored by Figure 4 which plots the outstanding value of each of the three payment media both as a fraction of GDP and on a per capita basis. Panels (a) and (d) reveal that not only is e–money considerably more widely used in Singapore than in the EA but that the rate of adoption is more rapid. This observation is distinctly consistent with Rogers' sigmoid adoption theory and suggests that e–money usage is gaining momentum in Singapore (i.e. that Singapore is further along the curve than the EA). This process will surely accelerate when e–money is formally granted the status of legal tender under the SELT initiative.

In the analysis of Figures 3 and 4, e–monetary value outstanding is assumed to be a crude proxy for the usage of e–money schemes, but it must be acknowledged that it does not capture the level of activity in e–money schemes *per se*, as e–money is typically destroyed in the process of being spent, unlike cash and bank deposits which are simply transferred. Hence, the data contained in the figures are likely to understate the importance of e–money in both the Euro Area and in Singapore. This may be overcome by the analysis of the relative importance of various payment media according to various criteria, including their share of total transactions. However, this data is not available at the EA level so the five member states covered by the CPSS surveys (Belgium, France, Germany, Italy and the Netherlands) are considered separately in the following analysis[15].

Relative Importance by Transactions Volume

Figure 5 plots the transaction shares of five classes of cashless payment instrument (credit and debit cards, cheques, credit transfers, direct debits and e–money) by volume. A number of general trends are common to each country. Firstly, the share of cheques is falling across the period considered in all cases. Secondly, the share of credit and debit cards is growing in all cases except Germany and Singapore, although at a decreasing rate (this could be seen as evidence that these technologies are in the late stages of sigmoid adoption). Thirdly, credit transfers and direct debits account for a large proportion of transactions by volume, and that proportion has remained relatively constant over the sample period in most countries, with the notable exception of Singapore.

The plots differ most significantly with regard to the role of e–money. In the largest of the three EA countries, e–money usage is negligible, while it is gradually growing in both Belgium and the Netherlands, accounting for 4.9% and 3.9% of all cashless payments in 2006 in each country, respectively. However, the most striking feature of Figure 5 is the remarkably rapid expansion of e–money schemes in Singapore, the market share of which has grown from 0.4% in 1997 to 84.2% in just nine years. This growth has come largely at the expense of cheques, debit and credit cards[16].

The most rapid growth of the market share of e–money occurred in the year 2001-2, coinciding

[15] In the data analyses based on the CPSS comparative tables, 'neg' (negligible) entries are replaced with zero. Furthermore, 'nap' (not applicable) and 'nav' (not available) entries are computed by extrapolation based on the 5 year growth rate where applicable. A detailed discussion of the data cleansing process may be found in the Appendix.

[16] Note that the share of e–money is total transactions value is minimal, standing at just just 0.2% in Singapore. This reflects the fact that e–money systems are typically used in low value frequent transactions (e.g. public transit fares).

with the government's announcement of the SELT initiative. This episode provides an example of the power of state–backing. Two of the greatest hurdles facing e–money schemes are overcoming the lack of trust and achieving widespread acceptance and interoperability. By announcing its plans for an electronic legal tender system, the Singaporean government has increased the credibility of electronic payment media with its end–users (the Congressional Budget Office, 1996, p. 45, makes a similar point concerning the public issuance of e–money), and has provided an institutional framework around which providers can rally, achieving greater integration and providing a unified service environment. For its part, the government has propelled Singapore into the international spotlight as a leading technological innovator and hopes to steal a march on its international competitors in the provision of integrated electronic payment systems, a market with massive growth potential. Furthermore, by moving toward an increasingly electronic payments environment, the government may hope to reduce the costs associated with the existing payments infrastructure and increase its efficiency (Low, 2002).

Number of Cards by Category

Figure 6 compares the number of cards issued in terms of their functionality. The data covers three classes of cards: cash cards, debit cards and e–money cards (i.e. hardware–based e–money schemes). The number of cards in circulation provides an indication of the degree of access to each payment instrument, as well as a measure of public awareness of, and interest in, each product[17].

Firstly, it is apparent that the proliferation of e–money cards has been very uneven between countries, with France and Italy displaying delayed adoption and the remaining four countries experiencing different patterns of growth. Among the remaining European countries, there has been a tendency toward stagnation after rapid growth in the late nineties, whereas Singaporean growth accelerated markedly with the announcement of the SELT initiative in 2001.

Around the turn of the millennium, the number of e–money cards in circulation in the Netherlands briefly equalled the number of debit cards, a feat not since repeated in any European country. By contrast, the number of e–money cards in Singapore exceeded the number of debit cards in 1999, *before* the major acceleration of e–money growth, and has now reached a relatively stable level at approximately one and a half times the number of debit cards.

The Singaporean data suggests that there are approximately three e–money cards per head of population in Singapore. However, if one accounts appropriately for the demographics of the population, there are probably at least five e–money cards per adult in Singapore, indicating that these cards perform different functions. In light of this, the recent cessation of growth in the issuance of e–money cards may be interpreted as evidence that the degree of interoperability of Singaporean e–money schemes is increasing (i.e. that fewer cards are required to perform the same number of functions).

Belgium and Italy are the only EA countries in the sample where the gap between the number of debit cards and the number of e–money cards in circulation is closing. Indeed, these are the only EA countries in which the number of e–money cards seems to be growing significantly.

ATMs and E–Money Loading Terminals

Figure 7 plots the number of automated telling machines (ATMs) and e–money loading terminals (ELTs) per million head of population. The purpose of ATMs and ELTs is essentially similar. ATMs are used to increase an agent's stock of cash (notes and, indirectly, coins) for use largely in purchase transactions[18]. Similarly, ELTs are used to increase the stock of e–monetary value held on an e–money device for use primarily in purchase transactions. In this sense, the relative number of ATMs and ELTs provides an indication of the shoeleather costs associated with each means of payment.

[17]Unfortunately, the coverage of the CPSS surveys in terms of credit card usage statistics is relatively limited and so this category is omitted. The same is true for delayed debit/charge cards. Note that there is likely to be a considerable degree of double counting between cash cards and debit cards. The spread reflects credit cards with a cash function as well as cash cards without a debit function.

[18]Of course, cash may also be held as a store of wealth (although it performs this role badly in an inflationary environment) and for speculative reasons, although the assumption that its dominant role is in exchange seems relatively innocuous.

Among the EA countries, the proportion of ELTs relative to ATMs is small and even negligible in some cases (especially Italy). The only exception is Belgium, where the ratio briefly exceeded 30% in 2003 and has been non–negligible throughout the sample. Unfortunately, ELT data is not available for Singapore, although the number of ATMs has been gradually declining (panel (f)) which may reflect a degree of substitution away from cash in favour of e–money.

Given the shortage of ELTs relative to ATMs, certainly in the EA countries, it may be reasonably inferred from the simple Baumol–Tobin framework that agents must hold larger e–money balances than cash balances in order to carry out their day–to–day transactions without incurring higher shoeleather costs. Given that neither e–money nor cash balances are interest bearing, the necessity to hold a larger average balance of e–money implies that its user–cost is higher than that of cash. If one assumes that the attributes of the two payment systems are essentially similar, then this observation provides an unambiguously continuing role for cash and suggests that there is no business case for e–money. However, as e–money is currently in relatively widespread use in a number of countries, it follows that it possesses unique attributes that induce a willingness to pay on the part of the consumer. These attributes include the removal of the 'exact change' problem, the increased efficiency associated with contactless card technology (i.e. time savings through reduced queueing), increased security relative to cash and the potential for remote use (e.g. for internet purchases).

Point–of–Sale and E–Money Purchase Terminals

Unlike the situation regarding the e–money loading infrastructure discussed above, e–money purchase terminals (EPTs) are gradually gaining ground relative to the established POS infrastructure in the larger European economies, with the possible exception of France (see Figure 8). The installed POS and EPT capacity in Belgium and the Netherlands is comparable, while in Singapore there have been more EPTs than POS terminals since 2001. An interesting trend which seems to be emerging in Singapore and, to a lesser degree, in the Netherlands and Belgium, is that the number of EPTs and POS terminals have come to track one another increasingly closely. This may be due to the adoption of multi–purpose purchase terminals that can accept payment from debit, credit and e–money cards.

In general, by comparing Figures 7 and 8, it is clear that access to e–money loading and unloading facilities seems to be in greater relative shortage than access to e–money purchase facilities, in the EA at least. The observation that, in some cases, EPTs outnumber POS terminals is, perhaps, not surprising given that many e–money schemes often provide either single–purpose or simple multi–purpose products where the range of uses is limited. Considered in this way, the apparent wealth of e–money purchase terminals may simply reflect a lack of interoperability. As has already been discussed, payments technology exhibits extreme network effects and the concept of interoperability is inextricably linked to that of liquidity. Hence, the apparent lack of coordination is both a serious impediment to the further development of electronic payment media, as well as a potentially profitable opportunity for existing firms and new entrants alike.

The effects of the announcement of the SELT initiative by the Singaporean government in 2001 can be discussed in either of two ways. Firstly, it could be argued that SELT was a response to the growing market share of e–money in Singapore prior to 2001 and that the government may have wished both to promote this growth and to regulate it for reasons of systemic security. If one subscribes to this reactionist view, there is little need for electronic legal tender laws in the EA because e–money usage in the EA countries is not even approaching the levels observed in Singapore in 2001.

The SELT initiative may also have been motivated by a desire to promote the growth and development of the new technology by increasing the credibility of the new payment instruments and providing a common framework around which service providers could coordinate, increasing interoperability. Given the relatively early stage of development of e–money systems in Europe, the European Commission faces a trade–off. One may argue that the deployment of a comprehensive regulatory framework risks stifling innovation. Alternatively, it could be argued that a carefully crafted policy outlining common standards for the industry could provide a nexus for coordination that could act as a catalyst to growth.

5 Forecasting the Future Growth of E–Money

The only serious attempts at forecasting the degree of uptake of e–money to date have taken the form of simple substitution models in which e–money is assumed to compete with cash for use in transactions below a certain threshold value (c.f. Boeschoten and Hebbink, 1996; Bounie and Soriano, 2003). The usefulness of such models is limited due to the strength of the assumptions upon which they rely. For example, it is typically assumed that the only payment instruments available for small transactions are cash and e–money. While this may be a relatively innocuous simplification for genuinely small transactions, the thresholds that are commonly discussed in the literature are €10 and €30 which provide scope for other forms of payment including credit cards, debit cards and cheques. In light of the data presented above which clearly demonstrates that e–money competes with other forms of cashless payment instrument as well as cash, this assumption becomes untenable. Moreover, the assumption that the probability of carrying out a transaction with cash as opposed to e–money is time–invariant is inconsistent with Rogers's sigmoid adoption hypothesis.

To date, no data–driven forecasts of e–money adoption and usage have been made publicly available for the Euro Area. However, the ECB has provided an e–monetary aggregate at a monthly frequency since 1997m9. Using this data, it is possible to forecast the growth of outstanding e–money balances. The Baumol–Tobin framework discussed above suggests that these outstanding balances are likely to be small on average because e–money bears a zero nominal interest rate (and therefore a negative real interest rate of $-\pi/(1+\pi)$, where π is the rate of inflation). However, if the stock of e–monetary value outstanding is closely related to the volume of transactions carried out using e–money, then one can draw inferences about the degree of usage of e–money. This assumption seems relatively innocuous in the short–term. Moreover, the empirical evidence shows that, between 2002 and 2006, the ratio of e–money/M2 to billions of e–money purchase transactions has been approximately constant at $2.14\text{x}10^{-4}$ and that the two series are strongly positively correlated ($\rho = 0.937$)[19]. This approach has the advantage that high frequency data on e–money balances outstanding may be used to compute sophisticated forecasts which may then be used to draw inferences about series for which no such data is available (data on transaction volumes is only available annually since 2000 for the Euro Area, for example). Moreover, these inferences do not rely on strong assumptions about the nature of the substitution of e–money for other forms of payment.

Three different forecast models are considered. Firstly, a simple geometric random walk model is estimated as a benchmark against which the performance of the other models may be evaluated. Secondly, a simple model–averaging exercise is undertaken in order to account for model uncertainty and to sharpen the resulting forecasts. Finally, the sigmoid adoption hypothesis is tested by fitting a Gompertz curve to the data.

5.1 The Dataset

Table 2 lists the variables used in the multivariate forecasting models. All series are seasonally–adjusted with the exception of the technology index which is interpolated from annual data (see the Appendix for details). E–monetary value outstanding, currency in circulation and demand deposits are expressed as a fraction of M2 so that the development of e–money schemes may be discussed in terms of market penetration rather than simply aggregate value outstanding. The ECB reports the stock of e–money as an overnight deposit, a category conventionally included in the M1 aggregate. However, given that e–money is theoretically a multiple of currency and deposits (the multiplier is currently set at 1 but this need not remain the case in the long–term) it seems more appropriate to consider the stock of e–money relative to M2. Table 3 provides descriptive statistics. Unit root testing (the results of which are presented in the Appendix) reveal that all series are I(1).

The series m_{hp} is smoothed using the method of Hodrick and Prescott (1997) in order to remove the high frequency noise characterising the raw data. This noise does not reflect pure seasonal variation as both component series (e–money and M2) are seasonally adjusted. Rather, it is a result of trial schemes and promotional activities which are not strictly relevant for forecasting the trend growth of

[19]Data on the volume of e–money purchase transactions in Europe comes from the Eurostat series PSS.A.U2.F000.IEM.Z00Z.NT.X0.20.Z0Z.Z.

the e–money stock. Minimal smoothing is employed so that the noise is attenuated while retaining as much of the informational content of the raw data as possible. Hence, the smoothing parameter λ is set to 14,400, the figure typically associated with quarterly data. This is considerably lower than the value of 126,400 recommended for monthly data by the frequency rule of Ravn and Uhlig (2002), and results in considerably reduced smoothing. The smoothed and raw series are compared in Figure 9.

5.2 The Benchmark Case: A Geometric Random Walk Model

The geometric random walk model is appropriate for series exhibiting exponential growth. The model is defined as follows:

$$lnY_t = \beta_0 + \beta_1 lnY_{t-1} + \epsilon_t \tag{1}$$

Due to its simplicity and relatively robust forecasting performance, the random walk model is used as a benchmark against which to evaluate the alternative specifications.

5.3 Model Averaging

In recent years, much applied forecasting work has employed various model averaging techniques in the Bayesian tradition in order to reduce the problems associated with model uncertainty and to sharpen the resulting forecasts. The principle difference between Bayesian econometrics and the frequentist approach is that the matrix of model parameters, θ, is treated as a random variable. Given a number of models, M_i, $i = 1, 2, ..., m$, which span the model space, one may calculate the posterior model probability which permits optimal weighting of these m models in the averaging process.

Here, a simplified version of the general Bayesian framework is employed in which models are averaged using the simple arithmetic mean with equal weights. This case is often used as a benchmark against which more sophisticated Bayesian systems may be judged and has the advantage that it is valid even when the 'true' model is not among the candidate set. The m component models will be:

AR Models AR(p) including the benchmark geometric random walk model;

ARIMA Models integrated ARIMA(p,d,q) models;

VAR Models p-th order VAR–in–differences models using the regressors in Table 2;

VEC Models p-th order cointegrating VAR models using Johansen's (1991) exactly identifying restrictions.

Every combination of the models containing up to four lags is considered, resulting in $m = 28$[20]. The computation of forecast intervals in the case of model averaging is non–trivial. The most obvious method is to generate bootstrap samples from the residuals of each model independently and use these to compute intervals for each of the candidate models. The resulting 28 pairs of intervals could then be averaged to yield the forecast interval for the model as a whole. An alternative method is to generate bootstrap samples from the residuals of the average model, and then re–estimate every component model for these samples which are common for all candidate models. In this way, the average model could be generated for each bootstrap replication, thereby generating an empirical distribution of forecasts from which the relevant intervals could be easily computed. However, these approaches are unlikely to yield the same result, and it is not clear which is preferable. Given this uncertainty, the computation of forecast intervals for the average model is left for future work.

[20] The cointegrating VAR models are estimated with five cointegrating vectors based on the Johansen trace statistic.

5.4 Forecasting from a Simple Sigmoid Specification

The model averaging exercise undertaken above accounts for model uncertainty in a simple but effective manner. However, it does not provide any obvious means by which the sigmoid adoption hypothesis may be examined. Among the class of sigmoid functions, the Gompertz function stands out for its simplicity and ease in estimation. The Gompertz curve is defined as:

$$y_t = \alpha e^{-\beta e^{\gamma t}} \tag{2}$$

where α denotes the saturation level, γ the rate of growth, β is a positive parameter determining the lateral position of the curve and t is a deterministic trend.

Franses (1994) provides a method for fitting a Gompertz curve based on simple estimation of a single equation using non–linear least squares (NLS), and where the coefficients and standard errors can be computed in the normal manner. By a process of log–linearisation, first differencing, further log–linearisation, and the addition of an idiosyncratic error term, Franses transforms equation 2 into the following form:

$$ln\left(\Delta ln y_t\right) = -\gamma t + ln\left(\beta e^{\gamma} - \beta\right) + \epsilon_t \tag{3}$$

The upper asymptote, α, is then estimated by substituting the parameter estimates obtained from NLS regression of equation 3 into the following[21]:

$$\hat{a_t} = e^{ln y_t + \hat{\beta} e^{-\hat{\gamma} t}} \tag{4}$$

Forecast errors and confidence intervals may then be computed by non–parametric bootstrapping. The boostrapping procedure involves the construction of B error series $\epsilon^{*(b)}$ by resampling with replacement from the residuals from initial estimation of equation 3. Using the parameter estimates $\hat{\beta}$ and $\hat{\gamma}$, one may then compute the series $y^{*(b)}$ associated with each of these error series using:

$$y_t^{*(b)} = -\hat{\gamma} t + log\left(\hat{\beta} e^{\hat{\gamma}} - \hat{\beta}\right) + \epsilon_t^{*(b)} \tag{5}$$

Equation 3 is then re–estimated on each of the B simulated datasets. For each of the models estimated in this way, forecasts $\widehat{y^{(b)}}_{t+h}$ may be generated over the horizon h by forecasting $\widehat{y^{*(b)}}_{t+h}$ and noting that $\widehat{y^{*(b)}}_{t+h} = ln\left(\Delta ln \widehat{y^{(b)}}_{t+h}\right)$ may be rearranged to yield $\widehat{y^{(b)}}_{t+h} = e^{ln\widehat{y^{(b)}}_{t+h-1} + e^{\widehat{y^{*(b)}}_t}}$ which is easily solved using the value y_T for initialisation. Forecast intervals are then retrieved as the relevant percentiles of the empirical distribution. Once again, more detail is provided in the Appendix.

In his original application, Franses fits the model to smoothed data. In the present application, such smoothing has the appealing feature that it renders the first difference strictly positive, avoiding the indeterminacy of the left–hand–side of equation 3 that would result from attempting to take the log of a negative number.

5.5 Pseudo Out–of–Sample Forecasting

The forecasting performance of each of the models may be evaluated in the usual manner by pseudo out–of–sample testing. The sample period used in estimation is restricted to 1997m9-2007m5 while the remaining 12 observations are reserved for comparison against the forecasts. Figure 10 plots the pseudo out–of–sample forecasts derived from each model. It is immediately apparent that all models have a tendency to over predict to some degree but that the average model performs considerably better than either the benchmark or the Gompertz specifications. Furthermore, the similarity of the Gompertz and random walk forecasts is quite striking.

[21] Franses (1994) assumes that α is constant so that it may be removed in the process of first–differencing. Estimates of α derived from equations 3 and 4 tend to support this assumed constancy. Note also that the Newey–West procedure is employed to adjust for the apparent serial correlation of the error process in equation 3.

Table 4 provides analytical statistics for each of the three models. The root–mean–squared forecast error (RMSFE) and mean absolute forecast error (MAFE) are of comparable magnitude for the benchmark and Gompertz models but considerably smaller in the case of the average model. Furthermore, the mean absolute forecast percentage error (MAFPE) of the average model is less than one seventh that of the random walk model, indicating considerably superior forecasting performance.

The Theil Inequality Coefficient of the average model is considerably smaller than those of the other models, again indicating a superior forecast (a value of zero indicates a perfect fit). In all cases, however, the bias and variance proportions are substantial, reflecting the persistent over–prediction of the forecasts. Ideally, the covariance proportion should be dominant as it reflects the unsystematic errors in forecasting.

5.6 Dynamic Out–of–Sample Forecasting

Simple h–step ahead dynamic interval forecasts are computed for both the average model and the Gompertz specification over the 60 months between 2008m6 and 2013m5. These may be compared to those derived from the benchmark geometric random walk model.

The forecast from the geometric random walk model is plotted in Figure 11(a) with analytical standard errors. The logarithmic approximation to the annualised rate of growth is presented in Figure 11(b). This simple benchmark case suggests a slowly decreasing growth path of the ratio of e–money to M2 over a five year horizon. Indeed, the rate of growth is forecast to fall below 4% in 2013m5. The model achieves an adjusted R^2 of 1.000 to 3d.p. and has a near–unit AR coefficient of 0.990.

The average forecast is plotted in Figure 12. The model indicates that the rate of growth of e–money as a fraction of M2 is likely to increase over a five year horizon, exceeding 7% per annum by 2013. These figures are considerably more optimistic than the benchmark case. It is interesting to note that the forecast rate of growth is considerably smoother than either the benchmark or the Gompertz forecasts (i.e. there is no spike at 2008m6).

The forecasts from the Gompertz curve are presented in Figure 13, including standard errors derived from non–parametric bootstrapping with 500 iterations. The model achieves an adjusted R^2 value of 0.670. The h–step ahead levels forecasts suggest that the rate of growth of e–money relative to M2 will decelerate over the five year horizon, falling below 3% by 2013m1. This is the most pessimistic of the forecasts, suggesting that the adoption of e–money technology may be in the latter stages of the sigmoid process.

The parameters β and γ are estimated as 1.909 and 0.012 respectively and both are highly statistically significant. β measures the lateral position of the curve and reflects the duration of the initial low adoption phase. γ measures the rate of growth of the curve. The mean saturation level $\widehat{\alpha}$ across the sample is 0.013% of M2. While this seems rather low at first sight, it must be remembered that e–money is destroyed in the process of being spent and so the outstanding balance is simply that which has been pre–loaded but not yet spent. The estimated saturation level does not greatly exceed the present level, indicating a rather limited scope for the development of e–money in the future (at least to the extent that the relationship between e–monetary value outstanding and transactions volume remains constant in the short–run).

The forecasts derived from the various models provide support for a range of scenarios concerning the growth of e–money. As the model which performed best in pseudo out–of–sample testing, it seems logical to place somewhat more faith in the average forecast than in either the random walk or Gompertz forecasts. Even though this is the most optimistic of the forecasts, indicating growth reaching 7% per annum by 2013m5, the figure remains relatively modest. With growth occuring at this rate it seems unlikely that the EC will be forced to reconsider its regulatory framework by sweeping change in the payments system, certainly in the foreseeable future (i.e. if one subscribes to the reactionist view then there is no case for regulatory change at this time). However, the EC may choose to change its regulatory framework precisely because of these uninspiring growth prospects, in an effort to foster growth and innovation.

6 Longer–Term Prospects of E–Money Systems

The forecasting exercises undertaken above indicate that the degree of adoption and usage of e–money technologies will grow moderately but uninspiringly in the medium–term. In the longer–term, the prospects of these innovative payments technologies depend critically on three issues: (i.) the incentives for end–users and issuers; (ii.) security issues and the potential for identity theft; and (iii.) developments in the capabilities of e–money systems.

i. Incentives

Three key groups may be identified in the e–money market: the issuers and the end–users, comprising both merchants and their customers (Wenninger and Laster, 1995). In order for e–money to succeed, the incentives for each group must be sufficiently strong. In an early contribution, Friedman (1999, p. 329) recognises the importance of these incentives:

> [a]s long as taking deposits and providing payment services is a source of profit for banks, bank customers - like telephone companies, New York's MTA [Metropolitan Transport Authority] or the merchants whom the MTA would like to induce to use its cards - have an incentive to recoup some of their costs by undertaking a form of this activity themselves. And to the extent that they can pass on some of what they recoup to their own customers, individuals will have an incentive to use these alternative payment vehicles just as non–bank firms will have an incentive to provide them[22]

The incentives for the issuers of e–money are relatively clear. As Friedman notes, to the extent that banks charge fees for their services, non–banks will attempt to avoid paying them or, better still, to appropriate some of the rent that would otherwise accrue to the bank. Similar logic can be applied to the central bank. If e–money were to substitute entirely for currency, the private sector would capture the seigniorage revenue OC^d from the central bank in Figure 1. Given such incentives, it is likely that both banks and non–bank financial institutions will continue developing innovative payment systems.

While the incentives for service providers are clear, the incentives for merchants and consumers are less so. Friedman's optimistic view outlined above suggests that those merchants that engage in e–money issuance may make cost savings and may choose to pass some of their savings on to their customers. However, in the first instance, it is unclear whether they would actually pass them on. Secondly, and more fundamentally, only a limited proportion of merchants are likely to enter the e–money market as issuers; the majority are likely to remain simple merchants. In order to accept electronic payments, merchants will have to invest in the relevant infrastructure, an outlay which represents a fixed cost which may be relatively high[23]. Furthermore, the costs associated with training staff to use the technology may be non–negligible. In order for merchants to be willing to bear these costs, they must expect to derive quantifiable benefits. In businesses that rely on providing a quick, efficient and convenient service, these benefits may derive from increased trade resulting from the increased efficiency of e–money (particularly contactless card technology) relative to payment with cash. Furthermore, given that e–money schemes eliminate the costs associated with handling and securing cash, the marginal cost to the merchant may be lower.

Finally, the incentives for the consumer must be considered. The cost of e–money to the consumer is typically positive. Many contemporary e–money schemes charge administrative fees and sometimes a commission on purchases (for example Giannopoulou, 2004, reports a 0.9% commission on Moneo transactions in France). Although it is true that there are costs associated with all payment systems, the customer is often unaware of them, as they are typically borne by the service provider. Hence, the user costs of e–money may actually prove higher than those of many other payment vehicles. The critical

[22]The implication that deposit–taking is a source of profit for depository institutions is somewhat misleading, as it actually represents a cost. The profit accrues indirectly through the lending operations of banks which maintain a spread between their deposit and lending rates.

[23]Low (2002, p. 154) provides a breakdown of the costs associated with an e–money trial in Singapore in which each terminal cost S$200.

issue is the willingness of consumers to pay for the benefits afforded to them by e–money. Wenninger and Laster (1995, p. 2) note a willingness to pay among US consumers of between 2 and 5 cents per transaction, or an equivalent annual fee. Provided that the value attached to the benefits derived from e–money exceeds the costs imposed by the issuers, consumers will adopt the new technology.

Irrespective of the willingness to pay, in some situations individuals may be obliged to use a specific means of payment. Examples include the requirement to use stored value cards to pay for parking in Paris (Giannopoulou, 2004) and in a number of cities in the Netherlands (De Nederlandsche Bank, 2002, p. 24) and for toll roads in Singapore (Van Hove, 2003). In such situations, the consumer has a simple choice between using the new technology and bearing the associated costs or excluding themselves from these services. Such initiatives exploit a little–known feature of legal tender laws in these countries whereby legal tender need not necessarily be accepted in exchange, merely in extinguishing existing debts (Van Hove, 2003, pp. 5-6). Of course, one may question whether it is ethical to impose e–money usage in this manner, but the fact remains that such policies will have significant impacts on public attitudes toward the new technology.

A common theme that pervades the preceding discussion is that of cost. A key factor in determining the extent to which a new product will displace an existing competitor is its relative cost (in the case of e–money, this is composed of two parts, namely the cost of its implementation and of its subsequent use). Meyer (2001, p. 7) and Stefanadis (2002) show that while the costs of operating an e–money system are very low, the initial fixed costs incurred in development and implementation are substantial. This suggests that while the marginal cost of e–money usage is presumably lower than that of cash (which is positive due to the expenses incurred in its transport, storage, counting etc.), its average cost is likely to be higher until it becomes sufficiently widely used. Overcoming this average cost barrier poses a problem: e–money schemes must achieve a critical mass before retailers will accept payment in e–money, and consumers demand for e–money will remain low until a sufficiently large number of retailers accept the new technology. Thus, there is a 'chicken–and–egg' problem (Van Hove, 1999a; Stefanadis, 2002; Krueger, 2002).

ii. Security Issues and Identity Theft

E–money is, in principle, more secure than cash for the end–user. If one loses an SVC, for instance, it is possible to cancel the card and recover any unspent e–monetary value. However, as already mentioned, counterfeiting could be a serious problem for e–money schemes as it is possible to produce a perfect, indistinguishable copy of an electronic image. Moreover, to the extent that online systems are vulnerable to hacking, remote theft is possible, adding to the complex task of securing the new payments technology. Finally, the fact that e–money schemes rely on computer networks suggests that viruses may be a further significant threat to security, whether deliberately targeted or otherwise. These security issues are likely to significantly shape the future development of e–money schemes (particularly network money) not simply because of concerns over monetary losses, but also due to the potential for identity theft. The issue of identity theft is likely to be exacerbated by the use of multi–purpose cards which incorporate a range of non–money functions. A prime example of this is the Malaysian Government Multi–purpose Card which combines stored–value functionality with an ID card, drivers license, passport and health records (Van Hove, 2003, pp. 15-16).

None of these security threats are insurmountable, they simply suggest that e–money issuers are likely to have to invest heavily in advanced encryption technologies and security software. Given public scepticism about the security of online systems in many countries, it is likely that firms will compete to some degree to offer the most secure service, or may use security to achieve product differentiation once the market becomes more developed.

iii. Developments in the Capabilities of E–Money Schemes

As mentioned above, the payments system is an extreme example of a network industry. The largest obstacle to the success of e–money schemes at the present time is their lack of interoperability. Until e–money systems are fully interoperable, e–money will not become widely accepted as a medium of exchange. The expectation of increased interoperability in Singapore following the announcement of SELT in 2001 provided a substantial impetus to the industry. While it is possible that e–money issuers will develop interoperable systems of their own accord without government intervention, it seems likely that there is a role for government in providing a basic framework around which issuers can coordinate.

The market for electronic payments is becoming increasingly competitive and dynamic. The growing interest of mobile telecommunications providers in e–payments solutions has led to rapid developments in m–payments technologies. Furthermore, the development of contactless smart–card technology has greatly increased the convenience of e–money relative to traditional means of payment. Continuing investment in such areas is likely to increase public interest in the new technology.

Finally, although e–money schemes are prevented from paying interest in many countries (although significantly not in Singapore) and from the extension of credit in most (if not all) countries, the record of private firms circumventing such regulations where a profitable opportunity presents itself is well established. Many e–money schemes are already paying *de facto* interest in a form of lottery, a practice acknowledged by the Financial Services Authority (FSA, 2002, pp. 9-11; 2006). Such circumventive innovations provide fresh challenges for policy–makers on the one hand, and on the other they provide fresh opportunities for both firms and consumers.

7 Concluding Remarks

E–money became a high profile topic at the turn of the millennium due to the proposed threat that it posed to the efficacy of monetary policy and the stability of the payments system. Once the debate concerning this threat had been largely settled, research interest in e–money dwindled. However, with the imminent launch of electronic legal tender in Singapore and the proliferation of prepaid smart–cards in many countries around the world, the subject is once again becoming topical. Furthermore, the ongoing development of the Single European Payments Area (SEPA) is providing a largely unprecedented forum for the discussion of issues relating to the design and regulation of (cross–border) electronic payments systems.

A number of regulatory challenges present themselves as a result of the development of e–money systems. Among the most serious are the possibility of bank runs, circumventive innovation, misreporting of macroeconomic statistics, systemic risks, social exclusion and the erosion of privacy. The extent to which these issues may be judged to be important depends on the degree to which the new technology is used and is likely to be adopted in the future. Comparison of the retail payments systems in the Euro Area and Singapore reveals that e–money usage in Europe is significantly less pronounced than in Singapore. Moreover, it is clear that there are significant regional disparities between EU member states. The forecasting exercises carried out in Section 5 suggest that e–money usage will continue to grow at a moderate rate in the Euro Area as a whole but that the probability of a significant shift toward increased electronification of the payments system is unlikely in the medium–term. In light of this, the EC may consider that e–money is not a threat at present and that its existing regulatory framework is sufficient. Alternatively, it may take a more proactive position and engage in regulatory reform to promote the development of electronic payments technology in a manner similar to the Singaporean government.

In the longer–term, regulatory reform is inevitable. Given the strong incentives for innovative firms to enter the market and attempt to circumvent the regulation, there is likely to be a regulatory 'arms–race' between the regulator on the one hand, and issuing firms on the other. In particular, the nature of the implicit multiplier between reserve assets and e–monetary value outstanding is likely to change substantially as both parties learn about the nature of the market. It seems likely that the reserve asset portfolios of issuers will come to contain less cash as estimates of the demand for redemption become increasingly precise. This will result in portfolios skewed toward less liquid assets with a higher rate of return. It is likely that such evolutions will lead to the establishment of a fractional–reserve system similar to those currently operated by banks.

References

Allen, H. (2003). *Innovations in Retail Payments: e-payments* (Technical Report). London: Bank of England.

Anderson, R. G. (2008). Paying Interest on Deposits at the Federal Reserve. *Federal Reserve Bank of St. Louis Economic Synopses*, *30*, 1-2.

Baddeley, M. (2004). Using E–Cash in the New Economy: An Economic Analysis of Micropayments Systems. *Journal of Electronic Commerce Research*, *5*(4), 239-253.

Baumol, W. J. (1952). The Transactions Demand for Cash: An Inventory Theoretic Approach. *Quarterly Journal of Economics*, *66(4)*, 545-556.

Bennett, P., & Peristiani, S. (2002, May). Are U.S. Reserve Requirements Still Binding? *Federal Reserve Bank of New York Economic Policy Review*, *8(1)*, 53-68.

Bernkopf, M. (1996). Electronic Cash and Monetary Policy. *First Monday*, *1*(1).

Boeschoten, W., & Hebbink, G. (1996, May). *Electronic Money, Currency Demand and Seigniorage Loss in the G10 Countries* (Staff Report No. 1). Amsterdam: De Nederlandsche Bank.

Borio, C. E. (1997). The Implementation of Monetary Policy in Industrial Countries: A Survey. *BIS Economic Papers*, *47*, 1-148.

Bounie, D., & Soriano, S. (2003, November). *Cash versus E–Cash: A New Estimation for the Euro Area* (Working paper). Paris: Telecom Paris ENST.

Capie, F., Tsomocos, D. P., & Wood, G. E. (2003). *E-Barter vs. Fiat Money: Will Central Banks Survive?* (Working Paper No. 197). London: Bank of England.

Committee on Payments and Settlement Systems. (2003). *Statistics on Payment and Settlement Systems in Selected Countries (Figures for 2001).* Basel: Bank for International Settlements.

Committee on Payments and Settlement Systems. (2004). *Statistics on Payment and Settlement Systems in Selected Countries (Figures for 2002).* Basel: Bank for International Settlements.

Committee on Payments and Settlement Systems. (2005). *Statistics on Payment and Settlement Systems in Selected Countries (Figures for 2003).* Basel: Bank for International Settlements.

Committee on Payments and Settlement Systems. (2006). *Statistics on Payment and Settlement Systems in Selected Countries (Figures for 2004).* Basel: Bank for International Settlements.

Committee on Payments and Settlement Systems. (2008). *Statistics on Payment and Settlement Systems in Selected Countries (Figures for 2006).* Basel: Bank for International Settlements.

Congressional Budget Office. (1996, June). *Emerging Electronic Methods for Making Retail Payments* (Technical Report). Washington DC: Congressional Budget Office.

Costa Storti, C., & De Grauwe, P. (2001, February). *Monetary Policy in a Cashless Society* (Discussion Paper No. 2696). London: Centre for Economic Policy Research (CEPR).

De Nederlandsche Bank. (2002). *Quarterly Bulletin.* Dordrecht (NL): Kluwer Academic Publishers.

European Commission. (2006, June 12). *Ministerial Declaration on e–Inclusion.* Declaration before the 2006 Riga Ministerial Conference entitled "ICT for an Inclusive Society".

European Monetary Institute. (1994). *Report to the Council of the European Monetary Institute on Prepaid Cards by the Working Group on EU Payment Systems.* Frankfurt am Main: European Monetary Institute.

Financial Services Authority. (2002, April). *The Regulation of Electronic Money Issuers. Feedback on CP117.* Policy Statement 117.

Financial Services Authority. (2006). *Sourcebook on Electronic Money (ELM).* London: Financial Services Authority.

Franses, P. H. (1994). Fitting a Gompertz Curve. *The Journal of the Operational Research Society*, *45*(1), 109-113.

Freedman, C. (2000). Monetary Policy Implementation: Past Present and Future - Will Electronic Money Lead to the Eventual Demise of Central Banking? *International Finance*, *3(2)*, 211-227.

Friedman, B. M. (1999). The Future of Monetary Policy: The Central Bank as an Army with Only a Signal Corps? *International Finance*, *2(3)*, 321-338.

Friedman, B. M. (2000). Decoupling at the Margin: The Threat to Monetary Policy from the Electronic Revolution in Banking. *International Finance*, *3(2)*, 261-272.

Fullenkamp, C., & Nsouli, S. M. (2004, February). *Six Puzzles in Electronic Money and Banking* (Working Paper No. 04/19). Washington DC: International Monetary Fund.

Furche, A., & Wrightson, G. (2000). Why do Stored Value Systems Fail? *Netnomics*, *2(1)*, 37-47.

Giannopoulou, I. (2004). The Evolution of Smart Cards: The Moneo Test. *Hertfordshire Law Journal*, *2(1)*, 55-61.

Goodhart, C. A. (2000). Can Central Banking Survive the IT Revolution? *International Finance*, *3(2)*, 189-209.

Hawkins, J. (2001, November). Electronic Finance and Monetary Policy. *BIS Papers*(7), 98-106.

Henckel, T., Ize, A., & Kovanen, A. (1999, July). *Central Banking Without Central Bank Money* (Working Paper No. 99/92). Washington DC: International Monetary Fund.

Hodrick, R., & Prescott, E. (1997). Postwar U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking*, *29*(1), 1-16.

Johansen, S. (1991). Estimation and Hypothesis Testing of Cointegrating Vectors in Gaussian Autoregressive Models. *Econometrica*, *59*(6), 1551-1580.

King, M. (1999). Challenges for Monetary Policy: New and Old. In *New Challenges for Monetary Policy, Symposium Proceedings 1999.* Kansas City: Federal Reserve Bank of Kansas City.

Krueger, M. (2002, January). *Innovation and Regulation - The Case of E–Money Regulation in the EU* (Background Paper No. 5). Seville: Electronic Payment Systems Observatory (ePSO).

Lanskoy, S. (2000). The Legal Nature of Electronic Money. *Banque de France Bulletin Digest*(73), 21-38.

Lee, B., & Longe-Akindemowo, O. (1999). Regulatory Issues in Electronic Money: A Legal–Economics Analysis. *Netnomics*, *1(1)*, 53-70.

Low, S. (2002). Singapore Electronic Legal Tender (SELT) - A Proposed Concept. In *The Future of Money* (p. 146-155). Paris: OECD.

Meyer, L. H. (2001, December 5). *The Future of Money and of Monetary Policy.* Speech delivered at the Distinguished Lecture Program, Swarthmore College, Swarthmore PA.

Moore, B. J. (1988). *Horizontalists and Verticalists: The Macroeconomics of Credit Money.* Cambridge: Cambridge University Press.

Palley, T. I. (2001). The E–money Revolution: Challenges and Implications for Monetary Policy. *Journal of Post-Keynesian Economics*, *24(2)*, 217-233.

Ravn, M. O., & Uhlig, H. (2002). On Adjusting the Hodrick–Prescott Filter for the Frequency of Observations. *Review of Economics and Statistics*, *84*(2), 371-375.

Richards, J. (2008, July 21). *Details of Oyster Card Hack to be Made Public.* The Times.

Rogers, E. D. (2003). *Diffusion of Innovations* (5th ed.). New York (NY): Free Press.

Rogoff, K. S. (1998). Blessing or Curse? Foreign and Underground Demand for Euro Notes. *Economic Policy*, *13*(26), 263-303.

Sellon, G. H., & Weiner, S. E. (1996). Monetary Policy Without Reserve Requirements: Analytical Issues. *Federal Reserve Bank of Kansas City Economic Review*, *1996 Q IV*, 5-24.

Sellon, G. H., & Weiner, S. E. (1997). Monetary Policy Without Reserve Requirements: Case Studies and Options for the United States. *Federal Reserve Bank of Kansas City Economic Review*, *1997 Q II*, 5-30.

Stefanadis, C. (2002). Why Hasn't Electronic Bill Presentment and Payment Taken Off? *Federal Reserve Bank of New York Current Issues in Economics and Finance*, *8(7)*, 1-6.

Tobin, J. (1956). The Interest Elasticity of the Transactions Demand for Cash. *Review of Economics and Statistics*, *38(3)*, 241-247.

Van Hove, L. (1999a). Electronic Money and the Network Externalities Theory: Lessons for Real Life. *Netnomics*, *1(2)*, 137-171.

Van Hove, L. (1999b). Electronic Purses, Interoperability, and the Internet. *First Monday*, *4*(4).

Van Hove, L. (2000). Electronic Purses: (Which) Way to Go? *First Monday*, *5*(7).

Van Hove, L. (2003, September). *Making Electronic Money Legal Tender: Pros and Cons* (Conference Paper). Prepared for "Economics for the Future" - Celebrating 100 years of Cambridge Economics, University of Cambridge, September 17-19, 2003.

Wenninger, J., & Laster, D. (1995, April). The Electronic Purse. *Federal Reserve Bank of New York Current Issues in Economics and Finance*, *1(1)*, 1-6.
Woodford, M. (2000). Monetary Policy in a World Without Money. *International Finance*, *3(2)*, 229-260.
Woodford, M. (2001, September). *Monetary Policy in the Information Economy.* (Mimeo: Columbia University, New York)

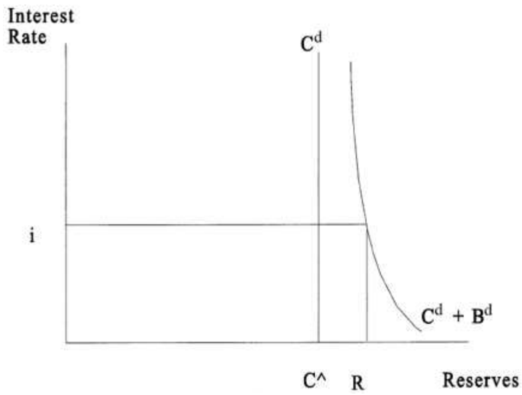
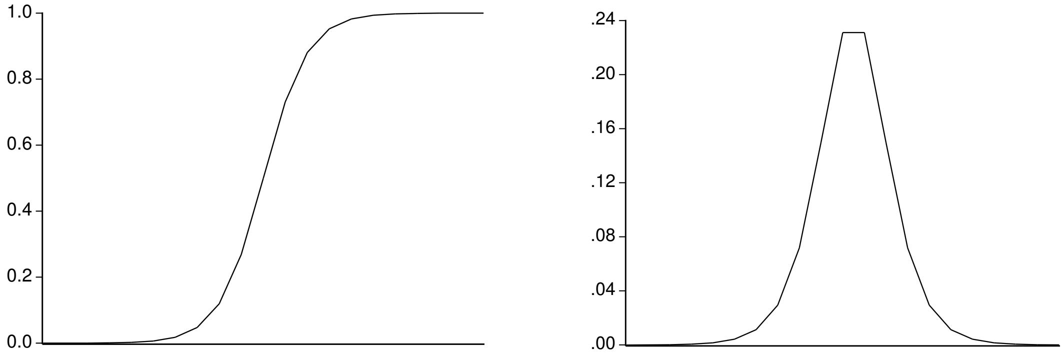
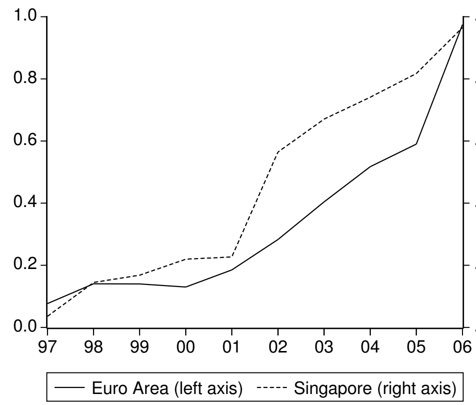


Figure 1: The Composition of Reserve Demand

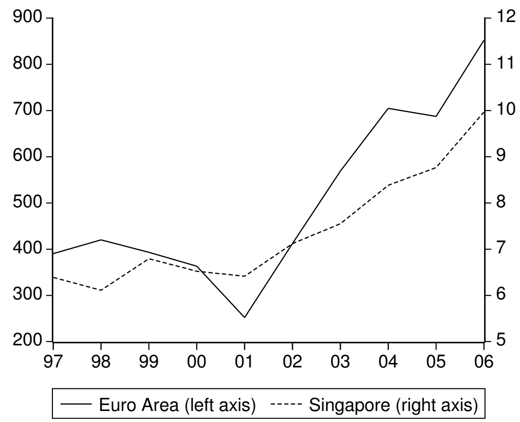


(a) Cumulative Adoption (b) Per–period Adoption

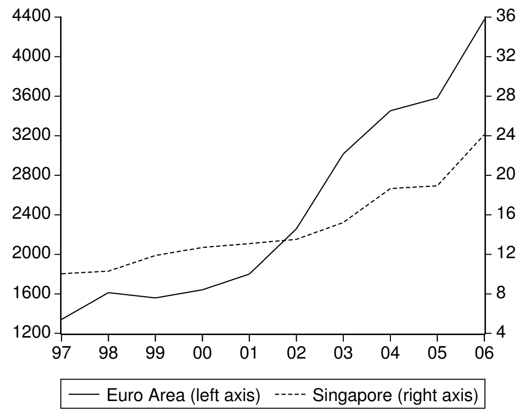
Figure 2: Sigmoid Adoption of Innovation



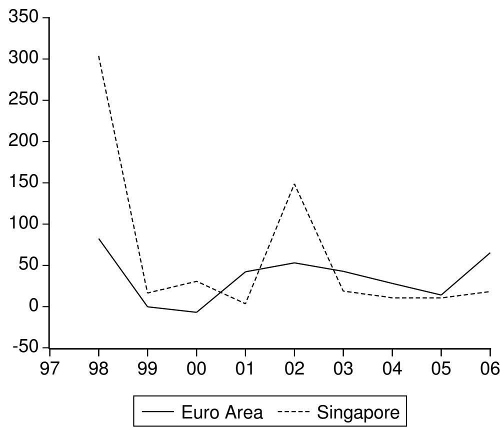
(a) E–Money



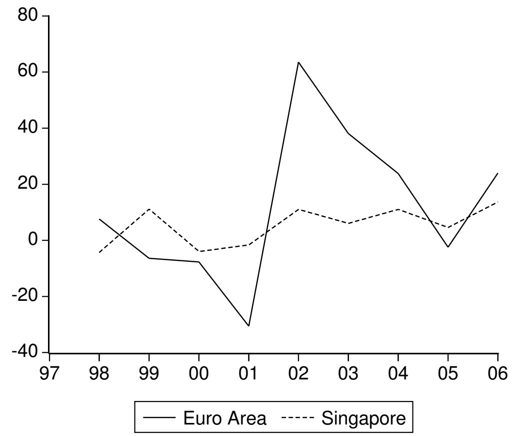
(b) Notes and Coins



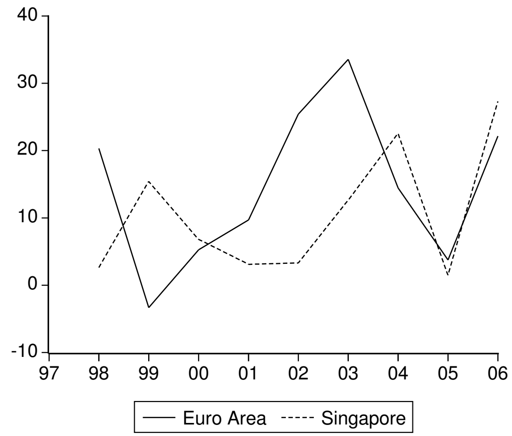
(c) Transferable/Overnight Deposits



(d) E–Money

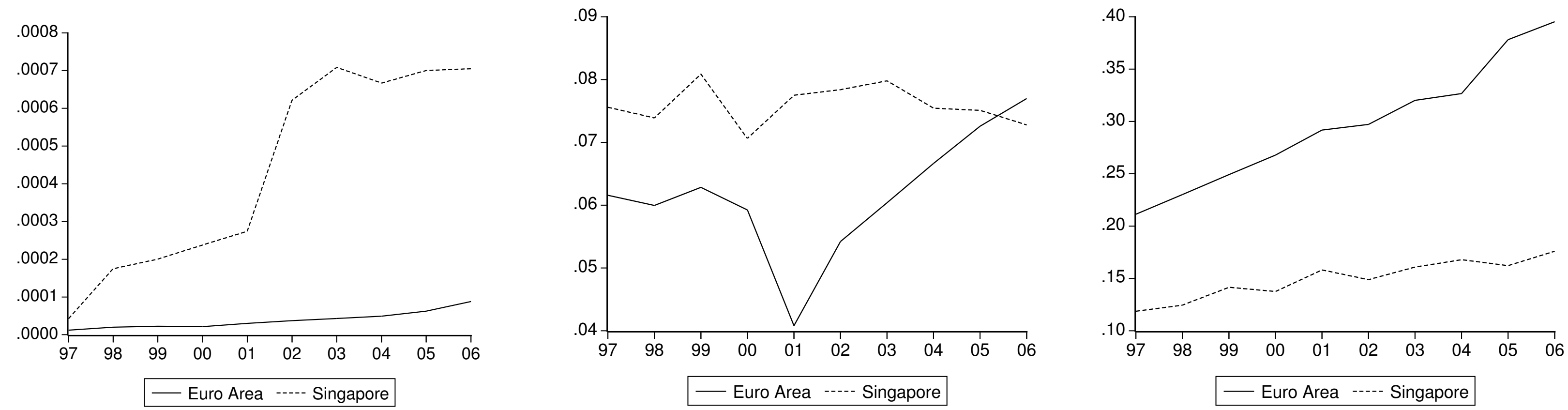


(e) Notes and Coins



(f) Transferable/Overnight Deposits

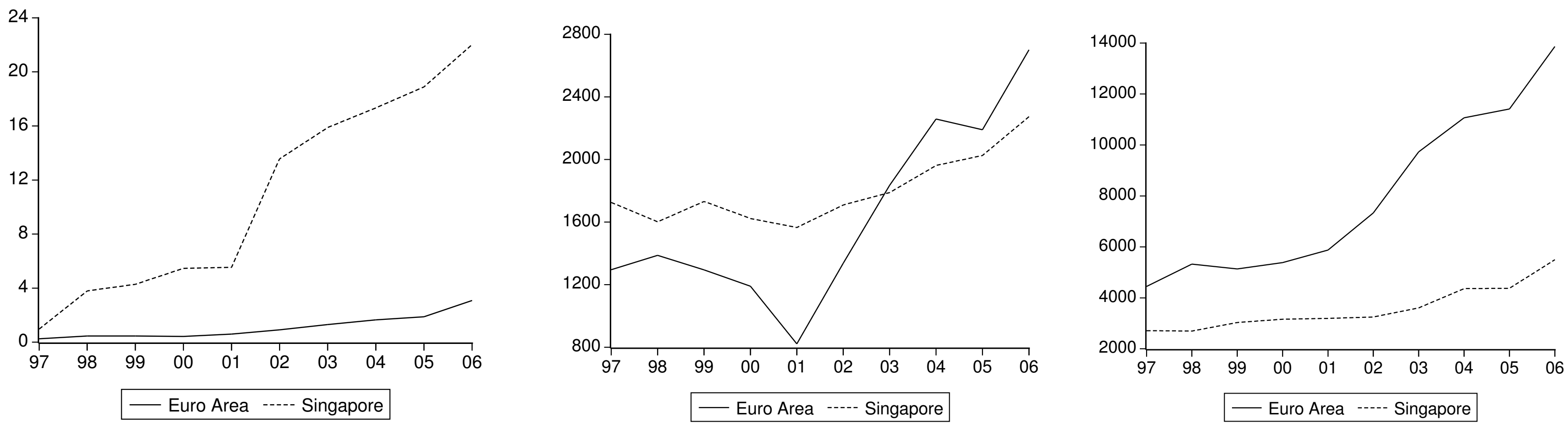
Figure 3: Outstanding Balances (panels a-c, billions US$) and Growth Rates (panels d-e, % p.a.)



(a) E–Money

(b) Notes and Coins in Circulation

(c) Transferable/Overnight Deposits

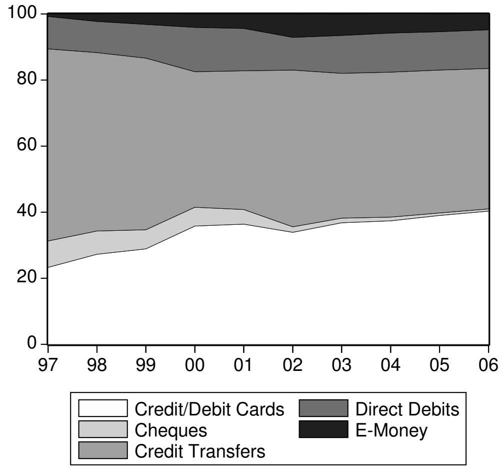


(d) E–Money

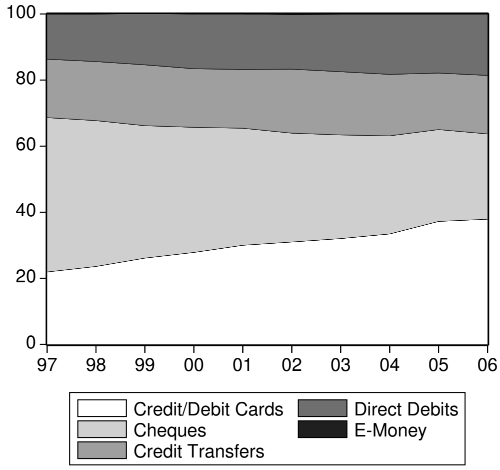
(e) Notes and Coins

(f) Transferable/Overnight Deposits

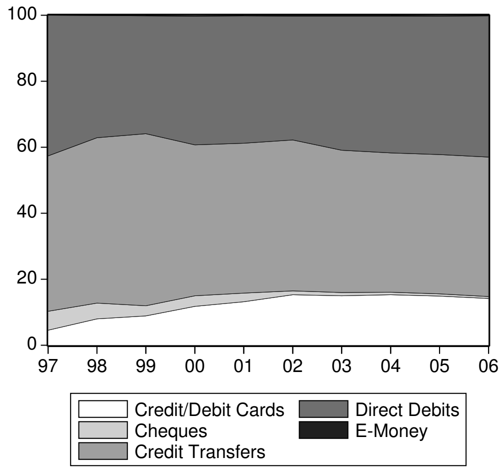
Figure 4: Outstanding Balances Relative to GDP (panels a-c) and per Capita (panels d-e, US$)



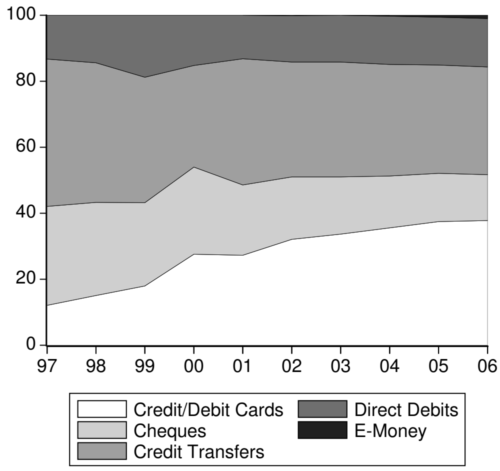
(a) Belgium



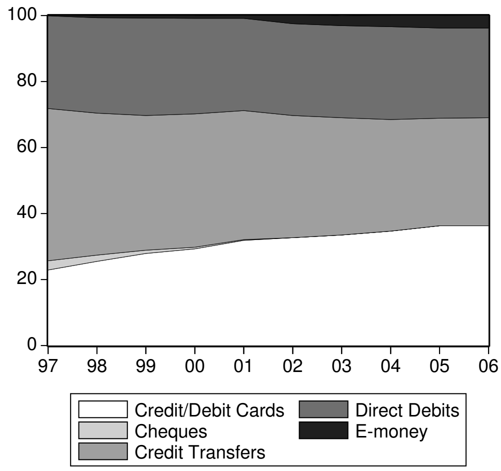
(b) France



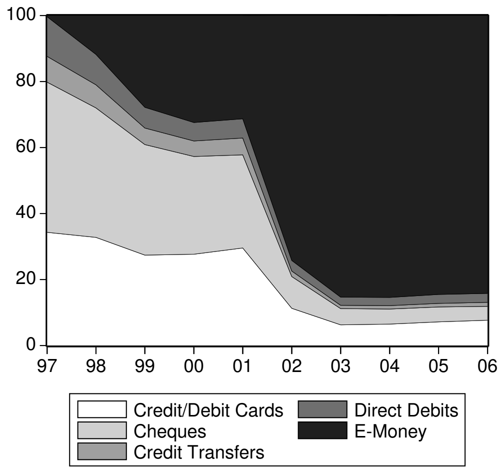
(c) Germany



(d) Italy (accounting for data revision)

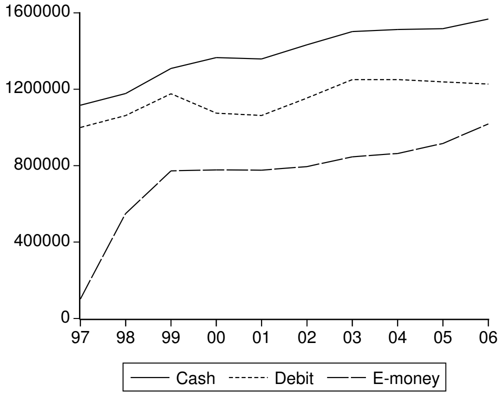


(e) Netherlands

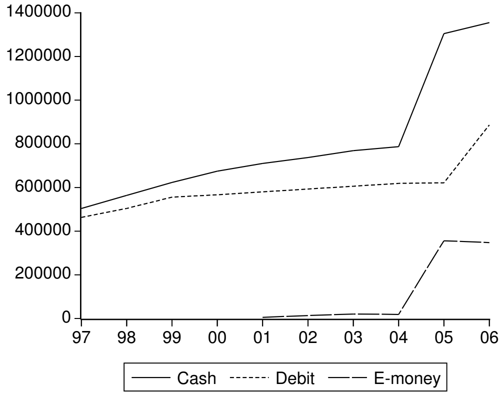


(f) Singapore

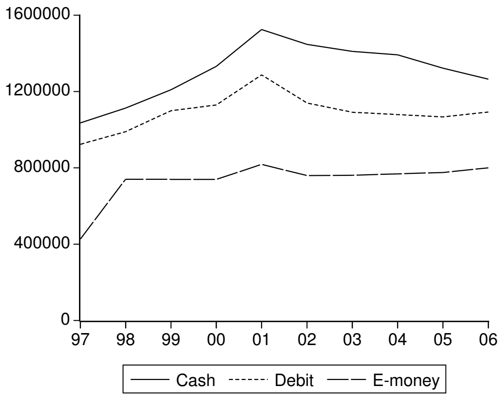
Figure 5: Relative Importance of Cashless Payment Instruments by Transaction Volume (percentage of total)



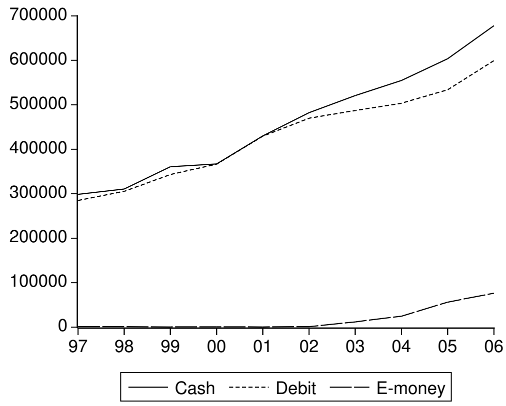
(a) Belgium



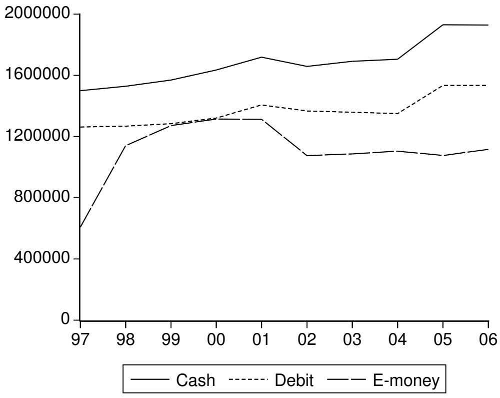
(b) France



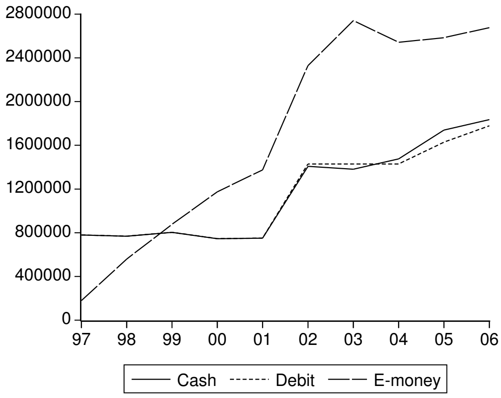
(c) Germany



(d) Italy

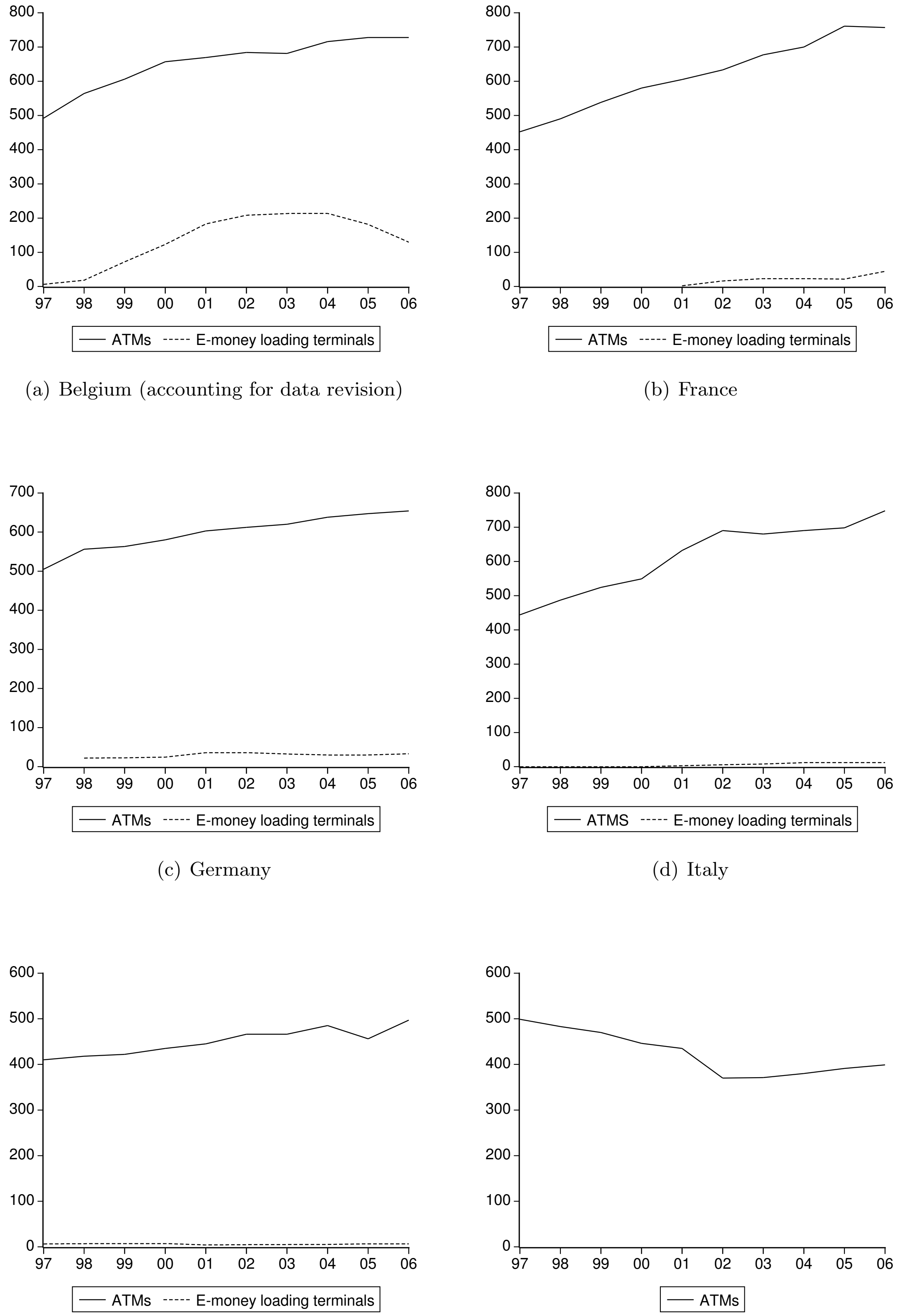


(e) Netherlands



(f) Singapore

Figure 6: Number of Cards per Million Inhabitants by Function



(a) Belgium (accounting for data revision)

(b) France

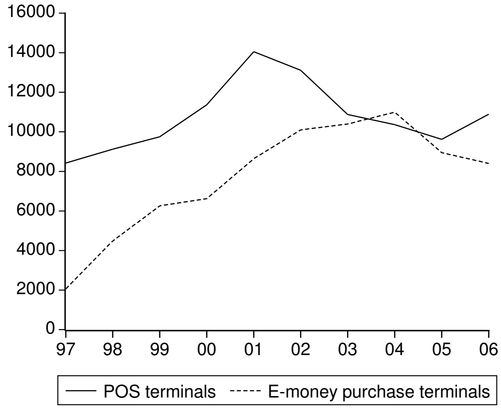
(c) Germany

(d) Italy

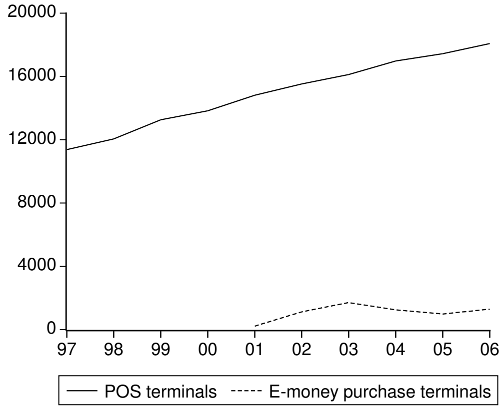
(e) Netherlands

(f) Singapore

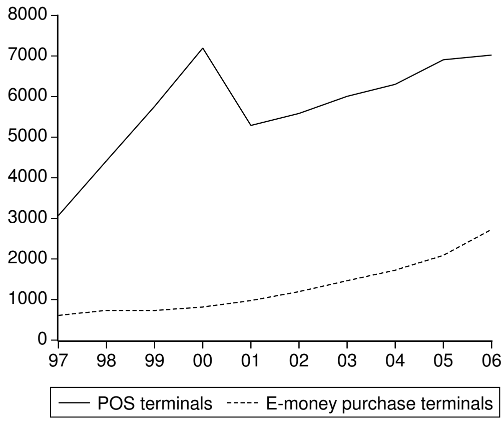
Figure 7: Number of ATMs and E–Money Loading Terminals per Million Inhabitants



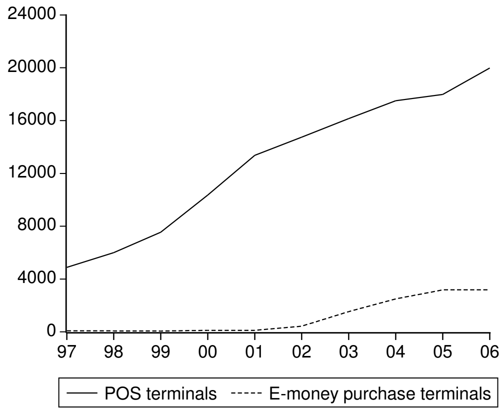
(a) Belgium



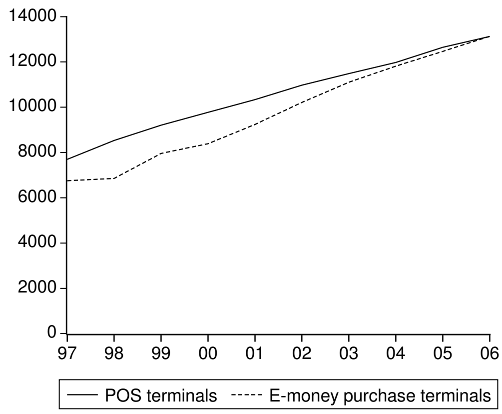
(b) France



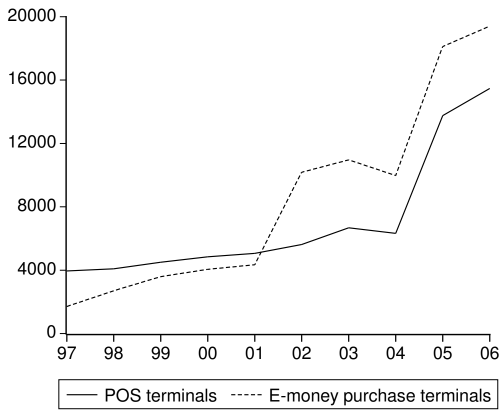
(c) Germany



(d) Italy

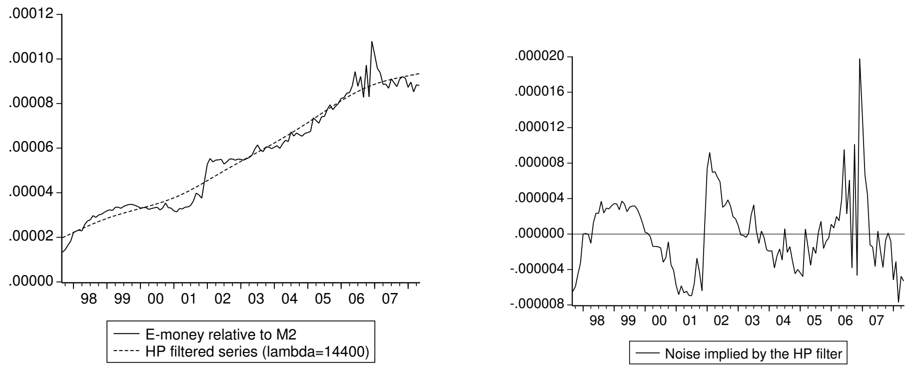


(e) Netherlands



(f) Singapore

Figure 8: Number of POS and E–Money Purchase Terminals per Million Inhabitants



(a) Raw and filtered series (b) Implied noise

Figure 9: Hodrick–Prescott Filtering of E–Money Relative to M2 ($\lambda = 14,400$)

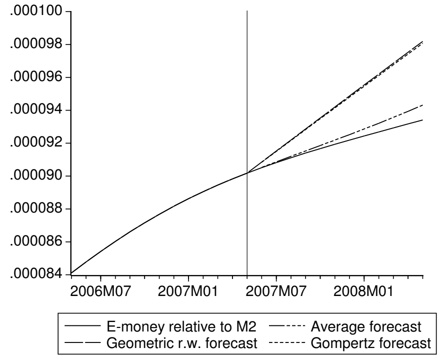
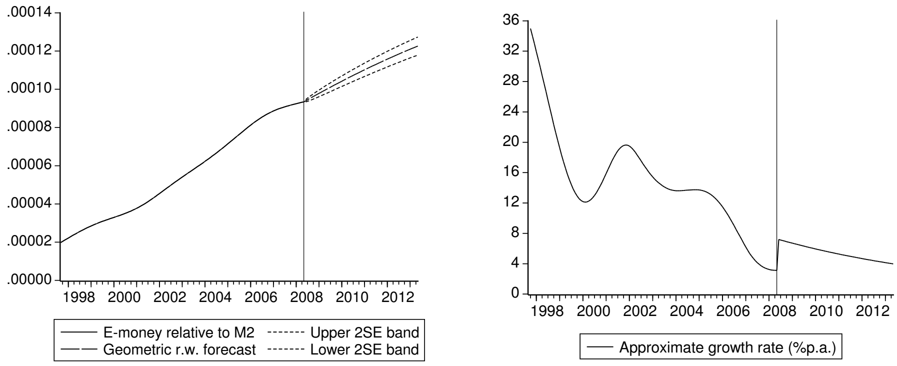
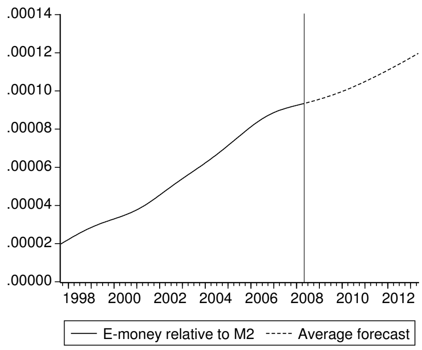


Figure 10: Pseudo Out–of–Sample Forecasts

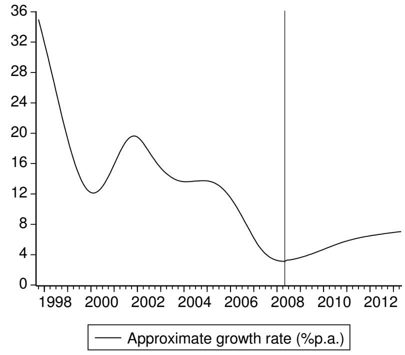


(a) Level (b) Growth Rate

Figure 11: h–step Ahead Geometric Random Walk Forecast

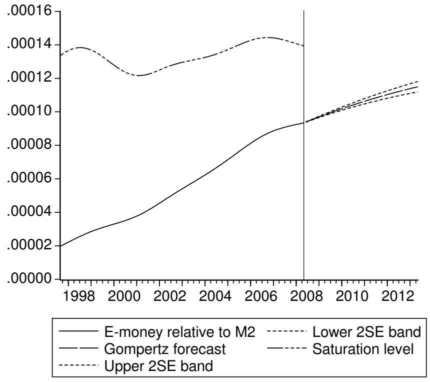


(a) Level

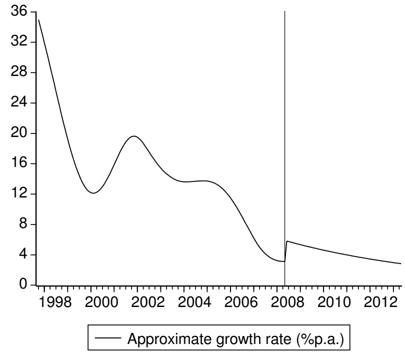


(b) Growth Rate

Figure 12: h–step Ahead Average Forecast



(a) Level



(b) Growth Rate

Figure 13: h–step Ahead Gompertz Forecast

Nodes	Possible Interactions
A	AA
A, B	AA, AB, BA, BB
A, B, C	AA, AB, AC, BA, BB, BC, CA, CB, CC
A, B, C, D	AA, AB, AC, AD, BA, BB, BC, BD, CA, CB, CC, CD, DA, DB, DC, DD

Table 1: Quadratic Growth of Interactions in Network Industries

Symbol	Variable definition
m_{hp}	Log of e–money balances outstanding relative to M2
c	Log of currency in circulation relative to M2
d	Log of demand deposits relative to M2
y	Log of real industrial production
r	Log of the 1 month Euribor
z	Log of the technology index
q	Log of the deflated NASDAQ adjusted closing price

Table 2: Variable Definitions

	m_{hp}	c	d	y	r	z	q
Mean	-9.886	-2.449	-0.904	4.562	1.156	4.881	3.999
Median	-9.826	-2.412	-0.889	4.559	1.208	5.029	3.945
Maximum	-9.278	-2.352	-0.764	4.623	1.598	5.560	4.849
Minimum	-10.828	-2.817	-1.136	4.524	0.714	3.551	3.403
Std. Dev.	0.457	0.099	0.100	0.022	0.289	0.562	0.280
Skewness	-0.293	-1.399	-0.578	0.799	-0.218	-0.878	0.917
Kurtosis	1.833	4.155	2.458	3.290	1.656	2.642	4.190
Jarque–Bera	9.171	49.272	8.772	14.171	10.725	17.248	25.688
Probability	0.010	0.000	0.012	0.001	0.005	0.000	0.000
Sum	-1275.350	-315.882	-116.662	588.467	149.075	629.633	515.855
Sum Dev.^{2}	26.711	1.261	1.269	0.063	10.671	40.371	10.039

Table 3: Descriptive Statistics

	Benchmark	Average	Gompertz
RMSFE	$2.87\text{x}10^{-6}$	$4.56\text{x}10^{-7}$	$2.80\text{x}10^{-6}$
MAFE	$2.51\text{x}10^{-6}$	$3.58\text{x}10^{-7}$	$2.44\text{x}10^{-6}$
MAFPE	2.710	0.387	2.640
Theil Inequality Coef.	0.015	$2.38\text{x}10^{-5}$	0.015
Bias proportion	0.762	0.617	0.762
Variance proportion	0.237	0.365	0.238
Covariance proportion	$3.65\text{x}10^{-4}$	0.018	$3.79\text{x}10^{-4}$

Table 4: Pseudo Out–of–Sample Forecast Analysis

A1 Appendix

The data used in the construction of Figures 3 and 4 comes from a variety of sources. Data on e–money outstanding, notes and coins in circulation and transferable deposits was retrieved from CPSS reports 54, 60, 74 and 82 country table 2 (CPSS, 2003; 2004; 2006; 2008). The Euro Area e–money series was unavailable prior to 2000 and was completed using the year–end value from the ECB's monthly e–monetary aggregate published in table bsi_emoney. Similarly, the data for notes and coins in circulation in the EU was retrieved from Eurostat series ICP.M.U2.N.000000.4.INX. Exchange rate data used to convert values into US$ was retrieved from country table 1 and completed for the Euro Area using Eurostat table ert_bil_eur_a. GDP data used in construction of the magnitudes relative to GDP was retrieved from Eurostat table daa10000 and from IFS series 57699B..ZF for Singapore. Population data used in the calculation of per capita values was sourced from Eurostat table demo_ppavg for the Euro Area and CPSS Table 1 for Singapore.

The data used in Figures 5-8 was mostly retrieved from CPSS reports 54 (for 1997-9), 74 (for 2000-1) and 82 (for 2002-6). Population data was retrieved from country table 1 in CPSS report 54 and comparative table 1 in CPSS reports 74 and 82. Where revision anomalies were apparent, data from report number 66 (CPSS, 2005) was substituted in some cases and extrapolation and interpolation were employed. The details of the data sources and manipulations are recorded in Table A1. Note that, where values are reported as 'negligible' by the CPSS, a value of zero is assumed.

Fig.	CPSS Tables Used	Notes
5	#54, Table C13 #74, Table C7a #82, Table C7a	Italian credit transfer data for 2000 comes from #54 to smooth a revision anomaly. Dutch e–money data for 1997 is extrapolated from the 5 year growth rate. Figures are re–scaled to sum to 100.
6	#54, Tables CS6 & C8 #74, Table C10 #82, Table C10	Missing French debit card data is interpolated between 2000 and 2004.
7	#54, Tables C5 & CS6 #74, Table C11b #82, Table C11b	Belgian ATM data breaks in 2002. Data from #66 is used for 2002-3 and 2004-6 is extrapolated using the growth rate observes after the break.
8	#54, Tables C6 & C8 #74, Table C11b #82, Table C11b	

Note: CS denotes a country–specific table in the CPSS report indicated while C denotes a comparative table.

Table A1: Data Sources for Figures 5 - 8

The sources of the data used in the forecasting exercises and the transformation procedures employed are recorded in Table A2. Unit root testing (not reported) confirms that all variables are I(1) with the exception of z, which the tests indicate may be I(2). However, it seems unlikely from a theoretical point of view that z should be I(2) so the analysis proceeds on the assumption that it is I(1).

Variable	Description (Data Source) and Transformation Procedure
m_{hp}	Total e–money outstanding (ECB: bsi_emoney) seasonally adjusted using Census–X12 and divided by M2 (International Financial Statistics, IFS: 59MBUZW), also seasonally adjusted using X12. The resulting series is indexed, HP filtered ($\lambda = 14,400$) and logged.
c	Currency in circulation (Eurostat: BSI.M.U2.N.C.L10.X.1.Z5.0000.Z01.E), adjusted with X12 relative to adjusted M2. The resulting series is indexed and logged.
d	Demand deposits (IFS: 34B.UZW) adjusted using X21 relative to adjusted M2. Demand deposit data is extrapolated for 2008m4&5 based on monthly growth rates over the previous 12 months. The resulting series is indexed and logged.
y	Industrial production (Eurostat: STS.M.I4.Y.PROD.NS0020.4.000) deflated by HICP (Eurostat: ICP.M.U2.N.000000.4.INX). The resulting series is indexed and logged.
r	1 month Euribor (Eurostat: FM.M.U2.EUR.4F.MM.EURIBOR1MD.LST). The resulting series is logged.
q	NASDAQ adjusted closing price (Yahoo! Finance) deflated by HICP. The resulting series is logged.
z	The mean of broadband subscribers per 100 inhabitants (World Development Indicators, WDI: IT.NET.BBND.P2), internet users per 100 (WDI: IT.NET.USER.P2), mobile phone subscribers per 100 (WDI: IT.CEL.SETS.P2) and PCs per 100 (WDI: IT.CMP.PCMP.P2). Series are extrapolated using the average 5 year growth rate where necessary (99% adoption of cellphones in 2008 is assumed to avoid it exceeding 100%) and linearly interpolated. The resulting series is indexed and logged.

Table A2: Data Sources for Forecasts