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ON THE ECONOMICS OF INTERBANK PAYMENT SYSTEMS

by Paolo Angelini and Curzio Giannini (*)

Abstract

The paper addresses some general questions raised by the continuous-time nature of most present-day interbank payment systems. Thanks to technological and organizational improvements, it is now possible for participants in net settlement systems to obtain real-time information on net positions during the day. The main benefits, in terms of improved cash management, accrue to the receiving bank and its customers. However, settlement and systemic risks may increase as a result of the availability of intra-day information, if the latter is used by the receiver either to undertake new intra-day transactions through gross systems, which by definition are immediately final, or to enter new binding commitments. The secular decline in the interval between consecutive settlements is also explained on the basis of additional risks that larger volumes and faster payment procedures entail. Highly developed financial markets tend to increase the relative attractiveness of gross settlement systems, in which the settlement lag is zero. As to their organization, we argue that due to externalities, a purely decentralized equilibrium entails a suboptimal (low) level of reserves; this may explain some of the problems experienced by existing gross systems.

Contents

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1. Introduction[1]

Centralized procedures for clearing and settlement of payments are almost as old as bank money. Despite a number of institutional and organizational complications, the underlying structure has hinged throughout the centuries on three common features: a) a discrete-time clearing process, generally entailing regulations on the types of admissible documents and the number of participants; b) a discrete-time settlement phase to be held immediately after clearing; c) a liquidity-enhancing scheme to be activated in case individual members proved unable to settle their net dues at the end of the process.[2]

Although until a few years ago this basic structure remained essentially unaffected, the lag between two consecutive settlements has decreased over time, from several months in the Renaissance, to one week or less in the nineteenth century according to the specific financial center and product, to one day in our times. This process has now reached its logical conclusion, as the recent wave of innovation has made it technologically feasible to do away with discrete-time procedures. That is, the clearing process may now be made continuous during the day, with a settlement

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1. We thank Franco Passacantando, Daniela Russo, Renato Serafini and two anonymous referees for their useful comments to previous drafts. Rita Camporeale provided valuable editorial assistance. Neither they nor the Banca d'Italia are responsible for the views expressed in the paper and remaining errors.

2. The first regular clearing and settlement procedures on which detailed evidence is available are the so-called "exchange fairs" of the late Middle Ages and the Renaissance; see Boyer-Xambeu, Deleplace and Gillard (1987). For recent discussions, see Frankel and Marquardt (1983); Garber and Weisbrod (1990).

phase at the end of it, as is the case in the so-called net settlement systems. Alternatively, payments may be settled continuously and on an individual basis, as in the so-called gross settlement systems. Moreover, the limits to the number of participants in the procedure and/or of admissible transactions, which in the past were partly due to technological constraints, are now mainly an organizational option. It is now technically feasible to send electronic payment messages in real time at a negligible cost, regardless of the size of the payment, the unit of account, and the location of the operators involved.

All this helps explain the unprecedented increase in the volume of payments, which in the main industrialized countries amounts now to several times annual GNP (fig. 1). As this growth is mostly accounted for by provisional payments,[3] there is increasing concern about settlement risk. This problem has been magnified by the rapid increase of cross-border transactions, whose settlement is complicated by organizational and legal differences among domestic payment systems.

Policy-makers are confronted with a range of options. At one extreme, they could adopt a policy of "benign neglect", letting the market choose the appropriate organizational structure of interbank payment procedures. At the other extreme, they could, either by fiat or through appropriate incentives, induce market participants to settle on a gross basis, so as to remove settlement risk altogether. In between, there lies a whole range of intermediate options,

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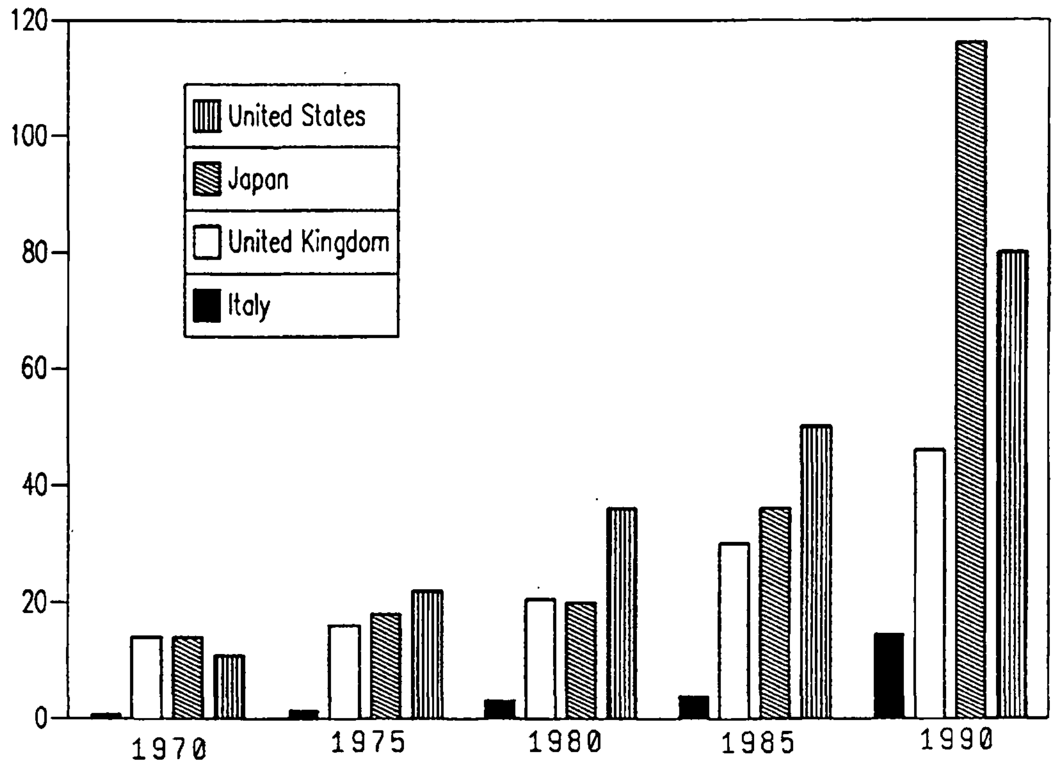
3. A payment is "final" when it is irrevocable and unconditional. Accordingly, payments handled by net settlement systems remain "provisional" until final settlement, unless a specific finality rule is adopted. On the issue of finality, see Mengle (1990); Board of Governors of the Federal Reserve System (1988).

Fig. 1

PAYMENT VOLUMES IN FOUR INDUSTRIALIZED COUNTRIES (*)



Source: BIS, Annual Report, June 1992; Banca d'Italia, Annual Report, May 1992.
(*) Ratio between the overall value of interbank payments and GNP.

such as promoting safer net settlement arrangements.

The heterogeneity of payment systems in the main industrialized countries bears witness to the complexity of the issues involved and the lack of a widely-shared analytical and policy framework. Only two elements are common to all countries: a pyramidal structure, with the central bank lying at the top, and restrictions on access to the clearing systems. Only a few countries have introduced gross settlement systems, but have organized them in different ways. Also business hours, membership criteria and risk control practices differ widely.

Greater perception of the policy issues to be confronted in the area of interbank payments has spurred a growing literature. Substantial effort has been devoted to collecting and comparing factual information on current institutional arrangements and practices,[4] and to the analysis of measures to increase the safety of existing procedures.[5] Comparatively little attention has been devoted to the economics of wholesale payment systems, and in particular to a theoretical assessment of alternative institutional arrangements.[6]

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4. See e.g. BIS (1989), (1990a); Banca d'Italia (1988), (1991); Borio, Russo and Van den Bergh (1991); Padoa-Schioppa and Saccomanni (1991); Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992a).

5. See e.g. Board of Governors of the Fed (1988), (1989); BIS (1990b); Humphrey (1986); Padoa-Schioppa (1988), (1989), (1992); Passacantando (1991), (1992); Banca d'Italia (1992); Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992b).

6. Notable exceptions are Frankel and Marquardt (1983) and Garber and Weisbrod (1990). See also Gelfand and Lindsey (1989); Lempinen and Lilja (1989).

This paper is in the latter strand of research, and concentrates on four sets of issues. In Section 2 we focus on the impact of intra-day payment information, which represents the main qualitative difference between old and present-day payment systems. Specifically, we use a simple model to analyze the usefulness of information flows, abstracting from risk considerations. In Section 3 we introduce settlement risk and look at the determinants of the settlement lag, i.e. the time interval between two consecutive settlements; in particular, we discuss the factors that may account for the observed secular decline in settlement lags and the conditions under which a zero settlement lag would be desirable. In Section 4 we analyze efficiency and risk features of different gross settlement systems, comparing the three basic organizational models that have so far emerged. In Section 5 we consider the relative desirability of alternative interbank payment systems and give some indications for further research. The final Section summarizes the main points and draws some conclusions.[7]

2. The value of intra-day information and its risk implications

In a discrete-time payment system the amount of information available to each participant - say a bank - prior to settlement depends on the payment instrument. For payments involving credit instruments (banknotes and cheques), a hypothetical bank A knows the amount of incoming payments, because the payment instruments are collected by A through its normal business. Outgoing payments, however, are

7. All throughout, we abstract from a number of institutional details and leave legal aspects aside. Section 5 contains some reflections on how the institutional and legal setting may affect the relative attractiveness of alternative payment mechanisms.

unknown until clearing, because bank A has no way to know how much of its banknote issue or how many cheques drawn on its customers' accounts will be presented at the clearing phase. For payments based on debit transmission procedures (payment orders, standing orders and direct debits), the reverse is true: bank A has real-time information on outflows, but not on inflows.[8]

Since the computation of net balances takes place just before settlement, the information regarding the size of net balances cannot be used in any way. On the contrary, in net settlement systems participants have real-time access to the information concerning both payment inflows and outflows, so that net balances are known in real time. The first theoretical issue raised by recent developments is therefore: is intra-day information valuable, to whom does this value accrue and how does it affect the choice of the parties involved?

In this Section we first abstract from risk considerations. We assume that the probability of default on provisional payments flowing through the interbank system is zero, and assess the distribution of the benefits of intra-day information among the relevant agents. We then move on to consider the risks related to intra-day information.

A bank that acts as sender and receiver of provisional payments on customers' behalf faces two sources of uncertainty: first, it does not know with certainty the amount of incoming payments; secondly, it does not know the exact amount of payments it will be required to send by its clients, who may come in at any time during the business day. Let t_0 and t_1 be the beginning and the end of the operating

8. On the distinction between credit instruments and money transmission procedures see Banca d'Italia (1988).

period, respectively (e.g. 9:00 a.m. and 4:30 p.m.). Define:

$$Z = \sum_{i=t_0}^{t_1} z_i \; ; \qquad Y = \sum_{i=t_0}^{t_1} y_i \; ; \qquad V = \sum_{i=t_0}^{t_1} v_i ;$$

where z_i and y_i are, respectively, the value of payments ordered by clients and received from other banks at time i. We assume that, from the standpoint of the individual bank, z_i and y_i are random variables with a known joint density function $g(y_{t_0}, \ldots, y_{t_1}, z_{t_0}, \ldots, z_{t_1})$. v_i may be thought of as payments resulting from operations that the bank undertakes to offset the flow of incoming and outgoing payments, which are out of its control. For instance, if during the business day the value of incoming payments exceeds that of outgoing ones, the bank will tend to be a net supplier of funds ($v_i<0$) on the interbank market. Let $X = Z - Y - V$. If $X > 0$ the bank will not be able to settle its end-of-day position, so that part of its outgoing payments will have to be postponed to the following day. Alternatively, the bank will have to borrow from the monetary authority at a penalty rate; in the worst case all its transactions will be unwound. If $X < 0$, after settlement the bank will be left with an excess of liquidity, and will incur the relative opportunity cost.

In short, the bank bears a cost when X is different from zero. In trying to minimize this cost, the bank has an incentive to postpone compensating operations v_i towards the end of the day, since the later decisions are made, the lower the uncertainty about X. On the other hand, the bank will plausibly face a cost related to postponing operations due to market imperfections.[9] In short, we may assume that the bank faces increasing costs if it postpones operations v_i too long. We describe these costs with a function $\gamma(v_t,t)$, increasing in both arguments.[10]

Thus, we can write the problem faced by the representative bank at time t as follows:

$$\min_{\left[v_i\right]_{i=t_0}^{t_1}} rV + \int_V^{\infty} hXf(Z-Y \mid I_{i-1})d(Z-Y) + \sum_{i=t_0}^{t_1} \gamma(v_i,i) \qquad (1)$$

where r is the rate on borrowing/lending funds in the inter-bank market, h is the cost of illiquidity (e.g. the rate on refinancing), $f(\cdot|\cdot)$ is the conditional probability density function over which expectations are taken and I_t is the information set, which is empty at t_0 or earlier. The term rV captures the opportunity cost (gain) of borrowing (lending) reserves, whereas the term in the integral captures the illiquidity costs described above. Consider:

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9. If postponing compensating operations until settlement time involved zero expected extra cost, i.e. if the market were perfectly liquid, the bank's planning problem would be trivially solved by lending or borrowing Z-Y in a lump at t_1. The bank may be induced to enter compensating operations in advance since the closer settlement time, the lower the probability to find interesting investment opportunities (or sufficient funds to borrow). In particular, for banks which expect to end the day in a net debtor position, the probability of having to resort to central bank credit at penalty rates increases with time. Further, inputting payment messages takes time and generally a confirmation message is required, so that the process cannot be shortened too much without running into technical difficulties.

10. We assume $\gamma'>0$ for $v_i>0$, $\gamma'<0$ for $v_i<0$, $\gamma''>0$. This is a special version of the model first proposed by Baltensperger (1974).

$$\Psi[f(Z-Y \mid I_{t-1})] \equiv \tag{2}$$

$$\equiv \underset{\left[v_i\right]_{i=t_0}^{t}}{\text{Min}} \quad rV + \int_V^{\infty} hXf(Z-Y \mid I_{t-1})d(Z-Y) + \sum_{i=t_0}^{t_1} \gamma(v_i, i)$$

Alternative assumptions about the information set I_t allow to characterize the difference between "old" and "new" clearing systems. Based on the previous discussion, assume that in the new systems the bank has access to real time information on incoming payments y_i. The information sets for the "old" and the "new" system at time t will then be $IO_t=(z_{t_0}, z_{t_0+1}, \ldots, z_{t-1})$ and $IN_t=(z_{t_0}, z_{t_0+1}, \ldots, z_{t-1}, y_{t_0}, y_{t_0+1}, \ldots, y_{t-1})$, respectively. The expected value of the additional "signals" $y_{t_0}, y_{t_0+1}, \ldots, y_{t-1}$, available to the bank in the electronic system can be found by taking the expectation of (2) with respect to IO_t and then applying Jensen's inequality to the resulting expression. Due to concavity of Ψ in f,[11] we get:

$$E\left(\Psi[f(Z-Y \mid IN_{t-1})] \mid IO_{t-1}\right) \leq \tag{3}$$

$$\leq \Psi\left(E[f(Z-Y \mid IN_{t-1}) \mid IO_{t-1}]\right) = \Psi[f(Z-Y \mid IO_{t-1})]$$

The last term in (3) is equal to the expected minimum cost in the "old" system. This shows that the expected cost in the latter is generally higher than in systems in which participants have access to intra-day information flows. The first order conditions are:[12]

11. For a proof see DeGroot (1970), chapter 8.

12. The second order conditions are easily verified.

$$\int_{V}^{\infty} f(Z-Y \mid I_{i-1})d(Z-Y) = \frac{r + \gamma_1}{h} \tag{4}$$

$$i = t_0, t_0+1, \ldots\ t$$

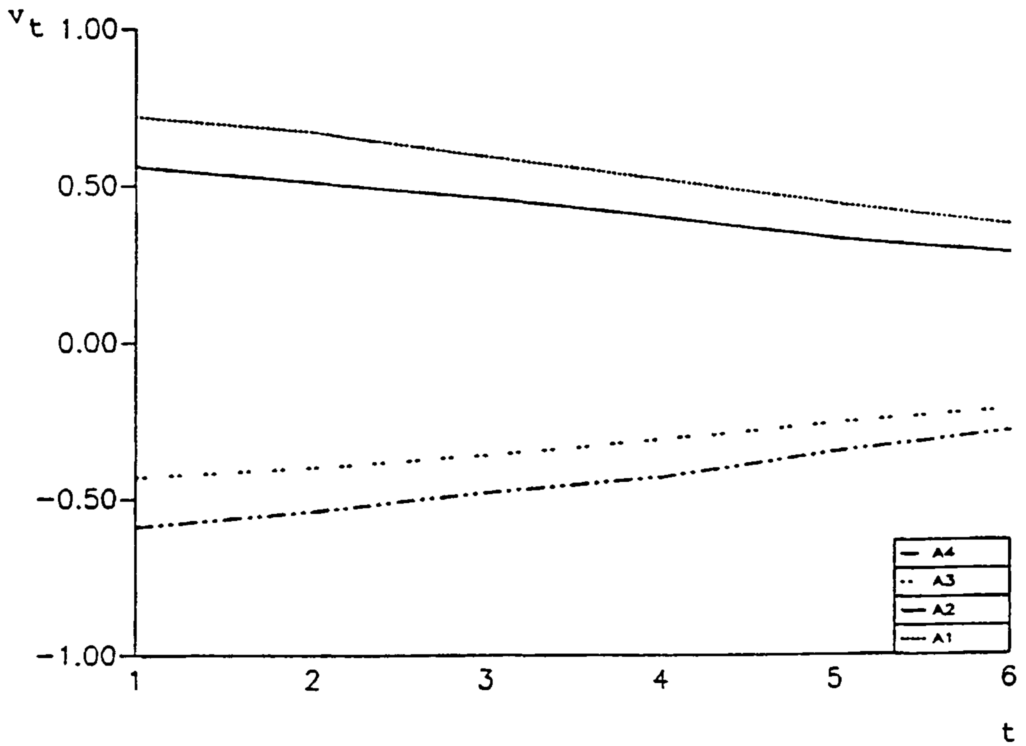
where the subscript on γ denotes differentiation with respect to the first argument. Since an analytical solution to the system (4) cannot be worked out, a numerical solution was computed; the resulting optimal trajectories for the control variables v_i are plotted in fig. 2 for various values of the parameters, given in the annexed table. According to the simulations, in the "new" system, where more information entails a lower degree of uncertainty (proxied by a smaller conditional variance), the expected cost and the level of reserves borrowed in the interbank market are lower (trajectories A1 vs. A2); an increase in the opportunity cost of borrowing reserves, r, or a higher than usual inflow of payments (a negative conditional mean of Z-Y) may induce the bank to change side of the market, becoming a net supplier of funds (trajectories A1 vs. A3, A1 vs. A4). In general, as shown in the table annexed to fig. 2, the expected cost Ψ will be positive.

To sum up, the important change caused by the introduction of provisional payments is the possibility for banks to know the flow of incoming payments before final settlement; <u>ceteris paribus</u> this reduces uncertainty about banks' end-of-day liquidity position and improves their planning of outflows.

Thus far, we have assumed that a bank's incoming and outgoing payments follow independent random processes. However, outgoing payments may be correlated with incoming messages. For example, if the bank immediately passes the information on incoming payments onto its customer, the

Fig. 2

NUMERICAL SIMULATIONS FOR EQUATIONS SYSTEM (4) (*)



(*) Discrete values for the control variables v_t are calculated by numerical solution of the system of first order conditions (4). We assume that there are six periods to the end of the business day, that the conditional density $f(Z-Y \mid I_{t_1-6})$ is normal with mean μ and standard deviation σ, and that $\gamma(v_t,t) = v_t^2 * t^2$. The trajectories A1-A4 are obtained with the parameter value (and yield the expected costs ψ) reported in the following table:

	A1	A2	A3	A4
μ	0	0	0	-0.2
σ	1	0.5	1	1
r	0.13	0.13	0.15	0.13
h	0.285	0.285	0.285	0.285
ψ	0.113	0.054	0.114	0.087

latter will have an incentive to exploit it, adjusting his portfolio accordingly. To do so the customer may send new payment messages before the close of the business day. This may introduce noise in the receiving bank's information set, partially offsetting the benefits of intra-day information flows. The receiving bank may therefore have an incentive to withhold the information from its clients. This is a typical principal-agent problem, whose outcome is likely to depend on the bargaining power of individual customers.[13]

Let us come to the issue of risks related to intra-day information flows. The main problem with provisional payment messages is that the sender may be unable to honor them at settlement. This generates settlement risk, which has been a growing cause of concern for both regulatory authorities and banks and has spawned the recent debate on systemic risk in net settlement systems. This debate has resulted in a widespread move towards the adoption of risk reduction measures and a growing interest in gross settlement. Let us therefore analyze in more detail the costs of a settlement failure.

Suppose that all payments were provisional until final settlement. If some of the payments that a bank has received were not settled at the end of the operating period, the bank could react by simply cancelling outgoing payments

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13. Thus, when the payee is a large corporation, the chances that intra-day information is timely released are fairly high. As a result, the practice of making funds available to customers prior to settlement has become relatively common in a number of large-value net settlement systems, such as CHIPS in the United States and FEYSS in Japan. Even when banks do not make funds available, but simply release the information on incoming payments, the independence between incoming and outgoing payments is no longer guaranteed if there are unused lines of credit from which corporate customers can draw automatically during the day.

for the same amount. The bank would be more exposed only to the extent that it had already used intra-day information either to undertake new final transactions (e.g. payments in cash or channelled through a gross settlement system), or to enter into some legally binding commitments. In this case the bank could find itself with a vanishing asset (the cancelled provisional payment) and a binding liability (the final payment or the irrevocable commitment). If no final payments were made, the unwinding of payments following a participant's failure to settle would entail no consequence for the surviving banks, other than additional transaction costs. Widespread concern about chain defaults is thus warranted only if substantial flows of irrevocable commitments are generated in connection with provisional payments, or if transaction costs are sizable.

It is natural to ask at this stage why not all payments are made on a provisional basis during the day. This is a special version of a more general question: why is there such a thing as final settlement? This is the issue we address in Section 3.

3. The optimal settlement lag

The main benefit of net settlement - and of clearing in general - is the reduction in transaction and opportunity costs it allows in terms of reserve holdings. If this were the whole story, however, it would be socially optimal to defer settlement indefinitely, thereby avoiding both the opportunity cost of holding reserves and the cost of moving them from one account to another.

But this is obviously counterfactual. First, clearing systems have always provided for periodic and regulated settlement. Second, the settlement lag has decreased over time, dropping down to zero in present-day gross settlement systems. Two questions must therefore be tackled: a) what determines the length of the settlement lag?; b) what has driven the observed secular decline?

The model used in the previous Section is inadequate to answer these questions, in that the time horizon was restricted to one operating period. Assume now that provisional payment messages are subject to default risk, and that the bank faces a horizon of n operating periods and can choose to settle every m operating periods, $1 \leq m \leq n$. When final settlement is postponed, there is a strictly positive probability P that the sending bank will fail to settle. P can be assumed to rise as the settlement lag s increases,[14] so that for a given exposure the bank faces growing settlement risk: $P'(s)>0$, $P(0)=0$. The exposure will be equal to the gross amount of payments received over a given period. Assuming for simplicity that the bank uses all its incoming payments to make irrevocable commitments, its expected credit-risk cost will be:

$$C1[P(s),\underline{Y}] = P(s)\underline{Y} = P(s)\sum_{i=1}^{n} Y_i \qquad (5)$$

where Y_i stands for total payments received during operating

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14. The underlying idea is that as the chain of provisional payments expands, the probability that some untrustworthy payor gets into the chain increases. Letting p be the constant probability of settlement failure in each operating period (e.g. the day), P would be the probability of recording at least one settlement failure over n operating periods; it could be computed from a binomial model and would tend to one as the settlement lag tends to infinity. Garber and Weisbrod (1990) note that growing settlement risk borne by the receiving bank is a key element in the determination of a finite settlement lag. On settlement risk, see Gelfand and Lindsey (1989).

period i, in analogy with the notation used in Section 2, and $n \leq \infty$ is the number of operating periods (e.g. days). The function C1 is represented in the top panel of fig. 3.

On the other hand, the bank bears a settlement-related cost, due to the fact that the target X=0 is normally missed at each settlement. Hence the bank has an interest in postponing final settlement as long as possible. Let X_i be the excess liquidity on the settlement account at the end of operating period i, and $\Psi(X_i)$ the related minimum expected cost, as in Section 2. Then the expected cost related to the frequency of settlement over n operating periods is:

$$C2[\underline{\Psi},s,a] = (a+s)^{-1}\underline{\Psi} = (a+s)^{-1} \sum_{i=1}^{n} \Psi(X_i) \qquad (6)$$

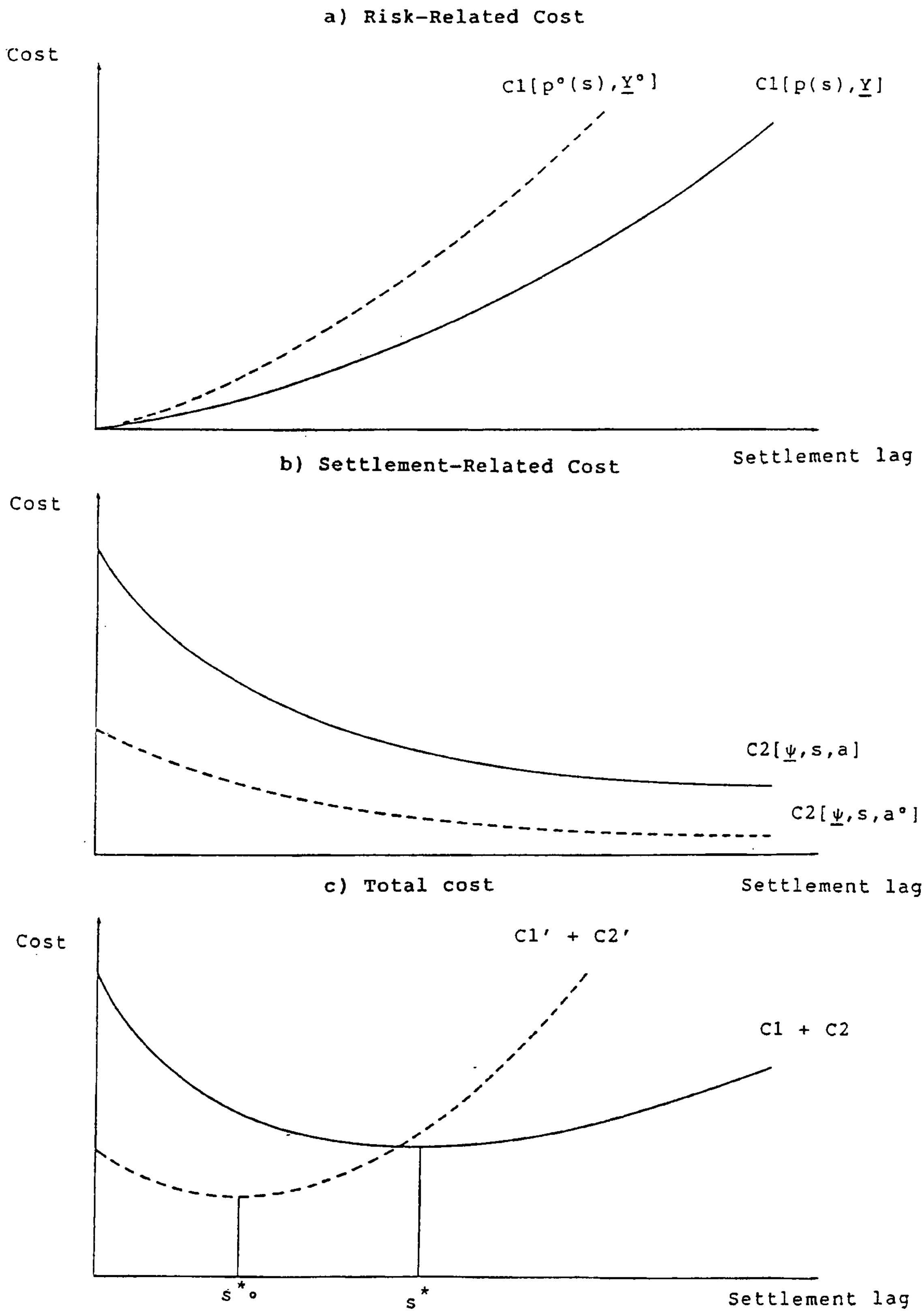
where a>0 is a constant that captures fixed unit costs. The idea behind (6) is that the costs due to market imperfections, captured by the function γ in Section 2, materialize only as settlement approaches. Thus, if n/s settlements occur over n operating periods, the costs of "missing the target" will be incurred n/s times, and will clearly be minimum for s=n. The function C2 is represented in the middle panel of fig. 3.

Therefore, by postponing final settlement the bank saves on settlement-related costs but incurs risk-related costs. Thus, a finite settlement lag results from a compromise between these conflicting effects. Minimizing the expected sum of (5) and (6), the optimal interval is determined by the following first-order condition:

$$P'(s)E(\underline{\Psi}) = E(\underline{\Psi})/(a+s)^2 \qquad (7)$$

Fig. 3

PAYMENT SYSTEM COSTS



where expectations are taken with respect to the appropriate densities.[15] The value of s that satisfies (7) corresponds to point s^* in the bottom panel of fig. 3.

Let us now turn to the second question: why has the settlement lag decreased over time? There are three main forces at work here: technological innovation, competition and integration.

Let us consider the impact of technological innovation first. As we have seen in Section 2, improved information flows reduce the expected settlement costs incurred in each operating period, and hence $\underline{Y}$. Unit transaction costs, measured by the parameter a, are also reduced. On the risk side, technological progress entails a higher volume of provisional payment messages flowing in during the day; besides, it may induce a lengthening of the transaction chain, due to the possibility of sending payments more rapidly, and hence a greater risk of running into some untrustworthy payor. Ceteris paribus, this produces a higher exposure $\underline{Y}$ and a higher probability of default P(s) for given s.

Turning to competition, an interbank payment system can be depicted as a cooperative equilibrium of a repeated game. As is well known (Axelrod, 1984), cooperation can be sustained if the game is repeated long enough, if agents have perfect monitoring capacity, and if the future is not heavily discounted (and the rate of discount is common knowledge). The equilibrium under which a centralized clearing procedure operates may be disrupted by shocks affecting the cooperative attitude of participants who, after all, are competitors not

15. Assuming that $P''>0$, the second order condition can be easily verified. $P''>0$ was assumed in drawing fig. 2.

only in the market for payment services but also in the credit market (Padoa-Schioppa and Passacantando, 1989). For example, if the degree of competition in the various markets on which banks operate suddenly increases, as has been the case during the eighties due to deregulation, established practices and mutual trust within the interbank payment system are bound to come under strain. The opening of new markets, the removal of existing barriers, or the entrance of new competitors in the payment arena can be expected to raise P(s) for given s.

Finally, international integration. The recent growth of cross-border payments raises particular problems, since the legal and institutional environments in which the parties involved operate may differ considerably, making it difficult to identify risks and respective responsibilities. Further, in foreign exchange transactions the presence of two units of account means that final settlement is likely to be split into two phases, possibly giving rise to what is known as "Herstatt risk".[16] Therefore, as the share of cross-border payments on the total increases, risks associated with delayed settlement will tend to rise; this will again increase P(s) for given s.

Fig. 3 summarizes the impact of these effects. Risk-related expected costs will be adversely affected by increased payments flows, competition and integration: for a given settlement interval s, an increase in $\underline{Y}$ and in P - for instance to $\underline{Y}°$ and P° - will rotate the curve C1 upwards. Technological innovation will tend to reduce unit costs and settlement costs, moving down the curve C2 and flattening it. The minimum of the joint-cost curve will accordingly move to

16. Herstatt risk occurs when the two legs of a transaction become final at different times, exposing the party that settled first to credit and liquidity risk. See Banca d'Italia (1992).

the left, so that the optimal settlement lag shifts from s^* to s^{*o}. As transaction costs tend to zero or the probability of default increases settlement will tend to become continuous.

Along these lines, it seems possible to explain not only why settlement lags are everywhere finite and declining, but also a number of features that have accompanied the evolution of clearing systems. First, the rather severe admission criteria and club-like practices which have been, and still are, typical of clearing procedures may be related to the need to promote mutual trust among participants and reduce the risk of conscious misbehavior.[17] Second, the approach may explain why "being a bank" is almost everywhere an important admission criterium: in facts, banks specialize in producing information, perform routinely both the receiving and sending functions on third parties' accounts and, finally, have access to lending of last resort facilities.[18]

4. Reserves and risks in gross settlement systems

So far, we have referred to gross settlement systems as if all had the same features and risk implications. In fact, the risk and efficiency properties of a gross system depend considerably on how the latter is actually organized. Disregarding a series of institutional details, gross systems can be grouped into three categories, which we label respectively "pure", "overdraft" and "queuing" systems.

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17. On the role of institutions as transaction-cost-reducing devices, see Eggertsson (1990); North (1991).

18. On the relation between banks' information-production features and their role in the payment system, see Goodfriend (1990); Folkerts-Landau and Garber (1992).

In a pure system an outgoing payment drawn on an account with sufficient funds is settled in real time; if available funds are insufficient, the payment is rejected and must be entered afresh at a later stage. In the latter case, there obviously arises a lag between the time the payment is ordered by the payor and the time it is credited to the account of the payee's bank. By contrast, in an overdraft system payments are processed and settled even if the sending bank's reserve holdings are insufficient, thanks to a "daylight" credit automatically granted by the central bank. Thus, compared to pure systems, overdraft systems guarantee the finality of transactions while allowing sending banks to hold a substantially lower (even zero) level of funds on settlement accounts during the operating period. A queuing system works like a "pure" system, except that whenever the value of outgoing payments exceeds available funds on the sender's account, the payment is not rejected and cancelled but automatically queued and released (generally on a FIFO basis) when sufficient funds become available.

If we consider these stylized systems as being composed of a certain number of representative banks which exchange electronic payment messages and minimize their costs, we may think of two different equilibrium configurations. In the first, participants base their decisions on individual cost minimization. In the second, the equilibrium reflects a cooperative agreement whereby banks minimize the sum of their respective individual costs. Comparison of the two equilibria may be based on three issues: the aggregate level of reserve holdings, the amount of daylight overdrafts granted by the central bank and the speed of payment execution.[19]

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19. A formal derivation of the results that follow can be found in Angelini (1993).

1. Level of reserves. Since the interest rate on reserves held with the central bank typically lies below market rates, the aggregate level of such reserves in a decentralized equilibrium will be lower than in the cooperative equilibrium. This happens because each participant's reserve holdings generate an externality that benefits all other participants in the system. An example may clarify this effect. Suppose that bank A must send a payment to bank B and that B must send a payment to a third bank. If A has sufficient reserves on its centralized account (or resorts to daylight overdrafts) and makes its final payment to B, the latter will not have to hold as high a level of reserves as it would have had without A's incoming final payment. Since holding reserves is costly, B has an incentive to wait for A to settle its transaction; if A settles, B benefits from a positive externality.[20] This situation can generate gridlocks.

This effect, which characterizes pure systems as well as queuing systems, seems to be empirically relevant. In Switzerland for example, as part of the reorganization of the national queuing gross system, SIC, reserve requirements for settlement accounts were eliminated in January 1988. As a consequence, in the following years the aggregate level of reserves dropped substantially (fig. 4).[21] Indirect evidence

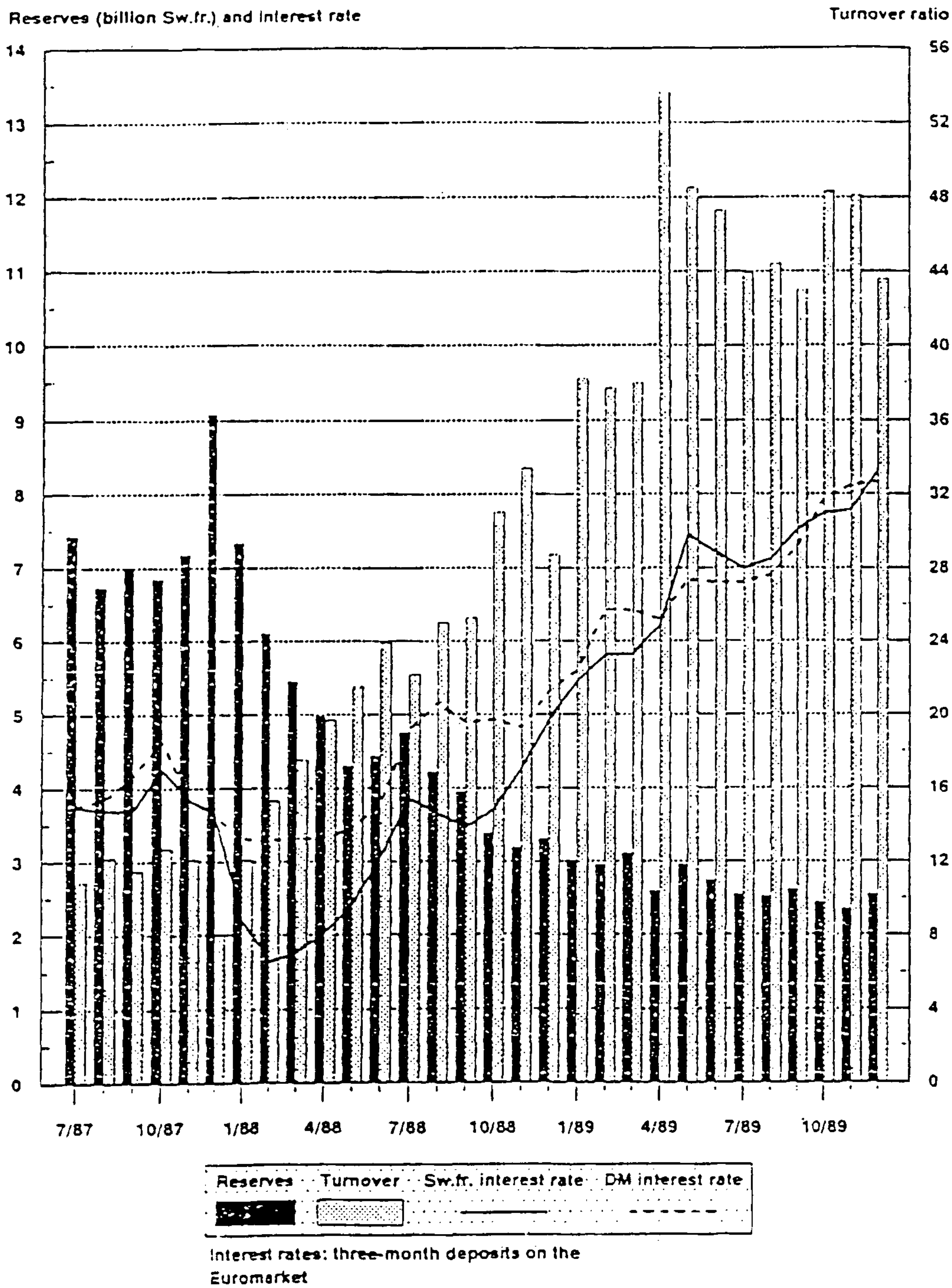
20. This effect, stemming from incomplete markets (there is no market in which A can make B pay part of the costs) is similar to the one found in the analysis of public goods. The aggregate demand for reserves is suboptimal for the same reason why, in equilibrium, the quantity of public goods is suboptimal: without exogenous constraints, each bank's demand for reserves will be lower than it would be if all the costs and benefits fell on the bank. A similar external effect was noted by Laidler (1977) within the context of money demand analysis.

21. See Vital (1989), (1990).

Fig. 4

RESERVE BALANCES, DAILY TURNOVER OF RESERVE BALANCES AND MONEY MARKET RATES

(Monthly averages of daily figures)



Source: Vital (1990).

is also provided by the fact that in several countries banks have proved to be somewhat reluctant to switch to gross settlement, unless backed by a liquidity-enhancing facility provided by the central bank.

2. Volume and impact of daylight overdrafts. In an overdraft system, daylight exposures guarantee the finality of the transaction even though the funds on the sending bank's centralized account are insufficient, thereby allowing sending banks to economize on costly reserves. Against this private benefit there is a social cost, that is the credit risk borne by the central bank. The discrepancy between private and social costs may lead to over-use of daylight overdrafts. A second reason why daylight overdrafts in the decentralized equilibrium may tend to be higher than in the cooperative equilibrium has to do with the suboptimality of reserve holdings. Suppose that bank A must send a payment to bank B for $100 and that its optimal level of reserves is $50. Then A shall resort to $50 daylight overdraft. Obviously, had A's equilibrium level of reserves been higher, resort to daylight credit would have correspondingly been lower.

The main existing overdraft system, namely Fedwire in the United States, has indeed experienced high levels of overdrafts use, giving rise to concerns that the social costs of the system had been underestimated.[22] Several risk reduction measures have been envisaged to deal with this problem, including incentives to roll-over and continuing contracts, collateralization, bilateral and multilateral

22. See, for instance, Mengle, Humphrey and Summers (1987) and Humphrey (1989).

caps, explicit pricing of daylight overdrafts.[23] However, the private benefit of daylight overdrafts does not accrue entirely to the sending bank, since overdrafts generate also a positive externality analogous to the one characterizing reserve holdings: if the sending bank resorts to the overdraft, the receiving bank can generally reduce its demand for reserves or its own overdraft. Thus, it is not obvious that the cost of overdrafts should be paid only by the sending bank, as the receiving bank might be willing to take on part of it, if there were an appropriate market for such a trade. In the absence of such a market, asymmetric pricing could have the undesirable effect of shifting the bulk of payment messages toward the end of the day, a point we shall deal with at some length later on in this Section.

Let us come to the issue of daylight exposures in queuing systems. Queues have two main advantages: with respect to net settlement systems, they reduce the amount of time a payment remains provisional,[24] and therefore settlement risk; with respect to pure gross systems, they have the desirable feature of matching automatically incoming and outgoing payments, thereby avoiding cancellation of payments for which available funds are not sufficient. As long as information on queued payments is made available to the receiving bank, however, systemic risk is not automatically removed. If a bank sends final payments based on the information of queued incoming payments it exposes itself to settlement risk; hence, queued payments are analogous to overdrafts in a net settlement system, in terms

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23. See Board of Governors of the Federal Reserve System (1988), (1989), (1992). The consequences of pricing daylight overdrafts have also been analyzed by Humphrey (1989).

24. In a net settlement system a payment remains provisional for the whole day, whereas in a queuing system it is provisional only as long as it remains in the queue.

of both their function and associated risks.[25] The Swiss experience with SIC seems to support this conclusion. In particular, it shows that these systems can lessen the liquidity burden on banks by tremendously increasing the reserve turnover ratio (fig. 4), with the side effect of increasing the average time spent by payment messages in the waiting queues (fig. 5). The expansion of waiting queues after the abolition of reserve requirements on settlement accounts was so strong that in the Spring 1989 peak-load-type pricing policies were adopted for SIC,[26] whose stabilizing effect is evident in figure 5.

3. Speed of payment execution. In pure systems, the practice of delaying the input of payments into the network (so-called "delayed sends") may be viewed as a side effect of the suboptimal level of reserves attained in the decentralized equilibrium. Individual participants may use delayed sends in the hope that others will settle first and incur the cost related to reserve holdings. If generalized, this behaviour will prove self-defeating, as the entire flow of payments will be shifted towards the end of the working day. Since receiving early information about incoming payments improves the receiving bank's cash management, delayed sends may thus cause higher than optimal costs at the system level. In overdraft systems, delayed sends may arise as a reaction to pricing of daylight overdrafts, if banks delay some of their payments. This practice may be effective in reducing the average value of exposures, but if all banks postpone the input of payment messages, for a given volume of reserves and daily payments, the peak value of overdrafts may

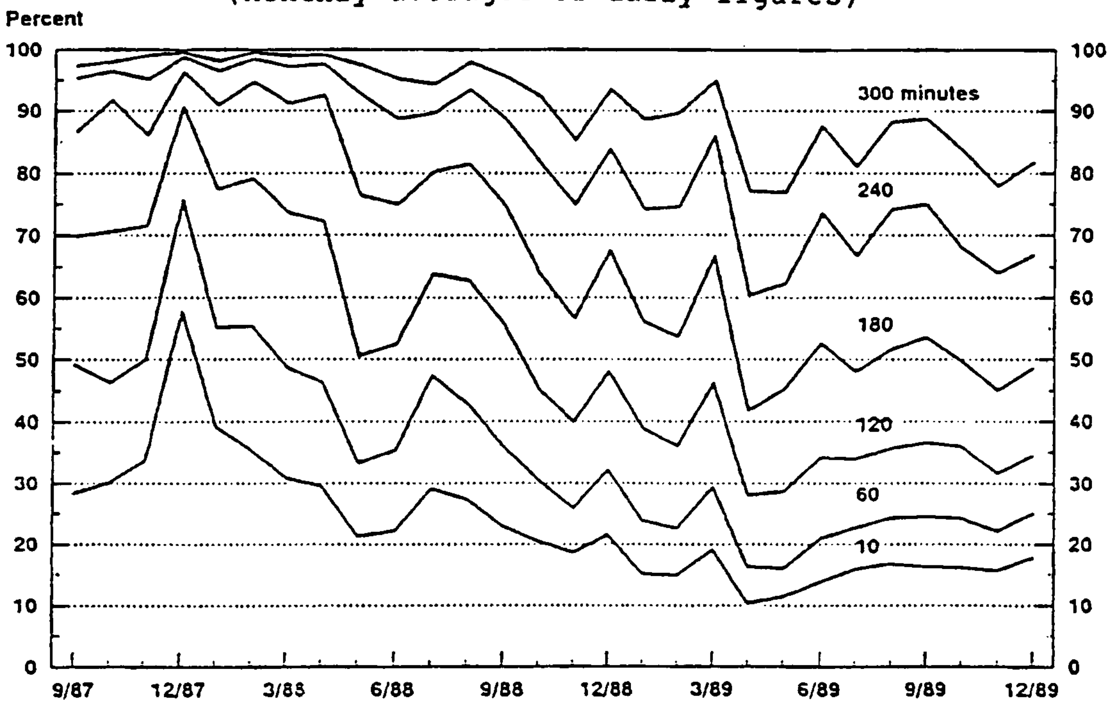
25. As noted by Mengle and Vital (1988), a queuing system will tend to approach a clearing system as the level of settlement reserves approaches zero.

26. Payments that spend more than a given amount of time in the waiting queue are charged a higher fee than normal. See Vital (1990).

Fig. 5

DURATION OF SETTLEMENT DELAYS: PAYMENTS VALUE

(Monthly averages of daily figures)



Source: Vital (1990).

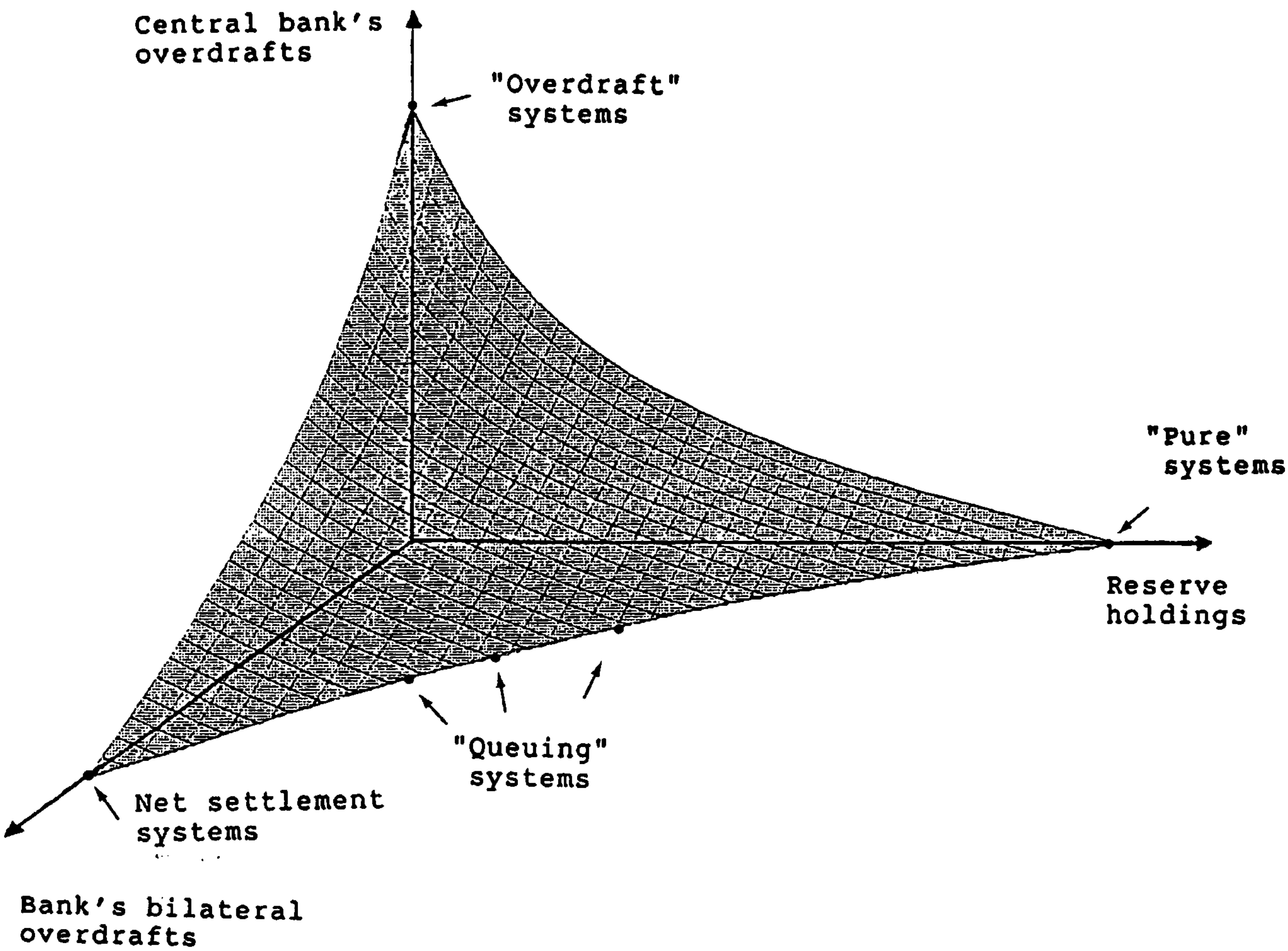
remain unchanged.

5. An overview of available options

Most real-world problems are beset with complex externalities and informational imperfections, so that the very notions of optimality and efficiency are often hard to pin down; when this is the case, institutions clearly matter in shaping actual economic performance. It is difficult, though, to identify on analytical ground what the "most appropriate" institutional arrangement would look like. Interbank payment systems make no exception to this rule. Previous analysis led us to identify a series of trade-offs in the organization of large-value payment systems, but did not yield by itself an univocal ranking of the different systems in terms of social desirability. Intuitively, the four major organizational options (net settlement plus the three varieties of gross settlement) may be thought of as alternative technologies to produce a given volume of payment messages, with reserves, bilateral (i.e. intra-bank) and central bank daylight overdrafts as inputs (fig. 6). Net settlement systems economize on reserves and central bank daylight overdrafts, but entail a large use of bilateral bank overdrafts and therefore a high level of settlement and systemic risk. Pure gross settlement systems eliminate settlement and systemic risk altogether, but impose a heavy liquidity burden on participants. This may induce the latter to postpone the input of transactions, thereby slowing down information flows. Overdraft systems, too, eliminate systemic risk but shift settlement risk onto the central bank, thereby creating moral hazard. Queuing systems may be viewed as a compromise between the high liquidity requirements of gross systems and the heavy credit-risk burden of net systems. In reality, the range of options is considerably enlarged by the existence of a number of "hybrid" forms. For example, the

Fig. 6

ALTERNATIVE PAYMENT SYSTEMS: A GRAPHICAL PRESENTATION



possibility of making irrevocable (i.e. legally binding) payments through finality rules considerably blurs the distinction between net and gross settlement systems. In the same vein, legal provisions such as the so-called "zero-hour rule", according to which all transactions carried out during the calendar day in which a company's bankruptcy occurs are legally void, may impair the degree of finality of payments handled by gross settlement systems.[27]

To identify the optimal input mix, one would need a set of input prices to compute substitution rates between the various categories of risk and the opportunity cost of holding reserves. In our view, input prices and hence the choice of the "best" system depend, among other things, on a number of structural features.

Most prominent among such features is the composition of payments. Highly developed financial markets tend to be characterized by large transaction volumes, often driven by short-run profit prospects which, however, may well fail to materialize. In this context, postponing settlement is riskiest, because the payor may default if the profit opportunity he is after does not materialize, setting in a chain reaction. Thus, the desirability of gross settlement can be expected to rise with the share of financial transactions over the total. Analogously, cross-border payments, which typically entail higher information costs and greater "institutional" uncertainty, tend to increase the desirability of gross settlement or of finality rules.

Secondly, several features of the institutional environment must also be taken into account. For example, the

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27. On finality rules in net settlement systems, see Mengle (1990). On zero-hour rules, see Borio and Van den Bergh (1993).

rules and standards governing the action of the central bank differ widely across countries, thereby affecting both the feasibility and desirability of alternative arrangements.[28] Furthermore, the legal framework determines the allocation of property rights and therefore has an impact on the risk implications of payment arrangements. Legal systems that embody unambiguous finality rules, for instance, tend to reduce the relative attractiveness of gross systems with respect to net settlement.

Finally, the structure of the financial sector may also matter, for two reasons. The first, already touched upon in Section 3, has to do with the structure of the banking system. Where the banking business is characterized by a small number of firms of similar size and range of activity a cooperative attitude is more likely to emerge. Accordingly, the benefits of clearing will tend to outweigh the risks involved in postponing settlement.[29] The second has to do with the relative weight of the banking and non-banking sectors. As noted by Folkerts-Landau and Garber (1992), banks have a comparative advantage with respect to "markets" in providing liquidity. When the banking sector dominates the financial system, the high liquidity needs of a gross settlement system of the pure variety are more easily met. By contrast, a

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28. In some countries, for example, the central bank has statutory responsibility for the stability of the payment system and/or for managing centralized clearing procedures; in others, it is assigned a more peripheral role and is formally prohibited from granting uncollateralized credit. See BIS (1990a); Committee of Governors of the Central Banks of the Member States of the European Economic Community (1992a).

29. Indeed, the practice of "correspondent banking", according to which banks establish bilateral accounts that are credited or debited in connection with payment flows, amounts to postponing final settlement. Correspondent banking is feasible when bilateral relations are stable over time, so that mutual trust can build up.

market-oriented financial system may find the burden of a gross system unbearable, unless the central bank stands ready to supply liquidity in case of need.

These admittedly rather sketchy considerations seem to accord well with a number of well-known stylized facts. For example, gross systems tend to specialize in financial transactions and are particularly active where the latter account for a large share of the total (Borio, Russo and Van den Bergh, 1991; Folkerts-Landau and Garber, 1992). Moreover, bank-oriented financial systems, such as those of Germany and Italy, do tend to play down the benefits of immediate finality (BIS, 1990a). Finally, the number of banks admitted to the clearing tends to be considerably lower in net settlement systems specialized in cross-border transactions, as a few large banks, having access to central bank's accounts, act as correspondent for all other banks (Borio and Van den Bergh, 1993).

6. Conclusions

In this paper we have addressed some general questions raised by the continuous-time nature of most present-day interbank payment systems. Our main conclusions can be summarized as follows.

1. Technological innovation has entailed two main benefits for interbank payment systems: lower unit transaction costs and the possibility for participants to obtain real-time information on net positions. In the past, participants knew only either the creditor or debtor side of their positions, depending on the payment instrument involved. The receiving bank and/or its client are those who benefit most from enhanced information flows, as a result of improved daily cash management. Provisional payments,

however, increase risk to the extent that the receiving bank uses the information contained in provisional payments to enter into some irrevocable commitment. In this case, if the sending bank fails to settle, the receiving bank will find itself with a vanishing asset (the provisional payment) and a certain liability (the final payment already settled or the legally-binding commitment). Besides raising the risk borne by the receiving bank, this use of intra-day information can indirectly increase the risks borne by all other participants, thereby leading to higher systemic risk.

2. Larger value and increased velocity of payment flows tend to reduce the optimal settlement lag, because they make it riskier for the payee to postpone final settlement. This conclusion seems consistent with the secular trend towards a reduction in the interval between consecutive settlements and can explain why, for a vast category of payments, it may now be desirable to eliminate the clearing phase altogether, to achieve real-time settlement. We argue that the settlement lag is crucially dependent on the technology, the degree of competition within the banking system and the openness of the economy. As technology improves, the financial structure of the economy deepens, the degree of competition within the banking system increases and cross-border payments grow, gross settlement tends to be preferable to net settlement.

3. In a decentralized equilibrium, "queuing" and "pure" gross settlement systems may end up working on a suboptimal (lower) level of reserves. This result stems from the fact that reserve holdings on settlement accounts generate positive externalities: the receiving bank benefits from faster payment finality made possible by a higher level of funds on the sending bank's settlement account, but the latter bears the full cost of reserve holdings. An "overdraft" system offering participants free daylight credit eliminates this externality as well as systemic risk, but

shifts credit risk onto the central bank. Given the subsidy implicit in free daylight credit, an overdraft system will tend to attract a higher volume of payments than socially optimal. Imposing a fee on sending banks for overdraft use may compensate the central bank, but does not hit the agents who benefits the most from overdrafts, i.e. the receiving bank and/or its client, possibly introducing distortions in the payment pattern. Queuing systems reduce the amount of time a payment remains provisional and hence settlement and systemic risk, but do not by themselves remove these risk. Externalities connected to reserve holdings on centralized accounts may generate gridlocks in the absence of specific measures preventing reserves from dropping to critical levels. Thus, a queuing mechanism can be seen as an attractive option only insofar as it is embedded in a broader organizational framework capable of containing systemic risk.

4. The four models of payment systems discussed can be thought of as different technologies to produce a given amount of payment services. In practice, the choice of the technology critically depends on a number of structural features of the economy, such as the composition of payment flows, the legal and institutional settings, the structure of the financial sector and of the banking system in particular. In general, the relative attractiveness of gross settlement tends to rise with the share of financial transactions; likewise, as the share of cross-border payments increases, so does the value of immediate finality.

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