An introduction to payments economics[*]

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1. Introduction

Payment systems are the plumbing of the economy—a collection of conduits that is essential, pervasive, and boring until there's a malfunction. Economists studying payment systems have long labored under the shadow of this unsavory metaphor. Recently, however, payments economics has begun to achieve some respect, because of the significant changes in payments technology and infrastructure, because of the important policy concerns associated with the industry, and possibly because of the sheer magnitude of payment activity.

This essay is an (admittedly idiosyncratic) introduction to some of the issues of payments economics and the empirical work on payment systems, but above all to the models used to understand the role of payments in an economy and the forms which payments take. By the end we hope the reader will conclude that plumbing can be an interesting object of study.

A payment occurs when one economic agent transfers an asset to another agent for the purpose of discharging a debt. In developed economies, the action of payment is so mundane and apparently simple that this definition hardly seems necessary. But economists have struggled to understand the nature of this everyday activity: constructing a convincing model of payments is a challenging task. Payments and payment systems, so ubiquitous and obviously essential to real-world economies, are conspicuously absent from the world of Arrow-Debreu.

But what precisely are the frictions that give rise to payment arrangements? Do these frictions, and the payment systems designed to overcome them, matter for economic allocations more generally? How do payment systems interact with the machinery of financial intermediation? And how will these systems evolve with the ongoing improvements in information technology?

1.1. Payments—big business and getting bigger

Payments are big business, even by the standards of macroeconomists. For example, 85 billion payments of $883 trillion were recorded in the United States in 2004, not

counting payments made in currency.[1] This figure corresponds to about $75 in payments for each dollar of GDP, a ratio that has been steadily rising over time. Payment statistics in all developed economies display similar levels and trends (summary statistics can be found in Committee on Payment and Settlement Systems 2006).

Much of the recent pickup in payments activity comes from the *large-value* or *wholesale* payment systems used to settle obligations between banks. Since the "funds side" of financial market trades[2] must ultimately settle through such systems, volume over these systems has mushroomed with the upsurge in financial market trading.[3] But volume is also expanding quite rapidly over certain types of *small-value* or *retail* payment systems, those used by households and non-bank firms. In the U.S., for example, usage of debit cards and direct transfers[4] is expanding at double-digit rates (measured either in terms of the volume or value of transactions), even as the usage of checks and cash is declining (Humphrey 2004; Gerdes et al. 2005; Garcia-Swartz et al. 2006a; Klee 2006a). Transactions that were once only conducted solely with cash are increasingly made using cards that electronically link buyers to their payment histories.[5]

The past decade has also witnessed tremendous innovation in payments. Besides the spectacular rise of card payments, innovative web-based payment systems such as PayPal have enabled individuals to "wire" funds across great distance, instantaneously and at low cost (Kuttner and McAndrews 2001). At the wholesale level, the multicurrency CLS system (beginning operations in 2002) has allowed banks to coordinate the settlement of foreign-exchange transactions across national borders, binding together all major national payment systems in a way that was unthinkable a decade ago. And there is no reason to believe that the rate of innovation will slow down anytime soon. The "pay-

[1] This figure also does not include the U.S. dollar payments made through the international, multicurrency CLS system, for which no precise figures are available. Adding these in would drive the total close to $1 quadrillion.
[2] Residual amounts left after any netting of securities trades.
[3] In fact there is a close connection between the study of payments system and the study of clearing and settlement systems for financial markets. Many of the policy issues are similar and many of the techniques used to design them are parallel. In Europe as a result of monetary unification, there has been concern with the competitiveness and industrial organization of financial settlement systems. For an introduction to these issues, see European Central Bank (2006) and Milne, (forthcoming).
[4] I.e., those made through the Automated Clearinghouse (ACH), such as direct deposit of payrolls.
[5] For a valuable examination of the history and growth of the use of credit cards see Evans and Schmalensee (1999); an informal theory of the process is found in Kahn (2006).

ment card" of the future will likely be just a "smart card," cell phone, or other portable computing device, able to instantaneously transfer value to anyone so equipped.[6]

1.2. Policy issues

While the technology-fueled expansion of payments activity has clearly generated tremendous economic benefits, it has also generated noteworthy and in many cases, unresolved questions for policymakers.

Important policy issues for wholesale payment systems include *access*, *liquidity*, and *systemic risk.* Important policy issues for retail payment systems include *competition* and *fraud*. *Cross-border coordination* is an important problem at both levels.

1.2.1 Wholesale systems

Economic models of banks have usually focused on the roles of banks as financial intermediaries, parties able to exploit the synergies between the provision of extremely liquid deposits and equally illiquid loans (e.g., Diamond and Dybvig 1983; Kashyap, Rajan and Stein 2002). But banks have always served another, equally essential role, as providers of payment services—as parties able to transfer liquid claims quickly and cheaply and with a minimum of legal uncertainty.[7]

Financial innovations such as securitization, syndication, and credit insurance have eroded banks' advantages as financial intermediaries, subjecting them to competition from both financial markets and non-bank financial institutions. But, for the moment at least, banks continue to enjoy significant advantages over non-banks as payment service providers. These advantages include, most critically, full access to wholesale payment systems. Such access is usually restricted to (regulated) banks, and sometimes only

[6] Although in the case of smart cards, it probably makes sense to be a little cautious. Observers have for many years been predicting their arrival as a major payment method. While they have begun to have an impact in other countries, they still are relatively unused in the U.S.

[7] The history of banking (see Kohn 1999 for a survey) indicates that banks arose first as providers of payment services—moneychanging and book-entry payments—and then diversified into the business of financial intermediation. Central bank participation in payment arrangements dates to at least the 15th century *Banco di San Giorgio* in Genoa (Fratianni and Spinelli 2006). By the 18th century, book-entry payments at the Bank of Amsterdam—the leading central bank of its day— were the dominant wholesale payment system in Europe (Quinn and Roberds 2006). For a reexamination of banking history from the point of view of payment systems, see Speight et al. (2006).

to banks whose home charter is in the same jurisdiction as the system itself.[8] Indeed it has been argued that such access has become *the* definitive feature of a bank (Lacker 2006). Recent policy discussions in the U.S. regarding the acquisition of banks by non-financial firms have focused on this issue. Wal-Mart and other would-be acquirers of banks have stated that their principal motivation is not to compete with banks as financial intermediaries, but instead to gain unfettered access to interbank payment arrangements.[9]

Liquidity is a concern because of the very high value of payments routed through wholesale systems, due to settlement of financial market trades. No intraday markets exist to allocate this liquidity. Instead, such liquidity has traditionally been allocated implicitly through agreements between banks to settle payments on a net basis. During the 1990's, however, net settlement of large-value interbank payments came under criticism as being too subject to *systemic risk*, roughly defined as the risk that a failure by one bank to settle might result in multiple settlement failures.[10] Chains of failures have rarely been observed in practice, but there have been enough "near misses" to produce considerable regulatory angst.[11] Consequently net settlement has in many cases been abandoned in favor of *real-time gross settlement* (RTGS).

Under RTGS, each payment by a bank to another bank consists of an irrevocable transfer of central bank funds. Until the payor has access to such funds, no payment can be made. RTGS systems[12] thus insulate an individual payee from systemic risk, but their operation requires many times more central bank liquidity than net settlement systems. How such liquidity should best be provided remains an open question. The Federal Reserve System, for example, routinely allows banks using Fedwire to incur uncollateralized intraday overdrafts, but other central banks (Euro area, Japan, U.K.) only grant such

[8] A condition for full participation in such systems is an account with the relevant central bank, even in cases where the system is privately operated. Central banks have traditionally limited access to such accounts, justifying this limitation both on moral hazard grounds (Bank of England 2002), and on a reluctance to compete with commercial banks (Green and Todd 2001).

[9] See for example the written testimony of Jane J. Thompson, Wal-Mart Financial Services, at the Wal-Mart Bank Federal Deposit Insurance Application Public Hearing, April 10th, 2006, Washington, DC. Available online at http://www.fdic.gov/regulations/laws/walmart/publichearings/walmartjane.html.

[10] See the "Lamfalussy report" (Committee on Payment and Settlement Systems 1990).

[11] Among the most famous occurrences resulted from the 1974 failure of Bankhaus Herstatt and the 1991 failure of BCCI; see the "Allsopp report" (Committee on Payment and Settlement Systems 1996) for the details of these and other incidents.

[12] Including Fedwire in the U.S., TARGET in the Euro area, BOJ-NET in Japan, CHAPS in the U.K., and many others.

credit against collateral. The Fed charges fees against overdrafts (over a ceiling), but many other central banks do not. Other large-value payment systems—CHIPS in the U.S., LTVS in Canada, and the multicurrency CLS—have opted for arrangements that employ modified versions of net settlement, often in conjunction with queuing arrangements that attempt to optimize the extent to which queued payments may be netted (Intraday Liquidity Management Task Force 2000; McAndrews and Trundle 2001, Willison 2005).

1.2.2 Retail systems

For retail systems, the principal policy controversies have centered on issues of competitive efficiency. Payment systems are a relatively expensive component of financial infrastructure, as much as 3 percent of GDP in the U.S. (Humphrey, Pulley, and Vesala 2000). In the U.S. case, one reason this figure is so high is the continued widespread use of checks, but the cost of electronic alternatives can also be substantial, particularly for card-based payments. Merchant dissatisfaction with the fees charged for card payments has resulted in some spectacular antitrust litigation in the U.S. (the "Wal-Mart case" against Visa and MasterCard, settled in 2003 for $3 billion; additional lawsuits are pending) and outright regulation of card fees in countries such as Australia (Lowe 2005). As is the case with some other "network" industries, there is little consensus on what constitutes an efficient fee structure for card-based payments (Rochet and Tirole 2006a).

Another policy controversy associated with retail payments has been the emergence of new forms of payments fraud such as "identity theft." Electronic payment systems can offer tremendous efficiency gains, by allowing for rapid and easy transmission of information across system participants. But the flipside of this efficiency is that these same systems can allow for rapid propagation of fraud. A single loss of confidential data, such as the compromise of 40 million credit card accounts at CardSystem Solutions Inc. in June 2005, can lead to significant fraud losses.[13] Payment service providers and policymakers have struggled to find a balance between the inherent advantages of information-sharing, and the potential costs that can arise due to fraud and loss of privacy.

[13] See Isabelle Lindenmayer, "Security Watch," American Banker, Friday, September 2, 2005.

Payment systems have traditionally observed national boundaries, but over the past decade cross-border arrangements have become increasingly common. Cross-border credit card and ATM card transactions are now routine, and cross-border direct (ACH) transfers are starting to see increasing usage. At the wholesale level, the Euro-area-wide TARGET system (beginning operations in 1999) and the multicurrency CLS system are now two of the world's largest payment systems, measured by the value of funds transferred. The advent of these cross-border arrangements has no doubt facilitated international commerce, but at the same time their operation has required a much greater degree of coordination between central banks and regulatory authorities than was previously the case.

2. Theory of payments

Payments arise in environments characterized by two potential impediments to exchange: a *time mismatch* of trading demands, and *limited enforcement* of pledges about future behavior.

The notion of a time mismatch is less stringent that Menger's celebrated "lack of double coincidence of wants." What is key is not an absence of counterparty-by-counterparty matchups in consumption good demands, but instead an inadequate supply of liquid (desirable) assets to allow for exchange to proceed as a sequence of spot trades.

Limited enforcement can arise in many ways. Enforcement of obligations might be hindered by geographical displacement of potential transactors, or by an inadequate legal system. Informational frictions can also play a role. For example, account-based payment systems must incorporate at least two critical information technologies, one for keeping track of an individual's actions over time, and another to verify identities. The scope and application of such systems is clearly limited by the efficiency of these underlying technologies.

Broadly defined, a *payment system* is any arrangement that enables exchange by overcoming the paired frictions of time mismatch and limited enforcement; payments economics is the study of such arrangements. As such, this field has drawn on many fields of economics, but as noted by Green (2004), its most important antecedent is monetary theory. The study of payments is in part a study of the techniques institutions

use to increase transactions velocity, i.e., to make payments more efficiently with the same stock of money (see, for example, Temzelides and Williamson 2001).

Despite its overlap with monetary economics, the study of payments is focused on very different issues from the study of money. Monetary theory focuses on questions about how money obtains its value, the relationship between inside and outside money, and how the supply of money should be optimally regulated. Payment economics is in a sense more fundamental, relying on information economics and mechanism design to characterize alternatives to money, and to explain how certain assets may take on money-like traits. Over the long run, changes in underlying features of economic environments and consequent structure of payments will continue to redefine what may be considered "money."

2.1. Two types of payment systems

A fundamental distinction should be made between payment systems that are *store-of-value systems* and those that are *account-based systems.* Store-of-value systems, such as commodity money, fiat money, and stored value cards, are founded on the transfer of some payments object (be it coins, notes, or electronic stored value) between payor and payee, and they depend critically on a payee's ability to verify the payments object. Account-based systems, such as charge accounts, checks, and credit cards, require the keeping of accounts in the name of the payor and payee. The success of account-based system hinges, most fundamentally, on the ability of its participants to verify the identities of account holders, to ascertain the link between transactors and histories. This dichotomy necessarily represents something of an idealization, and there are some types of systems (e.g., debit cards) that arguably do not fall so neatly into either of these camps. Nonetheless the overwhelming proportion of payments arrangements can be classified into one of these two forms. Why this should be so remains an interesting challenge (first posed by Green 2004) for the theory of payments.

For each of these types of system we first consider a "Platonic ideal"—a baseline model of how such a system might function in its most abstract form. For account-based systems this ideal will be pure, costless credit. For store-of-value systems it is spot trades using perfectly liquid assets. Whenever considering more complex systems, we will treat

these as attempts to approximate one these two ideals (for a similar approach, see Nosal and Rocheteau 2006).

2.2. Baseline 1: pure credit

Theoretical models of exchange there often examine "gift-giving" equilibria, but of course economic agents never give gifts selflessly. Instead successful gift-giving arrangements depend on agents giving gifts in anticipation of possible future rewards, possibly combined with fear of punishment if gifts are not handed over. Gift-giving arrangements are thus more likely to be successful given a sufficiently low discount rate, high probabilities of and stringent penalties for defection, and high anticipated future benefits. A classic example of gift giving arises is in Diamond's (1990) model of pairwise meetings with credit, where autarky is the punishment. Jin and Temzelides (2004) extend this idea in their study of the interactions of money and credit. In their model, the frequency of meetings between agents determines the possibility of credit relationships. Agents simultaneously maintain credit relationships with individuals with whom they meet frequently, and cash relationships with individuals whom they rarely meet.

In pure credit models, retaliation against defectors can take a variety of forms. One obvious possibility is a fine or nonpecuniary punishment ("jail"). Others include an individual refusal to trade, expulsion from a group, or even "the nuclear option"—economy-wide reversion to autarky.

In these highly stylized models of exchange, gift giving can be surprisingly robust. Araujo (2004) shows that gift-giving equilibria can be supported even if the identity of a defector is *not* known and acts of defection are *not* publicly revealed, as long as agents are sufficiently patient. Through a "contagion equilibrium," even a single refusal to trade can eventually lead to an economy-wide breakdown in reciprocity; thus agents are induced to adhere to the "social norm" of trade. Although Araujo's result provides a useful theoretical starting point, it is clear that much less patience will be required when defectors can be identified and punishments more sharply focused.

2.3. Credit with "hostages"

When credit is inadequate by itself, other institutions can arise to help support promises. These institutions allow, in effect, for the taking of hostages: agents agree on a (possibly costly) action making retaliation for defection easier or more potent.

Corbae and Ritter (2004) provide one example of such an arrangement where, in addition to the possibility of interacting in random meetings, agents can form partnerships that extend voluntarily over time. The message in the paper is that even if an individual is currently matched with a less-than-ideal partner, the continuation of the partnership can enforce promises by enhancing the cost of defection.

In the context of payments, a more typical form of hostage is collateral. There are numerous examples of collateral serving this role. In Shi (1996) and Li (2001) collateral is modeled as the taking of an agent's "tools" until a debt is repaid. The absence of the necessary implements makes consumption impossible. Koeppl and Monnet (2005) construct a model of central counterparties and margin posting, whereby payments are facilitated by collateral held in escrow by a third party. Kahn and Roberds (2001a) place a similar interpretation on the CLS system for international large value payments. They argue that CLS acts as an "escrow agent" able to impose greater penalties for nonperformance than could be imposed through purely bilateral arrangements.

Such arrangements depend on the ready availability of a collateral good for which there is a low cost of transfer into the creditor's control (low transportation costs, low likelihood of damage while hostage, no legal uncertainty about ownership). The cost of a loss of the collateral to the debtor should be high relative to its value to the creditor (Williamson 1985). Collateral also tends to reduce costs of keeping track of a debtor, since the debtor has an incentive to return to retake possession of the collateral.

2.4. Baseline 2: pure spot exchange

From hostage taking it is a small jump to spot trades in assets. Hostage taking occurs when a creditor does not value an asset posted as collateral, but anticipates that he original owner will pay to get it back. Trading in assets occurs when the "hostage" collateral good can be readily sold to third parties, so that accepting such a good in payment makes sense, even if the payee does not value the asset itself. In this sense, commodity

money is simply an asset with a negligible cost of transfer (Ostroy and Starr 1974, Kiyotaki and Wright 1989). At some point there is no longer the need to maintain accounts and the transferred asset becomes a "store of value."

Models with store-of-value payments often place agents into "wilderness" settings. An agent wanders about ("searches") through an uncharted rain forest, occasionally encountering a lone stranger. These encounters are never repeated, and agents are beyond the reach of any court. The only feasible interactions between agents are spot trades: each agent simultaneously holds out his own good while grabbing for the other. Absent a double coincidence of wants, goods can only trade for a store of value.

Working through the models of these environments is valuable for emphasizing the parsimony of information needed to effect payment under a store-of-value system. A trader needs to verify the genuineness of the proffered store of value, but need know nothing about his counterparty.

The canonical model of this type is the well-known search model of Kiyotaki and Wright (1989). But the essential idea of nonrecurring encounters can be found in earlier models such as Samuelson's (1958) overlapping-generations model and Townsend's (1980) turnpike model. "Island" models such as Freeman (1996) motivate the use of money through both overlapping generations and geographic dispersion. "Day/night" models such as Lagos and Wright (2005) have sought to increase the tractability of search by allowing for alternating periods of anonymous trade and trade in Walrasian markets.

The ingenious details of these models can sometimes obscure their key point, which is that trade in assets is useful if malefactors cannot be identified, caught, and punished. In other words, a market could be completely centralized, but if it were also completely anonymous, trade in stores of value will still be useful.

2.5. Fiat money as a store of value

Any good with the necessary physical characteristics can serve as a store of value. But if such assets are in short supply, one possibility is to create them in the form of fiat money. The are numerous theories about how intrinsically worthless fiat money may come to represent a store of value, but these can generally be split into two groups. The first group—the "soufflé theories"—postulates that money has value today because it is

believed to have value tomorrow (see references in the previous section). The other group—the "Mahagonny theories"[14]—asserts that money has value because it is needed to pay taxes (as in e.g., Starr 1974; Aiyagari and Wallace 1997). From the point of view of payments foundations, it does not really which group of theories is the more accurate. Once the money has future value, for whatever reason, it can function as a store of value.

When trade based on credit fails or is too costly due to limited enforcement, then trade in assets, including fiat money, may be an attractive alternative, imposing fewer informational and enforcement costs. But payment in money, like all store-of-value arrangements, is inherently a little less flexible than recordkeeping, because it is subject to a physical restriction in various stochastic realizations (as anyone who has ever searched for an ATM can attest). There is a strand of monetary theory which emphasizes this distinction (Kocherlakota and Wallace 1998).

Despite these apparently obvious and practical distinctions, at the theoretical level it can be difficult to distinguish between the functioning of money and credit. Numerous papers (e.g., Townsend 1987; Taub 1994; Aiyagari and Williamson 2000; Corbae, Temzelides, and Wright 2003; Berentsen et al. forthcoming) have shown, in some circumstances at least, that trade with money can deliver identical outcomes to trade with credit. Kocherlakota (1998) argues that this is because money functions as a cheap, easily transportable proxy for expensive public record keeping ("memory"), i.e., an agent's money holdings can effectively serve as a sort of portable account balance. Because this proxy is sometimes imperfect, however, Kocherlakota's argument implies that as the costs of recordkeeping fall, the use of payment systems based on store of value should likewise fall. Temzelides and Yu (2004) develop this idea somewhat further in a model in which money is used when it is not worthwhile to track credits and debts in more complex ways: small transactions use money. Over time, the margin where account-based payment systems become effective has grown ever smaller.[15]

[14] After the1930 Brecht musical *Rise and Fall of the City of Mahagonny*, which takes place in a city where the only crime is to be caught without money.

[15] The cost to a merchant of accepting card payments remains stubbornly high, in the U.S. about $.60 for a small ($11.52) grocery store transaction according to Garcia-Swartz et al. (2006a), while the same transaction in cash would cost the merchant only $.30. They argue that cards become more competitive for small transactions, when one takes into account consumers' costs of acquiring and carrying cash, as well as the benefits of paying by card.

Further complicating the comparison between account-based and store-of-value models is the fact that in practice, the latter may not be free from serious informational and enforcement frictions. Counterfeiting, virtually eradicated in the developed world, is much more prevalent in developing countries (Judson and Porter 2003). The limited information associated with cash leads to its use in payment for illegal activities (Camera, 2001). Another potential problem with store-of-value systems, as yet unmodeled in the literature, is how to enforce spot trades, i.e., how to keep anonymous, isolated spot trades from degenerating into swindles or simple robbery.[16]

We would argue that these and other practical difficulties have served to constrain the use of store-of-value payment systems, including the use of fiat money. But society is not limited to a choice of fiat money or autarky: instead, society can (and does) create alternative types of payment infrastructures. Specifically it can develop better courts, better surveillance techniques and communication systems, better ways of identifying people, and better recordkeeping. All of these increase the costs of non-adherence in account-based systems.

3. Hybrid payment systems

Most actual payment systems incorporate features from the two basic models outlined above. An idea common to all of these hybrid arrangements[17] is the use of privately issued, transferable debt (inside money) in one form or another. We can think of this debt as privately-, rather than publicly-issued pieces of paper (although nowadays they are more likely to take some electronic form). These pieces of paper derive their value from the issuer's credible promise to redeem them. Through the use of transferable debt, one person's credit (on account) becomes another's means of payment (store of value). Both sorts of verification will be necessary for a successful transferable debt: a payee needs to verify that a note is what it claims to be, and to verify that the issuer is good for it.

Papers such as Cavalcanti and Wallace (1999), Williamson (1999), Kiyotaki and Moore (2000), and Andolfatto and Nosal (2003) investigate a basic model of inside

[16] However, see He et al. (2005).

[17] Our use of the term "hybrid" as a combination of store-of-value and account-based systems, is in contrast to the policy literature, where the term "hybrid" is used to describe wholesale payment features that combine features of gross and net settlement (Willison 2005).

money. In this framework, only certain agents (who function as bankers) are able to transact for credit, because they possess some special advantage—they are easy to locate, famous, or just unusually upstanding individuals. Others cannot borrow on their own recognizance, but must use whatever store-of-value payment mechanisms are available: real assets or outside money. If these are in limited supply, then adding bankers' transferable debt to the set of alternatives extends the economy's payment capacity. In Williamson (1999) and Kiyotaki and Moore (2000) bankers function as financial intermediaries as well, holding illiquid claims while simultaneously issuing liquid debt; in short, bankers are engaged in the task of "liquidity transformation."

In these models, separation between own-debt payors and inside-money payors is strict. In other words, no one in these models ever uses a debt to pay a debt, in marked contrast to the arrangements we observe in practice. Kahn and Roberds (forthcoming) give an expanded model of transferable debt in which agents at various times move from one category to another. The move is occasioned by the mix of assets currently held by the agent (think of the conversion of raw materials to finished product over a production cycle). In this world it becomes useful to pay outstanding debts with other forms of debt, thereby enabling the removal of agents from a "credit chain" (Kiyotaki and Moore 1997) in a timely fashion.

We would argue that this alternative approach to inside money is potentially important for understanding the role of liquidity in firms. In the corporate finance literature, there has been recently been a renewed interest in the precautionary demand for liquidity, and the determinants of a firm's cash holdings (Opler et al.; 1998, Kim et. al.; 1998, Almeida et al. 2004). Focus has centered on the decisions to raise liquidity by foregoing investment projects or engaging in external finance. But the timing of payment is one more method by which a firm adjusts its financial portfolio—the act of payment is a reordering of the seniority of its liabilities. Thus, timing of payments is another means of liquidity management. In order to build a credible model of the timing of payments by financial institutions, and the costs and benefits of delay, an account of payment as settlement of debt is necessary.

Bullard and Smith (2003) present another model of the usefulness of inside money. In their account, inside money economizes on transportation costs. Bullion is

more expensive to move than paper is. Suppose a chain of debts needs resolution, and suppose that this chain wanders off temporarily into Frontierland, before returning to an ultimate creditor who is in proximity to the ultimate debtor. Better to send a lightweight store of value following the path, and let the gold move the short distance to make final settlement of the chain. In other words, geographical separation can also make transferable debt valuable. Transportation costs could well be significant for explaining movements of paper and specie in, say the 19th century U.S., although the explanation requires the assumption that a store of value form of payment was for some reason mandatory on intermediate links in the credit chain.

Although often overlooked, the simplest inside-money scheme is in fact "net settlement," a payment system where, by prior agreement, obligations owed *by* a particular agent are automatically cancelled or "set off" using obligations due *from* other participants; remaining obligations must be discharged in some other fashion. By compelling the use of an institution's "due-froms" as inside money, netting in effect allows for mechanical and virtually costless exercise of claims against a counterparty. Kahn, McAndrews, and Roberds (2003) present a model in which netting can effectively reduce the amount of collateral necessary to sustain trade.

Netting is an ancient method of payment that is still widely used today, e.g., in large-value payment systems such as CHIPS and CLS. But netting is also subject to some noteworthy limitations. To be effective, netting arrangements must allow their participants automatically to exercise prior claims against other participants, a power that in some legal settings can conflict with bankruptcy law (Bliss 2003). Netting is also unlikely to work unless all parties involved are reasonably creditworthy. More reliable agents may have an incentive to exclude riskier agents from netting arrangements, or to force them to undergo screening before they can take part (Kahn and Roberds 2003).

3.1. Hybrid systems as suppliers of information

An appealing feature of hybrid arrangements is that they can provide supplemental information on the behavior of individuals over their past trades. Kocherlakota (1998) and related papers have demonstrated that an accumulated pile of money may sometimes be a sufficient statistic for the relevant trading history, but in general it will be desirable

to supplement this statistic with additional records. An important function of hybrid (inside-money) payment systems is to provide such information.

Suppose, for example, that trades are only directly observable by the two parties to the trade. Rather than exchange a good for an oral promise, it becomes useful to exchange a good for documentation—evidence that the trade took place. IOU's and receipts are in fact important parts of payments arrangements: in their own ways they are also stores of value—in this case, evidentiary value. (IOU's in particular serve as hostages; redeeming them forestalls lawsuits). Characteristically, IOU's and receipts are one-sided evidence, in the spirit of Lacker and Weinberg (1989): you can easily hide a receipt, but it's difficult to counterfeit one. Kahn and Roberds (forthcoming) explore a costly enforcement environment in which optimal mechanisms include incentives for collecting evidence and presenting to a court in the case of counterparty malfeasance. In this model, inside money in the form of personally issued transferable debt further extends the parameter space in which efficient transactions can be achieved (see also Mills, 2004). In other words, transferable debt that is tied to an agent's identity (e.g., a check) can provide greater evidence of the course of transactions than would the circulation of an anonymous coin or government-issued paper.

It is worthwhile to point out that the need for evidence has nothing to do with spatial isolation in any meaningful sense—in fact it is likely to be compatible with Walrasian mechanisms. The nearest thing we have to Walrasian mechanisms in the real world are the (remaining) open-outcry pits on the Chicago futures exchanges. Nonetheless, in the midst of all that public competition, consummation of an individual trade is accomplished by a pair of traders locking eyes and nodding—an act unobserved by anyone else in the room. Thus, even in this centralized situation, identifying evidence in the form of trade slips is indispensable.

The role of hybrid arrangements in establishing identity is explored in recent papers by Kahn and Roberds (2005) and Martin, Orlando, and Skeie (2006). Devices such as credit cards become a way of reducing the cost of establishing identities. To the extent that such identification is imperfect, fraud in the form of identity theft arises as an equilibrium phenomenon. Payment systems only survive if they keep fraud to a manageable level, but it would be prohibitively expensive to eliminate it entirely.

4. Payments and monetary policy

The widespread use of RTGS systems for payments between banks implies a close connection between payments and monetary policy. Overnight "policy" interest rates (e.g., the fed funds rate in the U.S.) are, after all, simply the prices over which a central bank is willing to provide funds over an RTGS system today (e.g., Fedwire) in terms of a reverse transfer the following day. As noted in the Introduction, the use of RTGS requires that traditional, "overnight" monetary policy be complemented some mechanism for the provision of intraday liquidity. Such a mechanism effectively constitutes an intraday monetary policy—a set of conditions under which a central bank is willing to provide funds during its daily operations. Such intraday credit is usually provided on generous terms, relative to overnight credit. In the U.S., banks were historically given access to free, uncollateralized daylight overdrafts, and even now they are charged a very low (36 basis point) fee, and only for overdrafts that exceed a cap.[18] Other central banks require collateral for access to intraday credit, but conditions for such collateral is often liberal in terms of asset eligibility and haircuts. There is usually no charge for such intraday credit, apart from the implicit cost of posting the necessary collateral.

A number of papers, beginning with Freeman (1996), have sought to explore the dichotomy between overnight and intraday monetary policy.[19] A recurring theme in this literature is that intraday central bank credit serves a fundamentally different function from overnight credit. Papers in this literature argue that while the demand for overnight central bank policy is dictated by the private agents' need to smooth consumption over time, the demand for central bank policy arises from the agents' inability to control the timing of incoming and outgoing payment demands during the day. To the extent that the requirement to use RTGS systems constrains the ability of private agents to contract away these timing mismatches, the implication is that central banks should make intraday credit available on relatively easy terms (Green 2003).

[18] A substantially higher fee is charged if the intraday overdraft is not repaid by the end of the day.
[19] Subsequent papers include Green (1997); Freeman (1999); Zhou (2000); Kahn and Roberds (2001b); Temzelides and Williamson (2001); Williamson (2003); Martin (2004); Fujiki (2006); Lester et al. (2006); Mills (forthcoming).

This literature thus provides some support for existing central-bank intraday monetary policies, but this support is subject to some important caveats. In these models, when private agents are allowed access to more sophisticated arrangements (effectively, some form of net settlement) their need for intraday central bank credit often either diminishes or vanishes altogether. And, as Lacker (2006) points out, in today's world where the "overnight" period of monetary policy spans just a few hours,[20] the distinction between overnight and intraday monetary policy has become less and less relevant. Liquidity now provided via specialized intraday credit facilities could also be provided through other mechanisms—in the U.S. case, Lacker proposes the use of intraday repos combined with payment of interest on excess reserves (mimicking systems already in place in countries such as Australia and New Zealand).

A related literature[21] has provided a more detailed analysis of strategic behavior by banks under various configurations for large-value payment systems. Although this literature confirms the central logic behind RTGS—that injection of central bank liquidity through an RTGS system can stem contagious failures (see Freixas and Parigi 1998; Freixas, Parigi, and Rochet 2000)—this literature has also highlighted some of the drawbacks of RTGS. A common theme is that RTGS systems are inherently more susceptible to coordination problems and dominated outcomes (e.g., delay of payments in an individually rational, but collectively futile attempt to economize on liquidity) than are systems that make use of net settlement.

Such analyses point to a more fundamental, but still relatively unexplored question: why should banks pay each other in central bank balances, i.e., why RTGS? The beginnings of an answer may be found in papers such as Holmström and Tirole (1998) and Kocherlakota (2001), which argue that the coercive powers of government allow it to create collateral (government debt) in states where adverse shocks might undermine forms of collateral available to the private sector. Building on these arguments, Kahn and Roberds (2003) construct a model in which a central-bank sponsored payment system economizes on collateral needed for payment during times of duress, relative to the col-

[20] Fedwire closes at 6:30 p.m. New York time and Asian wholesale systems (e.g., BOJ-NET) open just a few hours later, enabling a virtually continuous flow of funds around the globe.
[21] Including Kobayakawa (1997); Angelini (1998, 2000); Bech and Garratt (2003); Kahn, McAndrews and Roberds (2003); Freeman and Hernandez-Verme (2004).

lateral that would be required by a private-sector system. But this robustness may come at price. Rochet and Tirole (1996) note that central bank involvement in payment systems may introduce a too-big-to-fail problem, diluting banks' incentives to monitor counterparty exposures that may arise in a payments context. A similar argument is made by Fujiki, Green, and Yamazaki (forthcoming), who construct a mechanism design problem in which payment disruptions are sometimes necessary to induce agents to private information about other agents' creditworthiness. In their setup, attempts to mandate an absence of payment disruptions—to remove "systemic risk," as through the requirement to pay via RTGS—may result in a deadweight loss, since it can cause such valuable information to be withheld. On the other hand, the effect of such shocks will also depend on banks' exposures and on the degree of interconnectedness between banks. Kahn and Santos (2006) argue that participation in publicly maintained wholesale payment systems necessarily imposes a high degree of interconnectedness between banks, perhaps in excess of what would be efficient under private contracting; maintenance of a public system may be defensible, however, given that much of the utility of a payment system derives from its universality.

5. The industrial organization of retail payments

Papers in the monetary literature often assume that payment arrangements are administered by a benevolent social planner, or by a club of payment system participants. Such exercises offer useful benchmarks, particularly for wholesale payments where government-sponsored or cooperative arrangements are the rule. At the retail level, however, payment services, apart from those provided by currency, are usually provided by profit-seeking firms. As purveyors of "information goods" (Varian 1998), payment service providers are subject to large economies of scale and various types of externalities. These factors have led to significant concentration in the retail payments industry, which in turn has inspired a burgeoning theoretical literature on the industrial organization of payments.[22]

[22] As this literature has been extensively surveyed elsewhere (e.g., Chakravorti 2003; Hunt 2003; Rochet and Tirole 2004; Evans and Schmalensee 2005; Rochet and Tirole 2006a), this section provides only a brief outline of some of the relevant topics.

At the center of this literature is a debate about the pricing of payments using credit and debit cards. While there seems to be widespread agreement that electronic forms of payment offer the potential for greater efficiency, card-based payments in particular have in many cases remained more expensive (for merchants) than paper alternatives.[23] The price of card payments is invisible to most purchasers, because contractual agreements (*no-surcharge rules*) between the card providers and merchants prohibit merchants from charging extra for card payments. Instead the cost of card payments is reflected in *merchant discounts*, fees paid by merchants to the card companies. When the cards are provided through an association such as MasterCard or Visa, an *interchange fee*, paid by the merchant's bank to the purchaser's bank, comprises a significant portion of the merchant discount. Interchange fees are set cooperatively by the card associations. Card providers have also imposed *honor-all-card rules*, requiring merchants to accept all types of cards issued by the provider, if they accept any.

Do the level of prices for card payments and their peculiar structure reflect the exercise of market power by the card providers, or do they simply reflect the nature of the service provided? Rochet and Tirole (2004) argue that the prevalence of the merchant discounts reflects, most fundamentally, a failure of the Coase Theorem to hold in payment situations, leading to what is termed a "two-sided" markets for payment services. If for example, as in Rochet and Tirole (2002) the typical retail transaction is between a household and a merchant with some degree of monopoly power, charging consumers for card payments may inefficiently discourage the use of credit, compounding the welfare losses due to monopoly. Charging the other side of the market, i.e., the merchants, for card use (and imposing the no-surcharge rule to make such pricing meaningful) eliminates this problem but may inefficiently subsidize card payments. A similar analysis can be applied to honor-all-cards rule (Rochet and Tirole 2006b). Beginning with Baxter (1983), the literature has also defended interchange fees as necessary incentives to guarantee participation by all parties (buyer, seller, and their associated payment service providers) to an account-based transaction (for an updated treatment see e.g., Wright 2003).

While this literature has provided numerous theoretical insights, some notable challenges remain. The first is a closer integration of the I/O literature with the monetary

[23] See e.g., Humphrey et al. (2003); Garcia-Swartz et al. (2006a,b).

literature surveyed above. The second is a need for more consensus building in economists' assessment of current pricing structures in the industry (Evans and Schmalensee 2005; Rochet and Tirole 2006a), a process that has been hindered by the lack of available data.

6. Empirical work in payments

Payment systems are in the business of producing and storing large amounts of data, potentially providing some of the richest datasets in economics. But since the use of this "primary" type of data poses serious confidentiality issues, to date relatively few researchers have enjoyed access to it. A major challenge in this area is to find some means by which researchers may analyze data collected by payment systems, without compromising privacy.

In the comparatively small number of cases where researchers have gained access to payments data, some meaningful studies have been produced. Most of these have been performed by central bank economists with privileged access to data on wholesale systems. In a pioneering effort, Humphrey (1986) used data on the CHIPS system to determine that under its then-prevalent settlement rules, the likelihood of a chain of settlement failures over CHIPS was markedly larger than had previously been supposed. McAndrews and Rajan (2000) examine Fedwire data to show that the pattern of payments made over that system—peaking in the late afternoon as participants await payments from other participants—accords well with the predictions of models in the theoretical literature. Also employing Fedwire data, Furfine (2000) demonstrates a strong statistical link between interbank payments volume and short-term fluctuations in the overnight federal funds rate; Kamhi (2006) provides a similar analysis for Canada's LVTS system. A number of recent studies use data on various wholesale systems to investigate the potential for efficiency gains through the use of queuing algorithms, selective netting, and related techniques (e.g., Johnson, McAndrews, and Soramäki 2004; Galos and Soramäki 2005).

Data recorded by wholesale payment systems can also provide an invaluable record of banks' behavior during times of duress. For example, Furfine (2006) employs Fedwire data to analyze the market for unsecured interbank lending during the Long-Term Capital Management episode, finding little evidence of disruption in this market.

McAndrews and Potter (2002) analyze activity over Fedwire during and shortly after September 11, 2001, providing evidence that the extraordinary liquidity demands experienced during this time resulted primarily from banks' inability to coordinate payment flows.

In the area of retail payment systems, most studies have focused on the issue of consumers' choice of payment method, with a particular emphasis on the shift from paper to electronic payment methods. Lacking access to more precise data, most studies of retail payments have tried to infer consumer payments behavior through household surveys. The most widely employed dataset is the (U.S.) Survey of Consumer Finances (SCF). Studies employing various vintages of the SCF (Kennickell and Kwast 1997; Stavins 2001; Klee 2006a, Mester 2006) have established that demographic factors such as age, income, and education strongly influence consumers' payment choices, and have documented the shift towards electronic means of payment in recent years (this trend is confirmed very extensive payments industry survey reported in Gerdes et al. 2005). Carow and Staten (1999) obtain broadly similar results using data from a survey by Purdue University. Zinman (2006) uses SCF data to infer that debit card use is more common among consumers who are likely to be credit-constrained. Another approach in the literature has been to infer consumer choice from aggregate data on payment systems and data from industry sources. Among the papers in this literature are Humphrey et al. (2000), Humphrey (2004), Bolt et al. (2005), Garcia-Swartz et al. (2006a,b).

While these analyses have been informative, their lack of transaction-specific data has limited researchers' abilities to model the microeconomic behavior of consumer. This shortcoming has been partially addressed in some recent studies that make use of surveys more specifically targeted at consumers' perceptions of various modes of payment. Hayashi and Klee (2003) use data from a survey by American Bankers Association to link consumers' use of electronic means of payment with their use of other information technologies. Loix et al. (2005) find similar results using data from Belgian survey. Jonker (2005) analyzes data obtained in a survey in the Netherlands, indicating that consumers there continue to prefer cash for many transactions, despite the perceived convenience of paying by debit card. Recent papers by Borzekowski and Kiser (2006) and Borzekowski et al. (2006) combine the two prevalent approaches in the empirical literature. They are

able to estimate demand functions for various methods of payment, using data from the Michigan Survey (demographic data plus consumers' attitudes toward different types of payment) with data on the "average" characteristics of certain payment types (electronic versus paper, time of use, bank fees, etc.).

Only a few empirical studies of retail payments have been able to use actual payments data, some notable examples being Klee (2004, 2006b), Fusaro (2006), and Rysman (forthcoming). Using data provided by a grocery retailer, Klee finds that a major determinant of consumers' payment choice is simply transaction size, with cash being highly favored for small-value transactions involving just a few items. Analysis of the same dataset indicates a marked transaction-time advantage for debit cards over checks, helping to explain the recent popularity of the former. Fusaro uses a sample of bank accounts to examine behavioral explanations for consumers' preference for debit over credit card transactions. Rysman uses data collected by Visa to determine that while consumers may hold multiple payment cards, in practice they tend to concentrate card payments on a single card network.

In short, empirical studies have provided some instructive snapshots of payments behavior at the retail and wholesale levels. But there are limits to what information can be gleaned from surveys and aggregate statistics—imagine what financial economics would be like if the only available data were surveys of traders and year-end closing prices. Obtaining a more complete understanding of how payment systems actually work, and why people choose to use them, will have to await the availability of more extensive, and more accessible data. And, better empirical work will lead to better theory.

7. Conclusion

Payment is more than a mechanical act. It is, in a sense, the quintessential economic activity, the "glue" that binds together the gains from trade. As such, an act of payment also represents a decision. The choice of whether, when, and how to pay depends on a variety of characteristics of the agents involved in the trade: demographics, value, variability, and liquidity of assets, differential information, risk aversion. The choice also depends on the environment: legal structure enforcing contracts, importance of reputation and ease of damaging it, market interest rates and prices. And in the back-

ground, the ability to establish particular terms—indeed the feasibility of trade itself—rests on the availability and cost of a payment system.

In times when payment infrastructure is unchanging, the background becomes opaque. The frequency, the very ordinariness of payment renders it difficult to analyze. We are *not* living in such times. The technological changes of the Internet, the dramatic declines in the costs of computation, and, not least, the institutional changes wrought by international competition and convergence, have led to important changes in the payment systems, both retail and wholesale—and thus made it obvious that payments and system design matter. In such periods renewed interest also arises in the institutional histories and workings of earlier payment regimes. On the horizon are linkups with the law and economics literature, reappraising our understanding of contracts and payments law (for example, the U.C.C.) in terms of the new insights. Also on the horizon are models of macroeconomic fluctuation with a better micro-foundation than the cash-in-advance paradigm provides.

While the empirical work is still in its infancy, the recent study of payments has also led to interesting theoretical insights and potential policy prescriptions. Our examination of this theoretical work leads to the following messages:

1. Despite our habit of modeling of money in geographically-dispersed frameworks, payments still matter even if the world is not decentralized. As long as a time mismatch in trade arises and enforcement of credit arrangements is imperfect, payment systems design will affect an economy.
2. Informational limitations are a key factor in limiting enforcement, and thus are a key factor in the success of a payment system. Verification of identity is central to accounts systems, just as counterfeit protection is central to store-of-value systems.
3. Informational limitations are not set in stone. At a cost, they can be and are overcome. Although anonymity places severe limitations on payment arrangements, anonymity can be pierced at a cost. If the benefit is high enough the institutions for gathering or recording the information develop.

Our models have made a start—but the models have just scratched the surface. Even if others find plumbing boring, plumbers (and plumbing inspectors) won't be out of a job any time soon.

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