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LIQUIDITY EFFECTS AND THE DETERMINANTS OF SHORT-TERM INTEREST RATES IN ITALY (1991-92)

by Ignazio Angeloni (*) and Alessandro Prati (**)

Abstract

The paper uses Italian daily data from January 1991 to July 1992 (a period in which the lira belonged to the narrow EMS band without foreign exchange controls) to measure the relation between bank liquidity and money market interest rates. Alternative indicators of daily liquidity in a system of monthly average computation of reserve requirements are compared and evaluated. Differently from the rest of the literature, we identify liquidity effects by constructing rather than assuming a perfectly inelastic daily supply function with respect to the interbank rate. In addition, we separate the part of interest rate variability due to foreign exchange factors (i.e., interest rate linkages in the EMS) from that attributable to other ("domestic") factors. Contrary to the pre-1990 period, we find that foreign exchange factors have had a dominant influence on interest rate variability.

Index

(*) Banca d'Italia.
(**) Banca d'Italia and CEPR.

1. Introduction

This paper examines the relation between bank liquidity and money market interest rates in the recent Italian experience. We use daily data from January 1991 to July 1992, a period in which the Italian lira belonged to the narrow EMS band without foreign exchange controls.

Research on the transmission of monetary policy has recently focused anew on the impact of central bank policy on the level and structure of interest rates. Ample empirical evidence, mainly on the US, has shown that monetary expansions (not necessarily unanticipated) tend to be followed by lower interest rates.[1] From a theoretical viewpoint, this result is noteworthy because it contradicts the implications of the standard general equilibrium model, in which a monetary expansion tends to raise nominal interest rates via inflationary expectations. From a policy standpoint, the crucial issue is clearly how strong and persistent these "liquidity effects" are; while it seems natural to observe a negative impact correlation between liquidity shocks and short term interest rates, the likely effect on longer term rates, which are presumably more affected by expectations about future growth and inflation, is more controversial.

The exchange rate regime of the country concerned is a key element in the link between liquidity and interest rates. Most of the recent research has focused on closed or

1. Cochrane (1989) and Christiano and Eichenbaum (1992b). Giovannini (1992) shows a case in which fully anticipated liquidity shocks reduce interest rates.

floating rate economies, thus neglecting this aspect.[2] In small open economies that peg the exchange rate and allow perfect capital mobility, domestic monetary shocks tend to be offset by reserve outflows, with little or no effect on interest rates, as in the standard Mundell-Fleming model. Yet, if money demand is interest elastic, one should still observe a negative correlation between money and interest rates as the domestic interest rate fluctuates with those in the international financial markets. Liquidity effects may exist but at the same time not be exploitable for policy purposes; their existence is a necessary, not a sufficient, condition for an active monetary policy.[3]

If a country's exchange rate fluctuates within a band or a target zone, the extent to which domestic interest rates can diverge from the international ones depends on the size of the band, the degree of capital mobility, the risk of parity changes (see Svensson, 1990), etc. In a currency area like the EMS, a fully independent monetary policy is the prerogative of the dominant country, the so-called "anchor" of the system. Other countries may enjoy some degree of independence in two cases: if they are large enough to have some influence on the overall area (evidence of a "symmetric" EMS has been found for the 1980s; see Fratianni and von Hagen, 1990; De Grauwe, 1989); if their money markets are

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2. Lucas (1990), Fuerst (1992), Christiano and Eichenbaum (1992a), Dotsey and Ireland (1993) present closed economy general equilibrium models accounting for the short-term negative correlation between monetary expansions and interest rates. Grilli and Roubini (1989) study liquidity effects in an open economy general equilibrium model with floating exchange rates.

3. For example, if a country reduces the supply of reserves in order to increase interest rates in response to an interest rise in another country, we will observe a negative correlation which is not evidence of the country's ability to influence domestic interest rates. This point is discussed further in Section 2.

insulated from the rest of the world by foreign exchange controls or other market imperfections. Effective insulation is more likely to arise for currencies with large exchange fluctuation bands, such as those used, at different times, by Spain, Italy and the UK.

The recent Italian experience is an interesting case-study for examining issues related to the measurement of liquidity effects and the degree of independence of monetary policy.

In October 1990, a new computation system for reserve requirements was introduced to allow banks to fulfill their reserve obligations on a monthly average basis, rather than each day.[4] This reform, together with the introduction of screen-based interbank transactions earlier in the same year, greatly increased the depth and efficiency of the money market, reducing the volatility of interest rates (Fig. 1) and strengthening the short run relationship between bank liquidity and interest rates.[5] For the purpose of measuring liquidity shocks, one should take into account the intertemporal optimization problem faced by the banks in a regime of reserve averaging.

On the external side, Italy's foreign exchange regime changed substantially in recent times. In the eighties, capital controls and other market imperfections, together with the large exchange fluctuation band, effectively

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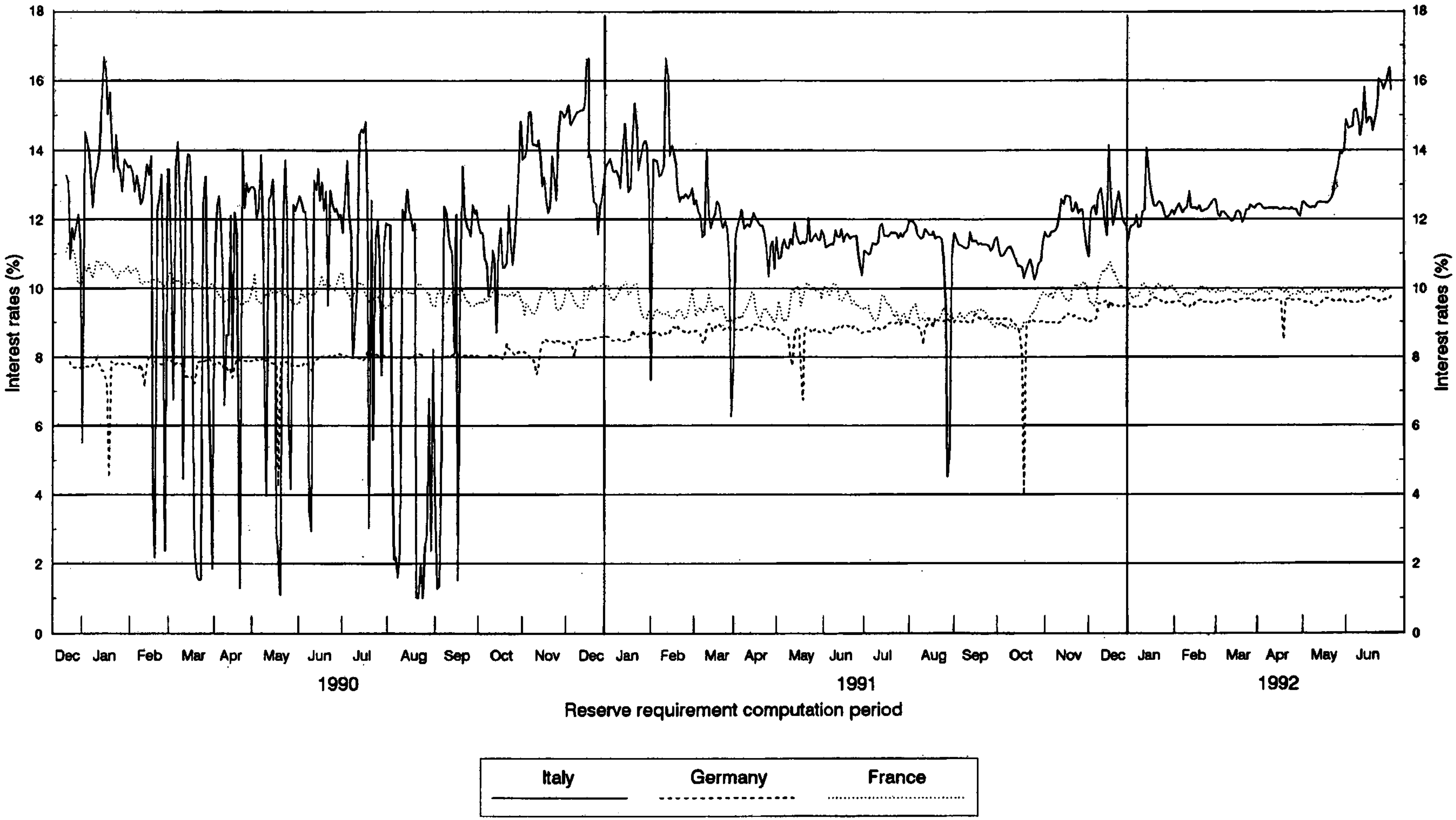
4. Required reserves in Italy are very large, amounting, in the period examined, to nearly 20 per cent of banks' deposit liabilities. Banks are allowed to use up to 5 per cent of their required reserves, provided that the obligation is met on average over a computation period running from the 15 of each month to the 14 of the following month.

5. Evidence on the effects of these reforms can be found in Bank of Italy, Economic Bulletin, n. 12, February 1991.

Overnight interest rates: Italy, France and Germany

Fig. 1



insulated the Italian money market from the rest of the EMS. In 1990, most of these factors disappeared: in January, the lira joined the narrow band; in May, all residual controls on foreign capital flows were removed. The lira remained in the narrow EMS band, without exchange controls, until September 1992. One may expect that some of the earlier results on a "symmetric" EMS changed or need to be qualified once attention is focused on the more recent, narrow band period.[6]

The radical modifications of the Italian reserve requirement and foreign exchange regimes suggest to measure the liquidity effects in the early 1990s separately from those in the previous period. Therefore, we focus on the period January 1991-July 1992 characterized by a stable monetary regime.[7] Daily data do not only provide enough degrees of freedom for the econometric analysis but they also allow us to make use of prior knowledge of certain institutional features of the Italian payment system and of the Bank of Italy's operating procedures, which permit to unambiguously identify supply shocks in the market for bank liquidity.[8] Differently from the rest of the literature, we do not need to make assumptions on the elasticity of the supply curve, because we can build daily liquidity indicators which are perfectly inelastic with respect to the interest rate of the day. As discussed in Section 4, the predetermined versions of the liquidity indicators include foreign exchange

6. Fratianni and von Hagen (1990) include Italy among the countries enjoying monetary policy autonomy in the 1980s.

7. Gordon and Leeper (1992a) and Pecchi (1991) show how structural breaks due to monetary regime changes affect the estimates of liquidity effects.

8. The problem of identifying monetary policy shocks has been debated at length in the literature; recent discussions are in Bernanke and Blinder (1992), Christiano and Eichenbaum (1991) and Gordon and Leeper (1992b).

and open market operations, which are settled with a two-day lag, as well as repurchase agreements, which are decided the day before; they exclude, instead, refinancing operations, which are affected by the level of the overnight rate of the day.

The paper begins with the discussion of a simple model of domestic liquidity, money market interest rates and foreign exchange shocks (Section 2). Section 3 is focused on the issue of what daily indicators of liquidity are appropriate under average computation of reserve requirements. Section 4 discusses the identification of supply shocks. The empirical results are presented in Section 5. We start by measuring the unconditional dynamic correlations between liquidity and interest rates, following the approach taken by the recent literature on liquidity effects. We then attempt to separate the part of interest rate variability due to foreign exchange factors (i.e., interest rate linkages in the EMS) from that attributable to other ("domestic") factors.

2. A simple model of liquidity effects with foreign exchange shocks

Consider a simple model in which the domestic short-term interest rate is determined by domestic and foreign monetary shocks as follows:[9]

(1.1) $L_t = -\alpha r_t$

(1.2) $LD_t = dr_t + \eta_t$

(1.3) $LF_t = \beta(r_t - x_t)$

9. The model is an open economy version of the one used by Bernanke and Blinder (1992) to study the effects of liquidity shocks on interest rates in different monetary regimes.

(1.4) $L_t = LD_t + LF_t$.

Equation (1.1) is a demand for bank liquidity, expressed as a negative function of the domestic interest rate. The supply of liquidity can be split in a domestic and a foreign component, LD_t and LF_t. The first is explained by (1.2), where d is a feedback coefficient expressing the sterilization behaviour of the central bank and η_t is a random shock. The foreign component, (1.3), is assumed to depend on the domestic interest rate and x_t, the sum of the foreign interest rate and expected depreciation. β represents the degree of monetary integration; a high β implies that domestic rates can diverge little from foreign rates, corrected for expected depreciation. The higher β, the tighter the exchange constraint, and the more x_t will tend to coincide with the domestic interest rate.

By substitution in (1) we obtain the money market equilibrium condition:

(2) $-\alpha r_t = dr_t + \eta_t + \beta(r_t - x_t)$

where the sources of supply shocks are η_t (domestic) and x_t (foreign).

For the sake of simplicity we assume a perfectly stable demand function, LD. In the empirical analysis, the predetermined liquidity indicators discussed in Section 4 would allow us to identify liquidity effects even if demand shocks were present.

Equation (2) can be used to study the correlation between r_t and L_t, with or without a separate effect of x_t and under different degrees of monetary autonomy, expressed by values of β. Solving (2) for r_t and L_t and assuming independence of η_t and x_t,[10] we can write the covariance between the two variables as follows:

$$(3) \qquad Cov(r_t, L_t) = k(\sigma^2_\eta + \beta^2\sigma^2_x), \text{ where } k = -\frac{\alpha}{(\alpha+d+\beta)^2}.$$

The covariance is negative and depends on the size of the two shocks and the other parameters of the model. A high value of d (sterilization by the central bank) tends to stabilize r_t, making L_t endogenous and reducing the covariance.[11] For a high value of β (high money market integration), r_t tends to coincide with x_t, and $E(r_t, L_t) = -\alpha\sigma^2_x$; the liquidity effect still exists, even under full capital mobility, but it is entirely due to the external shock and cannot be exploited by the policy maker to influence interest rates.

To see how the inclusion of foreign exchange variables affects the size of liquidity effects, we can compare the covariance in (2) with that conditional on x_t, given by:

$$(4) \qquad Cov(r_t, L_t | x_t) = k\sigma^2_\eta.$$

Notice that (4), unlike (3), vanishes for high values of β; if money market integration is high, liquidity effects are generated only by external shocks. Comparison of (3) and (4) allows to jointly verify the existence of liquidity effects and their domestic versus international origin, once adequate proxies for L_t and x_t have been identified.

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10. This seems reasonable once the reaction of the central bank is already expressed by the sterilization parameter d.

11. As found by Bernanke and Blinder (1992) with reference to the US in the pre-October 1979 period.

3. Daily indicators of liquidity with average computation of reserve requirements

Under average reserve requirements computation, a meaningful measure of liquidity on day t must take into account not only the actual amount of bank reserves observed on that day, but also the reserve positions observed in previous days and expected for future days within the computation period.[12] The goodness of a liquidity indicator in such a system thus depends on how good assumptions it embodies about market information on future liquidity flows, including central bank operations. The importance of expectations is higher the longer the computation period.[13] For the purpose of this paper we have constructed four liquidity measures (see Figg. 2 to 5), defined as follows:

1) A "naive" indicator (NAIVE), given by the cumulated reserve positions from the beginning of the computation period up to day t; the implicit assumption is that the expected value of excess reserves in future days is always equal to zero.[14]

2) A forward-looking indicator (FOR1), given by the cumulated reserve positions over the whole computation period. Expected future values are constructed using ex-post information, assuming perfect foresight on all reserve flows except on future operations by the Bank of

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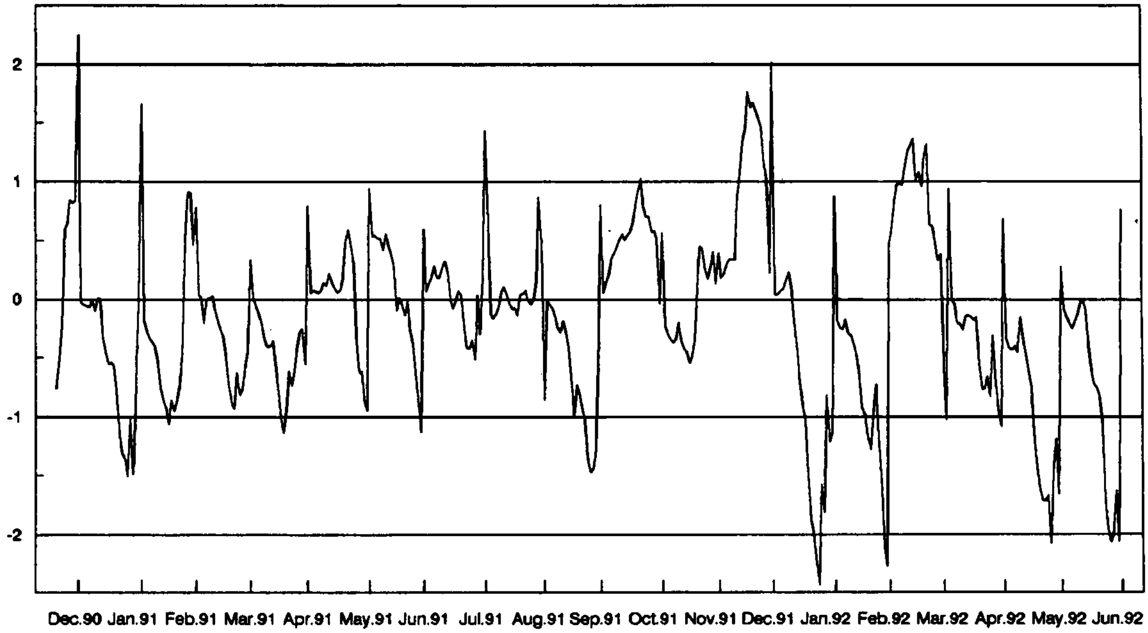
12. See Poole (1968). A formalisation of the relationship between liquidity and interest with average reserve computation is presented in Appendix 1.

13. The computation period in Italy is one month, the longest among EC countries together with France and Germany.

14. The value of this index for the aggregate banking system is published daily by the Bank of Italy through Reuters.

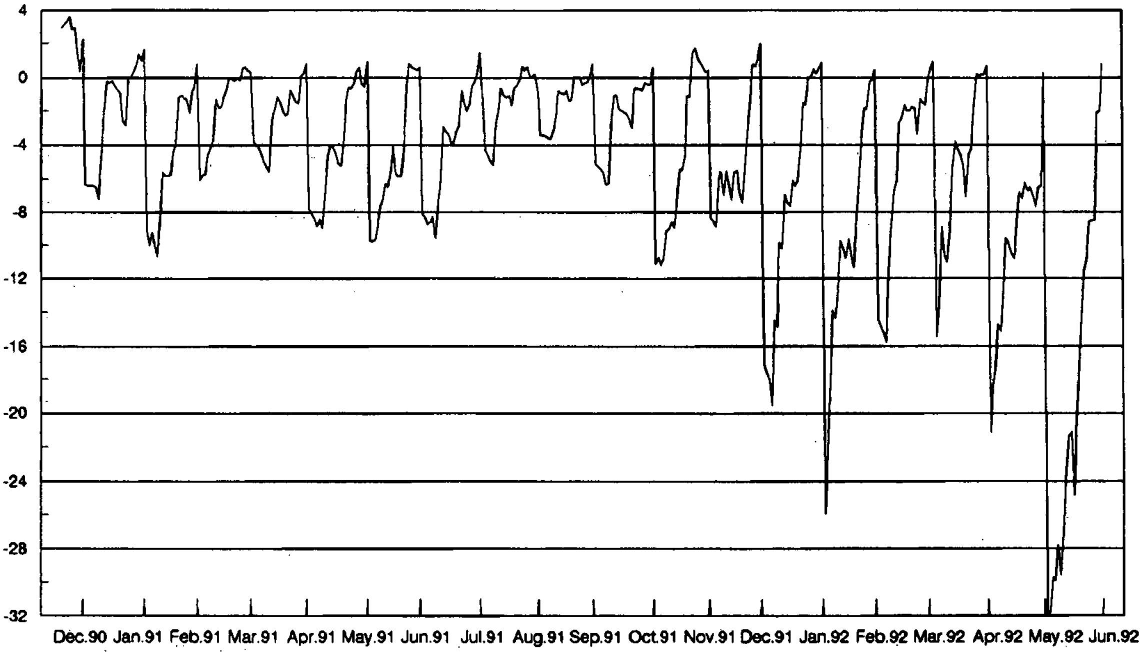
NAIVE indicator

Fig. 2



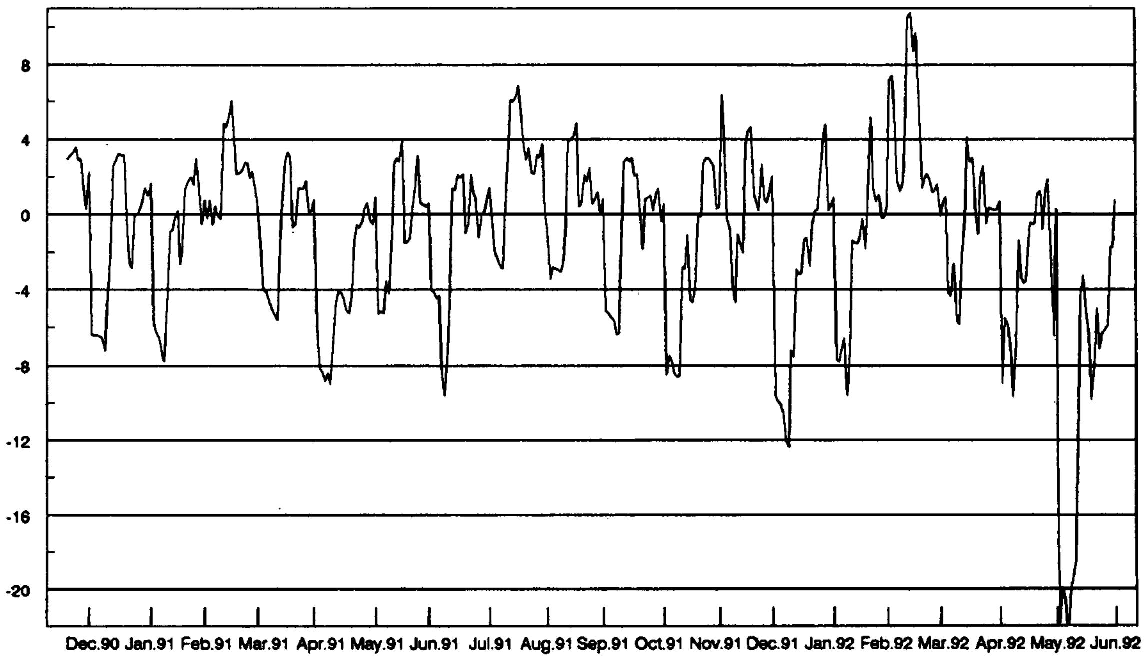
Forward-looking Indicator (FOR 1)

Fig. 3



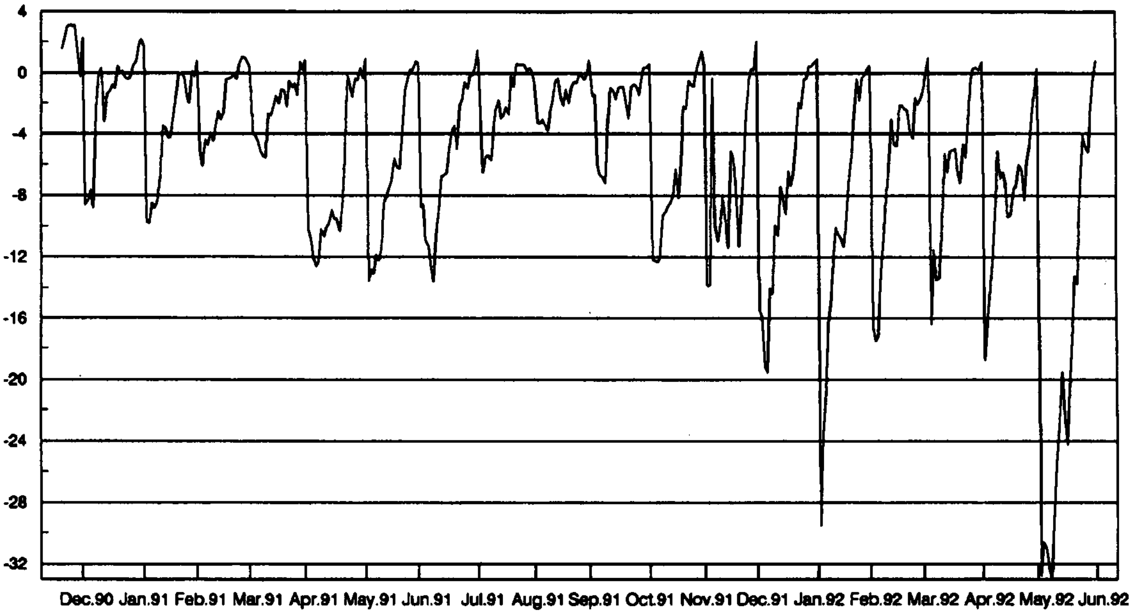
Forward-looking indicator (FOR 2)

Fig. 4



EX-ANTE indicator

Fig. 5



Italy.[15]

3) Another forward-looking indicator (FOR2) similar to the preceding one, but in which market agents assume that the Bank of Italy will renew all existing repurchase agreement operations at their maturity.[16]

4) A true ex-ante indicator (EX-ANTE), routinely computed by the Bank of Italy for operational purposes on the basis of information available to the Bank (not necessarily to the market) each day.[17] As in 2), this indicator assumes no roll-over of outstanding repurchase operations.[18]

In addition, we also considered an indicator related to the level of bank reserves on each single day. The reason for looking at this index is that in the Italian system

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15. Market agents are assumed to ignore all future Bank of Italy's operations (except for forward transactions already agreed upon) either on the domestic (repos, outright open market, refinancing operations) or on the foreign exchange market.

16. Repurchase agreements are the main monetary policy instrument in Italy. Usually the banking system is short of liquidity, so that there is a continuous roll-over of repurchase operations. Since the average maturity of repos is shorter than one month, FOR2 is systematically higher (i.e. indicates more liquidity) than FOR1.

17. EX-ANTE is calculated daily by the Money and Financial Markets Department of the Bank of Italy for the purpose of programming open market operations. We are grateful to G. Teodori of the Money and Financial Markets Department of the Bank of Italy for kindly providing these data.

18. All indicators from 1 to 4 are divided by the number of days left to the end of the computation period; therefore the value of a given amount of cumulative reserves is higher the closer the end of the period. See Appendix 1 for an interpretation within a simple model of reserve market equilibrium. To standardize the units of measurements, all indicators are expressed as a percentage ratio of required reserves.

banks' daily drawings on reserve deposits cannot exceed 5 per cent of compulsory reserves, so that the possibility of shifting reserves from one day to the other within the computation period is not unlimited. The fifth measure of liquidity is then (Fig. 6):

5) A "daily" indicator (DAILY), given by the sum of excess reserves at the end of each day and the unused margin on "ordinary advances".[19]

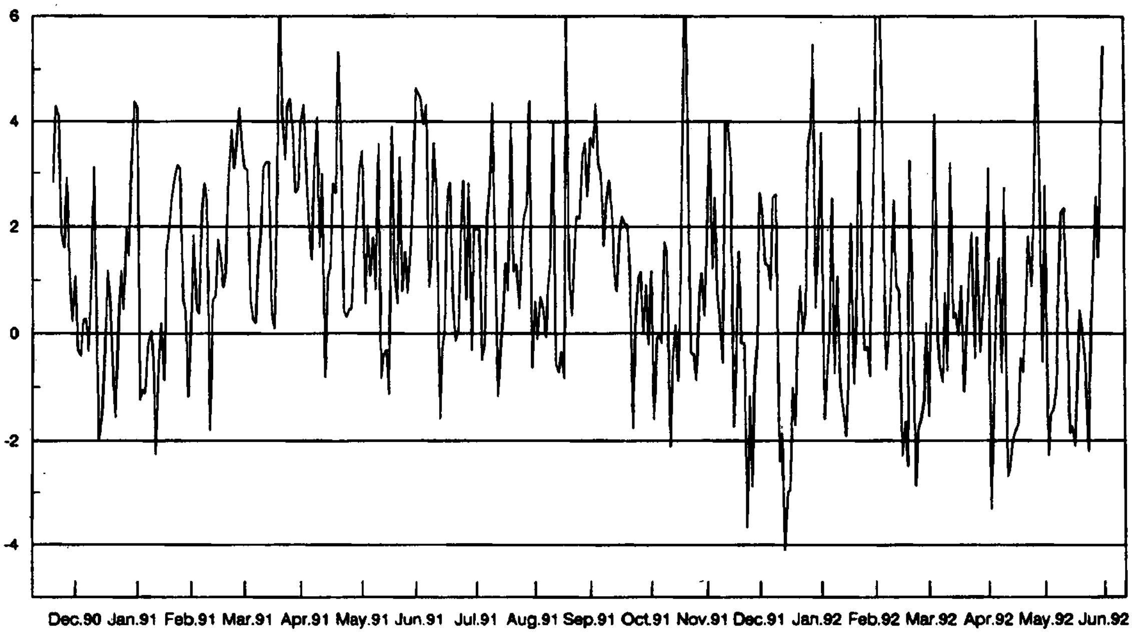
4. Identification of liquidity effects

In order to identify liquidity effects, a perfectly inelastic money supply function is usually assumed (see, for example, Christiano and Eichenbaum, 1991). However, other empirical works (see, for example, Bernanke and Blinder, 1992) make the opposite assumption of a perfectly elastic supply curve with the central bank providing all the liquidity demanded at the target level of the interest rate; in this case, monetary policy shocks are measured by innovations in the targeted interest rate. Both extreme assumptions are criticized by Gordon and Leeper (1992b), who argue that the actual supply function is likely to be positively sloped. In this paper, the daily supply of liquidity is not assumed but constructed as perfectly inelastic with respect to the interbank rate. In fact, a priori knowledge of the institutional features of the Italian payment system and of the Bank of Italy's operating

19. Ordinary advances are a small overdraft facility available to all banks at a cost equal to the discount rate. DAILY approximates the notion of maximum amount of reserves available each day, since for a given level of reserve requirement, the aggregate volume of reserves available to the banking system is equal to 5 per cent of the requirement plus excess reserves (positive or negative) plus the unused margin on ordinary advances.

DAILY indicator

Fig. 6



procedures allows us to build predetermined liquidity indicators.

From an econometric point of view, none of the five indicators defined in Section 3 can be considered predetermined with respect to the interest rates on day t; the reason is that they are all affected by same-day settlement operations by the Bank of Italy which depend on the level of interest rates on the same day. In order to identify supply shocks, we calculated predetermined versions of NAIVE, EX-ANTE and DAILY, excluding in each day all Bank of Italy operations which depend, at least partly, on the same day's level of interest rates. Clearly, predetermined versions could not be computed for FOR1 and FOR2, since they contain expected future reserve flows which may depend on current levels of interest rates.

An institutional feature of the Italian payment system is that foreign exchange and most outright open market operations by the Bank of Italy are settled with a two-day lag; as a consequence, liquidity flows caused by these operations do not depend on the same day interest rate and can be included in the predetermined measures. Instead, repurchase agreements, some outright open market operations and all refinancing operations are settled on the same day. Repurchase agreements are decided in the evening of the day before, so they can safely be assumed to be predetermined in each given day. Outright open market operations are scattered throughout the day, but they are relatively small and can be assumed to be scarcely influenced by current interbank interest rates. On the contrary, refinancing operations are mainly done late in the afternoon and are significantly affected by the liquidity conditions of the day. Thus, the predetermined versions of NAIVE, EX-ANTE and DAILY were obtained excluding each day all refinancing operations extended in the same day.[20] In the empirical analysis, the predetermined indicators were used as instrumental variables in the GMM regressions and directly as liquidity indicators in the VAR.

5. Empirical results

Figures 7 to 11 show unconditional dynamic correlation coefficients of the five main indicators with the overnight interest rate.[21] In the main, the correlation patterns suggest the existence of liquidity effects.[22] The forward indicators, FOR1, FOR2 and EX-ANTE, are negatively correlated with the daily rate with several days' lead. FOR2 shows the highest correlation, as well as the longest lead. All the three display an inverted positive correlation between the rate and lagged liquidity; an indication that shocks in the overnight rate generate a lagged, "lean against the wind" type reaction by the central bank. The NAIVE indicator shows weak correlations and no lead at all. The contemporaneous correlation with DAILY is significant, but no regular lead or lag pattern is visible.

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20. The Bank of Italy uses two types of refinancing operations. The first, called ordinary advance, is at the discretion of the banks, which freely draw on an overdraft facility within a narrow limit, paying a fixed cost equal to the discount rate. The second, called fixed-term advance, is extended at the discretion of the central bank, acting on a request by the banks; the rate charged is higher than the discount rate. This penalty rate sometimes called "Lombard", due to the similarity with the German case.

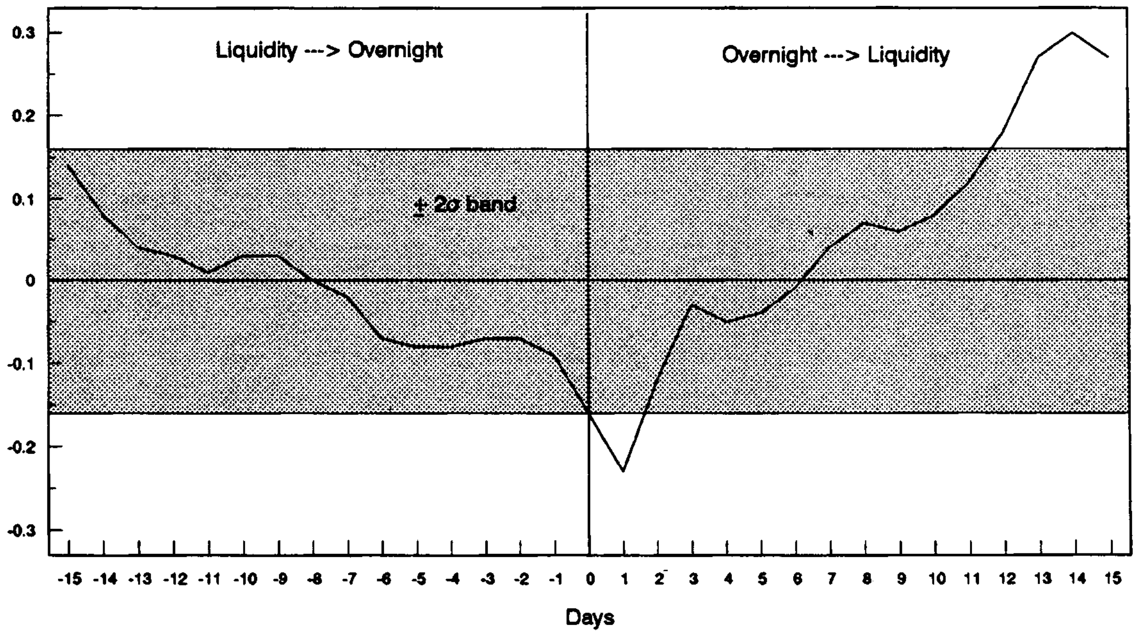
21. Correlations are computed for the period from May to December 1991, in which the official discount rate remained constant.

22. Compare, for example, the results of Christiano and Eichenbaum (1992b).

Correlation coefficients between

the overnight rate and the NAIVE indicator (*)

Fig. 7

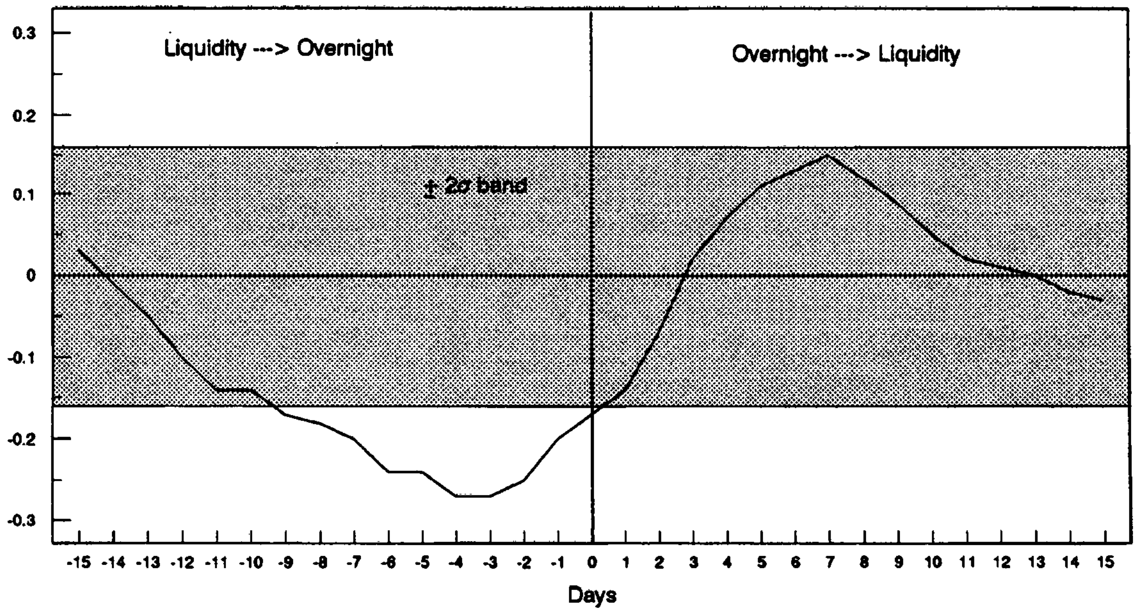


(*) Larger values of the indicator correspond to a monetary expansion; a negative correlation is then evidence of liquidity effects.

Correlation coefficients between

the overnight rate and the forward-looking (FOR 1) (*)

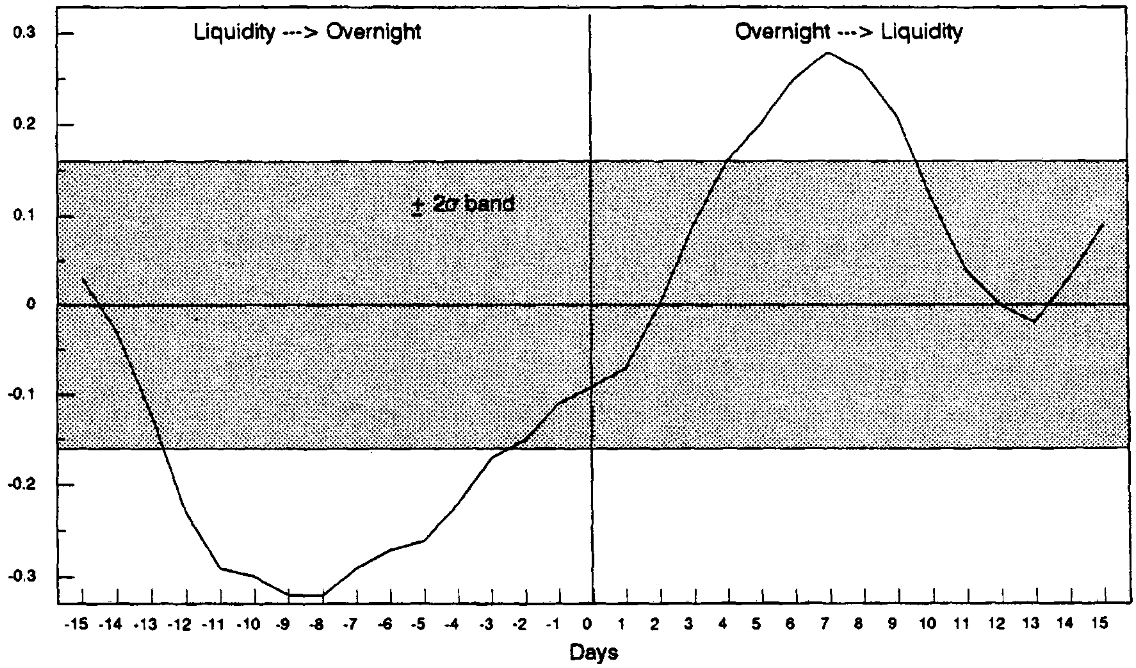
Fig. 8



(*) Larger values of the indicator correspond to a monetary expansion; a negative correlation is then evidence of liquidity effects.

Correlation coefficients between the overnight rate and the forward-looking indicator (FOR 2) (*)

Fig. 9

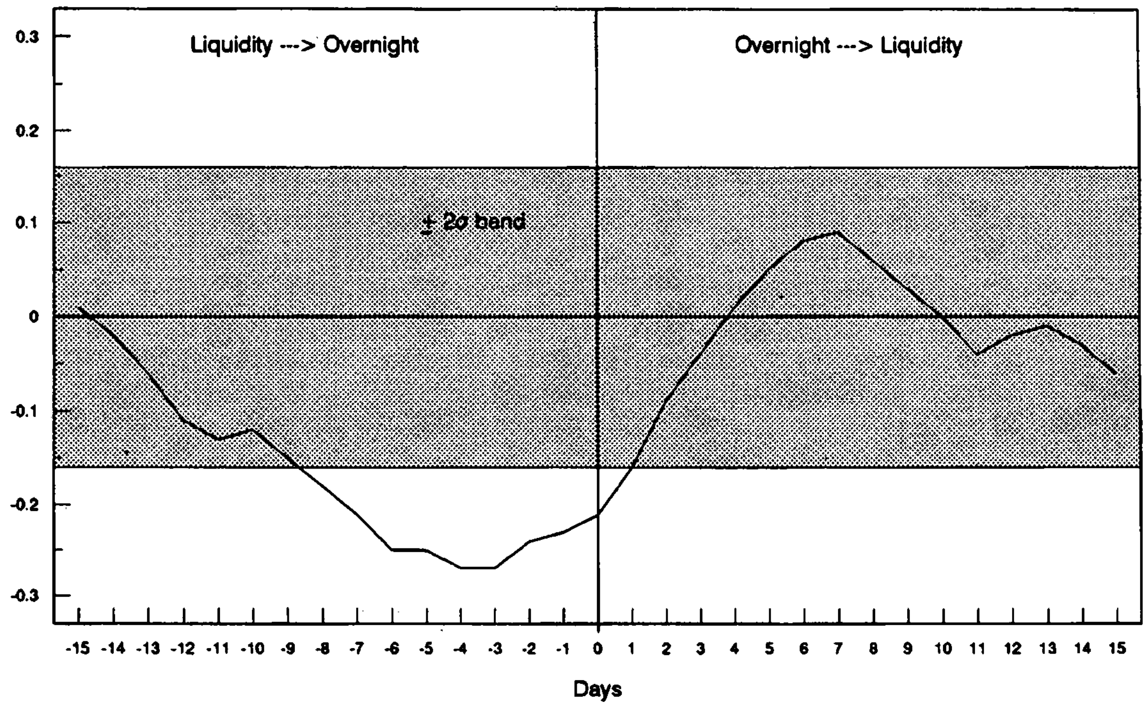


(*) Larger values of the indicator correspond to a monetary expansion; a negative correlation is then evidence of liquidity effects.

Correlation coefficients between

the overnight rate and the EX-ANTE indicator (*)

Fig. 10

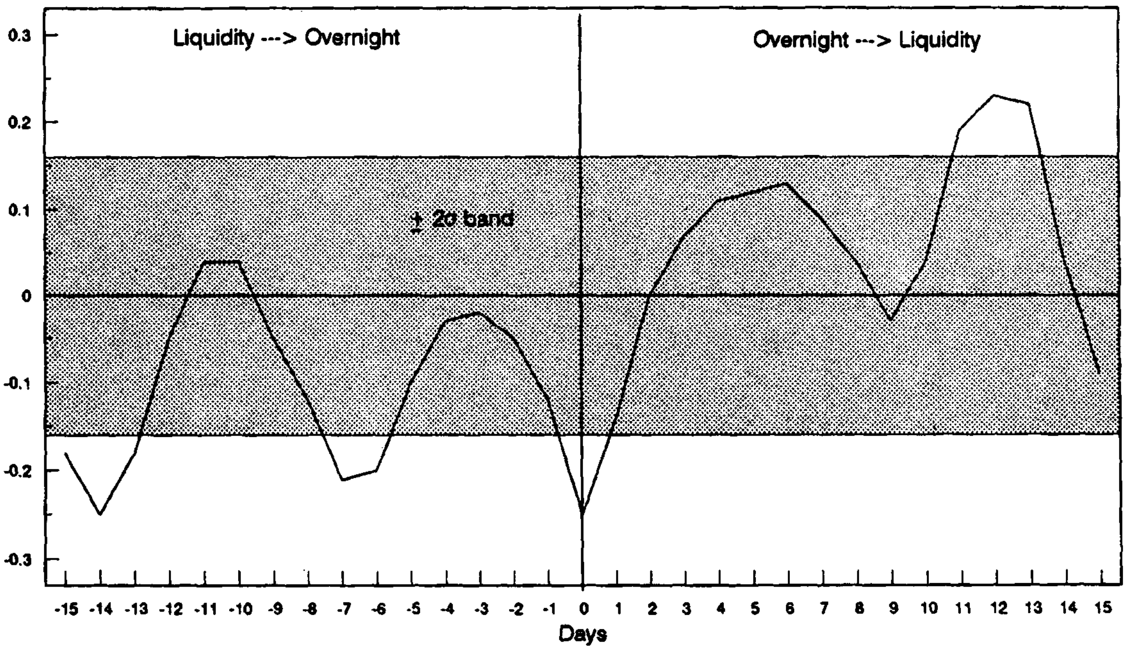


(*) Larger values of the indicator correspond to a monetary expansion; a negative correlation is then evidence of liquidity effects.

Correlation coefficients between

the overnight rate and DAILY indicator (*)

Fig. 11



(*) Larger values of the indicator correspond to a monetary expansion; a negative correlation is then evidence of liquidity effects.

Table 1 shows simple dynamic regressions linking the overnight rate to the liquidity indicators, excluding for the moment all variables related to the foreign exchange market. In each equation we jointly included the daily indicator and a monthly one, chosen among the four discussed in the previous section; this is consistent with the view that the interest rate in each day may be affected partly by the liquidity expected to be available in the whole computation period, and partly by the liquidity available on that same day.[23] All estimates were performed using White (1980) heteroskedasticity consistent method, and replicated with the Generalized Method of Moments (GMM) estimator with instrumental variables (see Hansen, 1982), to correct for simultaneity and moving average error term.[24]

The table reports, for brevity, only the sums of the

23. Dummy variables were inserted to correct for outliers in the overnight rate (6 out of a total of 394 observations). Jumps in the level of daily interest rates can be observed (see Fig. 1) at the end of the computation period if banks cannot "carry over" their excess reserves to future periods. Non-working days were excluded from the regressions.

24. Cumby, Huizinga and Obstfeld (1983, p. 337) show that serial correlation of the error term may arise when a model with current expectations of future events is estimated substituting future realizations to unobservable expected values. This is the case of forward-looking indicators, which are constructed assuming knowledge about future reserve flows. The number of moving average terms in the GMM estimates was set to 20, since 20 days is the longest possible forecast horizon (which roughly corresponds, excluding weekends, to the length of the computation period of reserve requirements). For instrumental estimation we used the following exogenous variables: the contemporanous predetermined versions of NAIVE, EX-ANTE and DAILY, the contemporanous and lagged values of repurchase agreements (which are predetermined as already noted) and the French and German overnight rates.

Table 1

OVERNIGHT AND LIQUIDITY

	OLS				GMM			
	Lagged overnight	Monthly indicator	Daily	R^2_c	Lagged overnight	Monthly indicator	Daily	R^2_c
EX-ANTE	.89** (23.97)	-.0074 (-1.52)	-.054* (-2.34)	.873	.91** (51.45)	-.0048** (-2.50)	-.065** (-6.76)	.872
NAIVE	.87** (22.48)	-.155** (-3.41)	-.080* (-2.69)	.875	.87** (42.80)	-.17** (-7.09)	-.076** (-4.88)	.874
FOR1	.88** (22.21)	-.011 (-1.93)	-.052* (-2.26)	.873	.90** (48.76)	-.0088** (-3.79)	-.063** (-6.41)	.872
FOR2	.88** (24.05)	-.021** (-3.14)	-.060* (-2.66)	.877	.88** (52.21)	-.026** (-8.89)	-.076** (-6.57)	.875

Sum of the lagged coefficients; White (1980) t-statistics robust to heteroskedasticity in parentheses.
One star (*) indicates significance at the 5% level.
Two stars (**) indicate significance at the 1% level.
All regressions include 6 lags of the independent variables (lag length selected using Akaike's information criterion). The order of moving average disturbances in the GMM estimates is 20.

lagged coefficients and their t-statistics.[25] The results are consistent with the claim that strongly significant liquidity effects exist; both daily and monthly measures appear to be important. GMM instrumental estimates sharply increase the significance of all coefficients. The "best" GMM equation is the one including FOR2 and DAILY, as suggested by the simple correlations; however, NAIVE performs almost equally well.

In Table 2 the same regressions are shown with the inclusion of variables meant to express the effect of the foreign exchange market on domestic interest rates. After some specification search, two variables were selected: the dollar/DM rate (FXCR), a proxy for German monetary policy and other factors affecting the EMS versus the rest of the world, and the position of the lira (PXIT) in the Exchange Rate Mechanism (ERM).[26] The estimates show that both the DM rate and the position of the lira are strongly significant. A DM appreciation leads to an increase in the Italian interest rate; the same effect is given by a deterioration of the position of the lira in the system.[27] The importance of the foreign variables is confirmed by the exclusion restriction tests in Table 3. Observe that the significance of the domestic liquidity indicator is substantially weakened, but only the effect on DAILY appears to be completely cancelled;

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25. Lag length was selected at 6 using Akaike's information criterion. All regressions shown in this paper are estimated in levels; the limited time span prevents an analysis of integration and cointegration. First difference equations with error correction were tried and yielded results which are similar in terms of significance and ranking of the regressors, but with a lower percentage of explained variance.

26. As instrument for PXIT, we used a measure of maximum bilateral divergence in the EMS calculated excluding the lira.

27. Chen and Giovannini (1992) interpret PXIT as a proxy for the expected change in the ERM parity.

Table 2

OVERNIGHT, LIQUIDITY AND FOREIGN EXCHANGE

	OLS						GMM					
	Lagged overnight	Monthly indicator	Daily	FXCR	PXIT	R^2_c	Lagged overnight	Monthly indicator	Daily	FXCR	PXIT	R^2_c
EX-ANTE	.75** (14.27)	-.010 (-1.77)	.0075 (.30)	-.025* (-2.51)	-.27** (-2.98)	.886	.77** (24.69)	-.007* (-2.29)	-.0002 (-.013)	-.020** (-3.89)	-.26** (-3.50)	.884
NAIVE	.72** (13.64)	-.18** (-4.13)	.0280 (.98)	-.021* (-2.53)	-.40** (-5.12)	.892	.75** (19.25	-.20** (-3.99)	.051* (2.27)	-.017** (-2.92)	-.42** (-9.48)	.887
FOR1	.74** (13.55)	-.012 (-1.88)	.0079 (.32)	-.025* (-2.59)	-.25** (-2.81)	.886	.77** (23.52)	-.010** (-2.61)	.0006 (.038)	-.020** (-3.79)	-.25** (-3.46)	.884
FOR2	.75** (14.76)	-.020** (-3.13)	-.0055 (-.23)	-.022* (-2.49)	-.26** (-3.10)	.888	.77** (21.93)	-.027* (-4.73)	-.027 (-1.78)	-.019** (-3.38)	-.19** (-3.12)	.886

Sum of the lagged coefficients; White (1980) t-statistics robust to heteroskedasticity in parentheses.
One star (*) indicates significance at the 5% level.
Two stars (**) indicate significance at the 1% level.
All regressions include 6 lags of the independent variables (lag length selected using Akaike's information criterion).
The order of moving average disturbances in the GMM estimates is 20.

Table 3

TEST OF EXCLUSION OF FOREIGN VARIABLES

	OLS[1]	GMM[2]
EX-ANTE	54.2**	32.6**
NAIVE	69.4**	54.7**
FOR1	52.6**	30.6**
FOR2	48.0**	30.3**

1 F-test with 14 and 347 degrees of freedom.

2 χ^2-test (Gallant-Jorgenson, 1979) with 14 degrees of freedom.

Two (**) indicate the null hypothesis of exclusion of the foreign variables (FXCR and PXIT) from the regressions presented in Table 2 is rejected at the 1% level.

the monthly indicators retain some explanatory power, but the coefficients are smaller and less significant than in Table 1.

The regression results do not provide a measure of the relative weight of domestic vs. foreign factors in determining domestic interest rates. In the "foreign" component one should consider not only the direct effect that foreign variables may have on domestic interest rates, through expectations, signalling, etc., but also the effect that runs indirectly, through central bank intervention that affects domestic liquidity. A way to obtain such measure is the vector autoregressive (VAR) variance decomposition. A well known difficulty with this technique, pointed out by Cooley and LeRoy (1985), is that in the absence of prior restrictions on the VAR simultaneous coefficients, the causality links are not fully identified and the decomposition has no clear interpretation in terms of the structural model. VAR analysis can instead be implemented without difficulty if the underlying structural model can be written in recursive form, with triangular matrix of simultaneous coefficients and diagonal residual covariance matrix (see Appendix 2).

Even with daily data, simultaneity problems are likely to be serious in our case. If the dollar/DM rate can be safely assumed to be exogenous, liquidity indicators and the lira's position in the ERM cannot, even in a weak sense. To overcome this difficulty we have written the system in block recursive form, using the predetermined versions of DAILY, NAIVE, and EX-ANTE described in Section 4 and substituting the endogenous variable PXIT with some of the variables used in the instrumental regressions.[28] The system

28. These variables are the German (OVGE) and French (OVFR) overnight rates and a measure of maximum bilateral divergence in the EMS calculated excluding the lira (PX).

in this form consists in three recursive blocks, ordered as follows: the "foreign" variables; the "domestic" indicators; the overnight rate. From the standard VAR decomposition results[29] we have computed percentage shares of variance attributable to the groups of domestic and foreign variables, at lags up to two months; VARs were computed alternatively by including each of the domestic liquidity indicators and the two combinations: (DAILY, NAIVE) and (DAILY, EX-ANTE).

The results, shown in Figures 12 and 13, suggest that the share of interest rate variability attributed to domestic liquidity factors is high only in the very short run, but decreases quickly. Its share is in all cases lower than 30 per cent after one month and 20 per cent after two months. The effect exerted by the DAILY indicator is strong in the very short run, but decays very quickly, confirming the regression results that showed the sum of the coefficients on this variable to be insignificant. NAIVE is stronger than EX-ANTE in the very short run (two days), but the second prevails thereafter. For comparison, we computed an analogous VAR model for 1988-89 including DAILY[30] plus the foreign variables (Fig. 14); the domestic indicator dominates, accounting for a share of the variance of the overnight rate equal to over 90 per cent in the short run and over 80 per cent after two months; after 1990, the comparable numbers are 90 and 10.

The block recursive form of the system allows us to identify impulse response functions only when there is a single variable in each block. This is the case of the

---

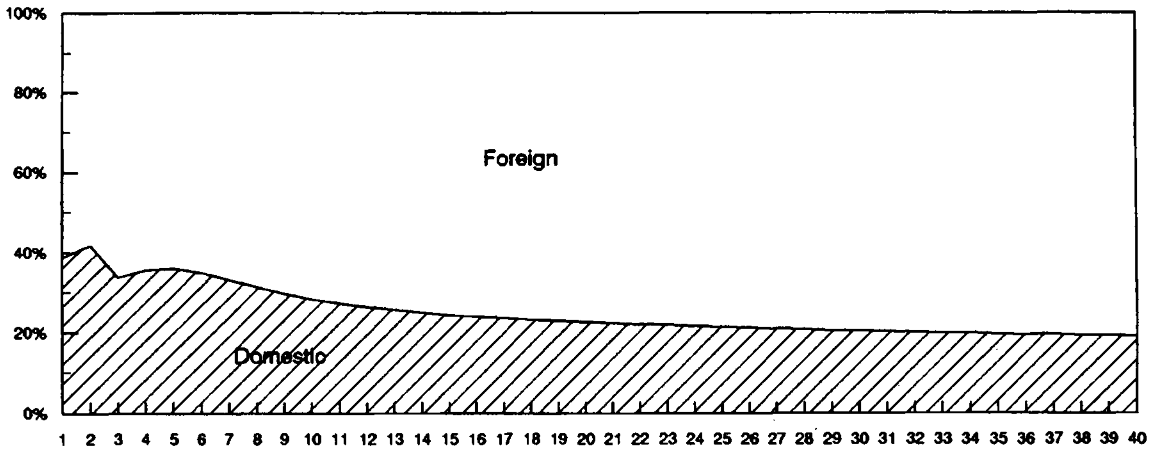
29. VAR estimates were computed in level form, as recommended by Clements and Mizon (1991), Campbell and Perron (1991) and Sims, Stock and Watson (1990) even if unit roots may be present.

30. Before 1990 average reserve computation did not exist.

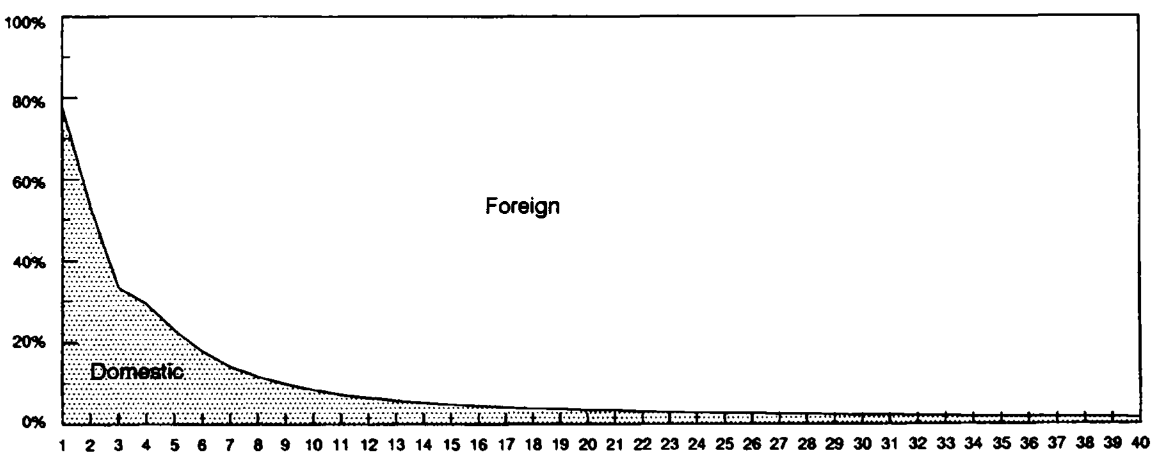
Variance decomposition of the overnight rate

Fig. 12

EX-ANTE indicator: 1991-1992



NAIVE indicator: 1991-1992



DAILY indicator: 1991-1992

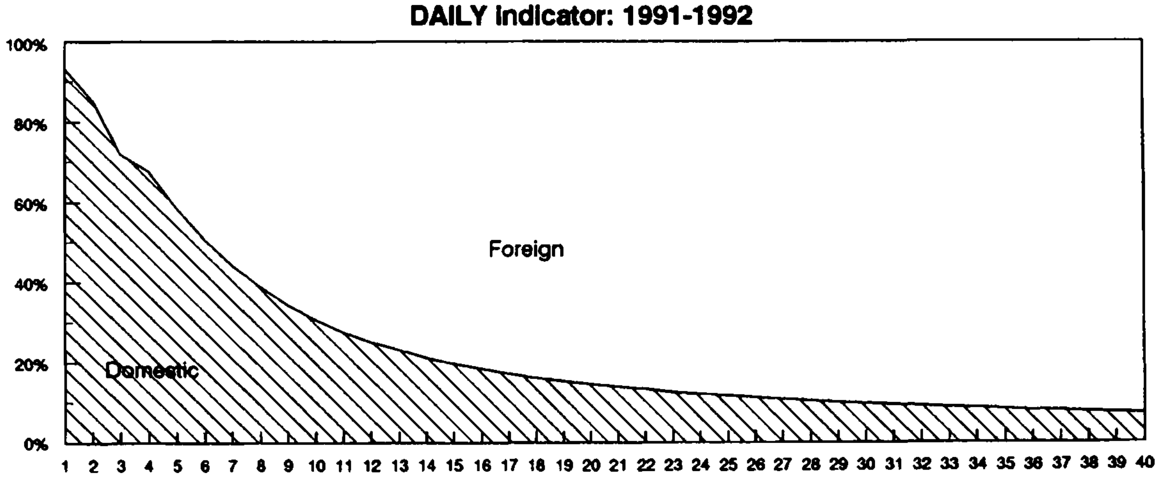
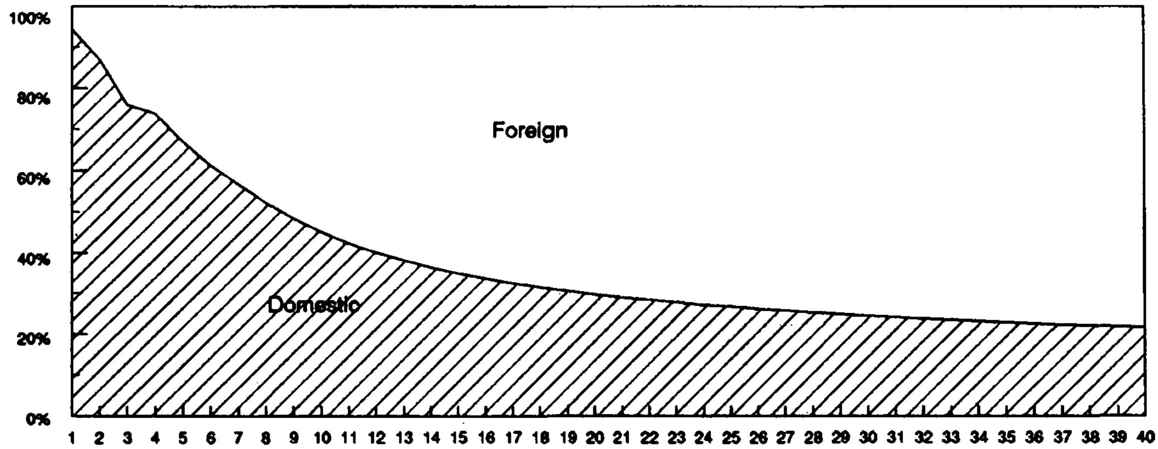


Fig. 13

Variance decomposition of the overnight rate

EX-ANTE + DAILY indicators: 1991-1992



NAIVE + DAILY indicators: 1991-1992

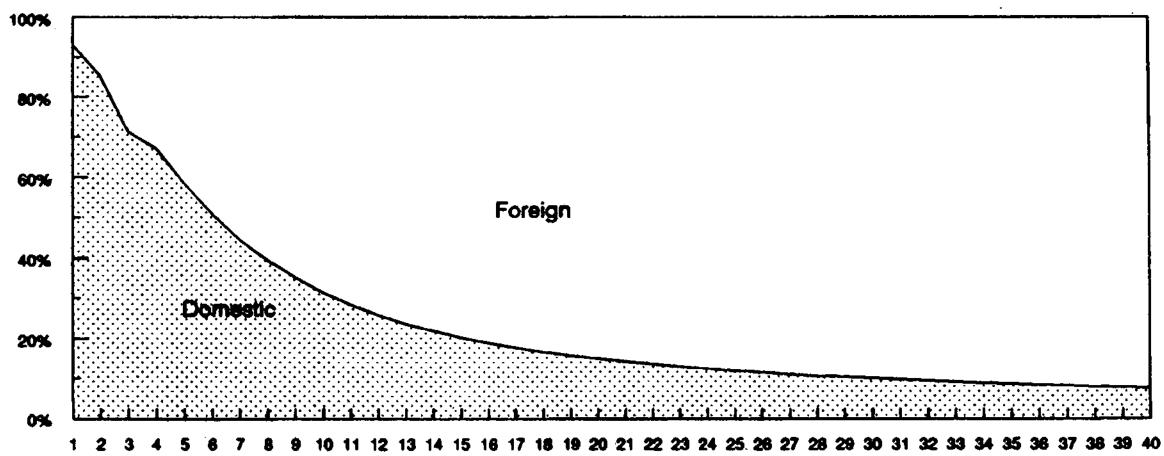
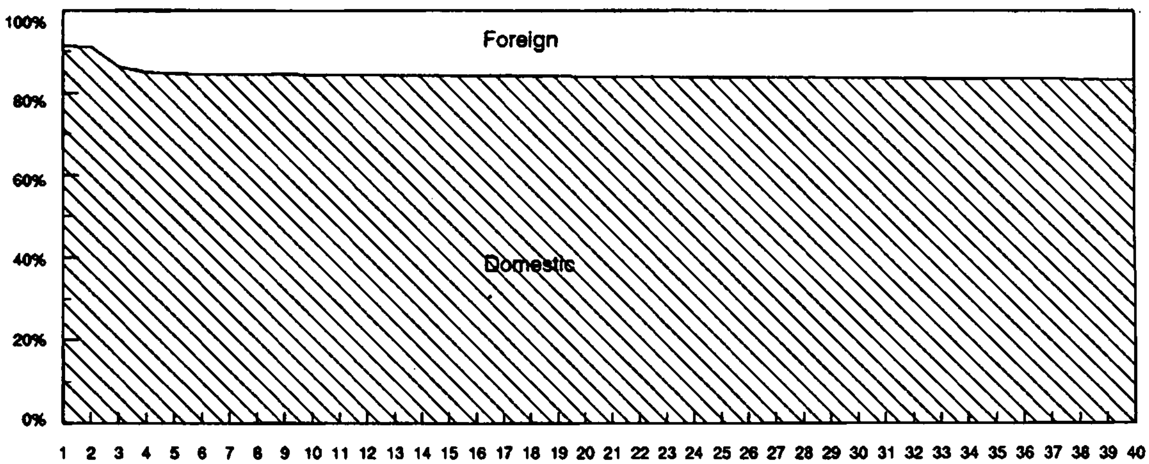


Fig. 14

Variance decomposition of the overnight rate

DAILY indicator: 1988-1989



liquidity indicators in the first three VARs; in the last two VARs, two liquidity indicators are used and it should not be possible to separately identify the effect of each of them without prior information. This identification problem should be kept in mind when the impulse response functions of Figures 15-16 are analyzed. The innovations of both domestic and foreign variables have the expected impact on the overnight rate; notice that only EX-ANTE, which incorporates information on future expected liquidity flows, has a lasting effect, while the effects of NAIVE and DAILY are very short-lived.

We have checked the robustness of our results by extending our regression and VAR analysis to longer term interbank rates (one week to three months). If anything, the results appear to be strengthened. Table 4 reports the regression of the three-month rate on the overnight rate and the domestic and foreign variables. The table conveys three central messages, namely: 1) the overnight rate is the most powerful explanatory variable for the longer term rate; 2) the domestic liquidity indicators are weakly significant and occasionally appear with a wrong sign, 3) among the foreign variables, a significant effect is exerted by the lira's position in the band. The latter result can be interpreted in terms of the expectational theory of the term structure; a weaker exchange rate raises expected future overnight rates and thus drives the three-month rate up with respect to the current overnight rate.

The variance decomposition can again be studied using the block recursive VAR methodology. The system now includes the three-month rate at the end of the causal chain. Figures 17 and 18 report variance shares analogous to those shown in Figures 12 and 13; again, domestic liquidity accounts for a very small part of the variance in domestic rates. This is particularly true at short lags; if in the case of the

Fig. 15

IMPULSE RESPONSE FUNCTIONS
(one liquidity indicator VARs)

DOMESTIC | FOREIGN

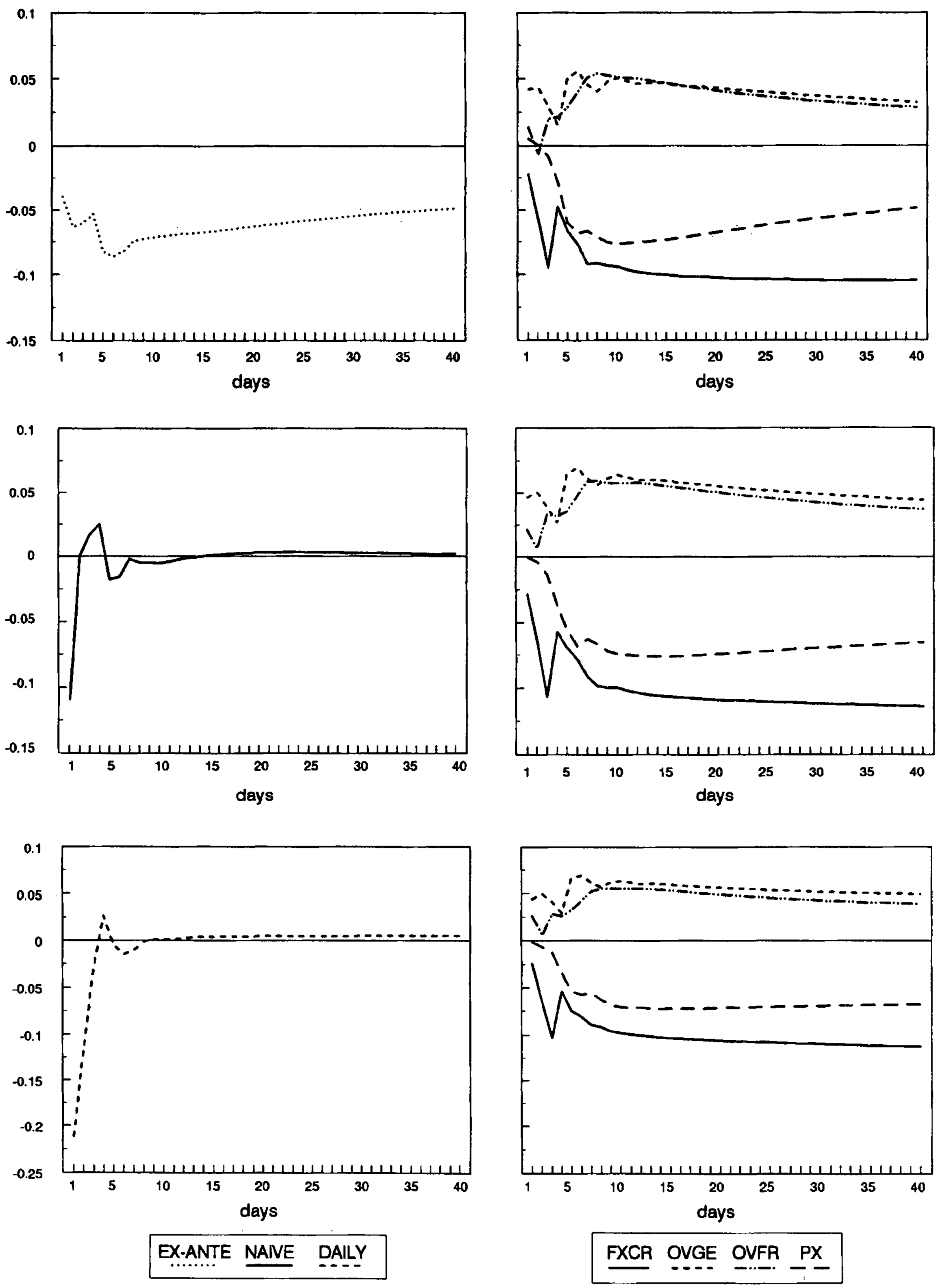


Fig. 16

IMPULSE RESPONSE FUNCTIONS
(two liquidity indicator VARs)

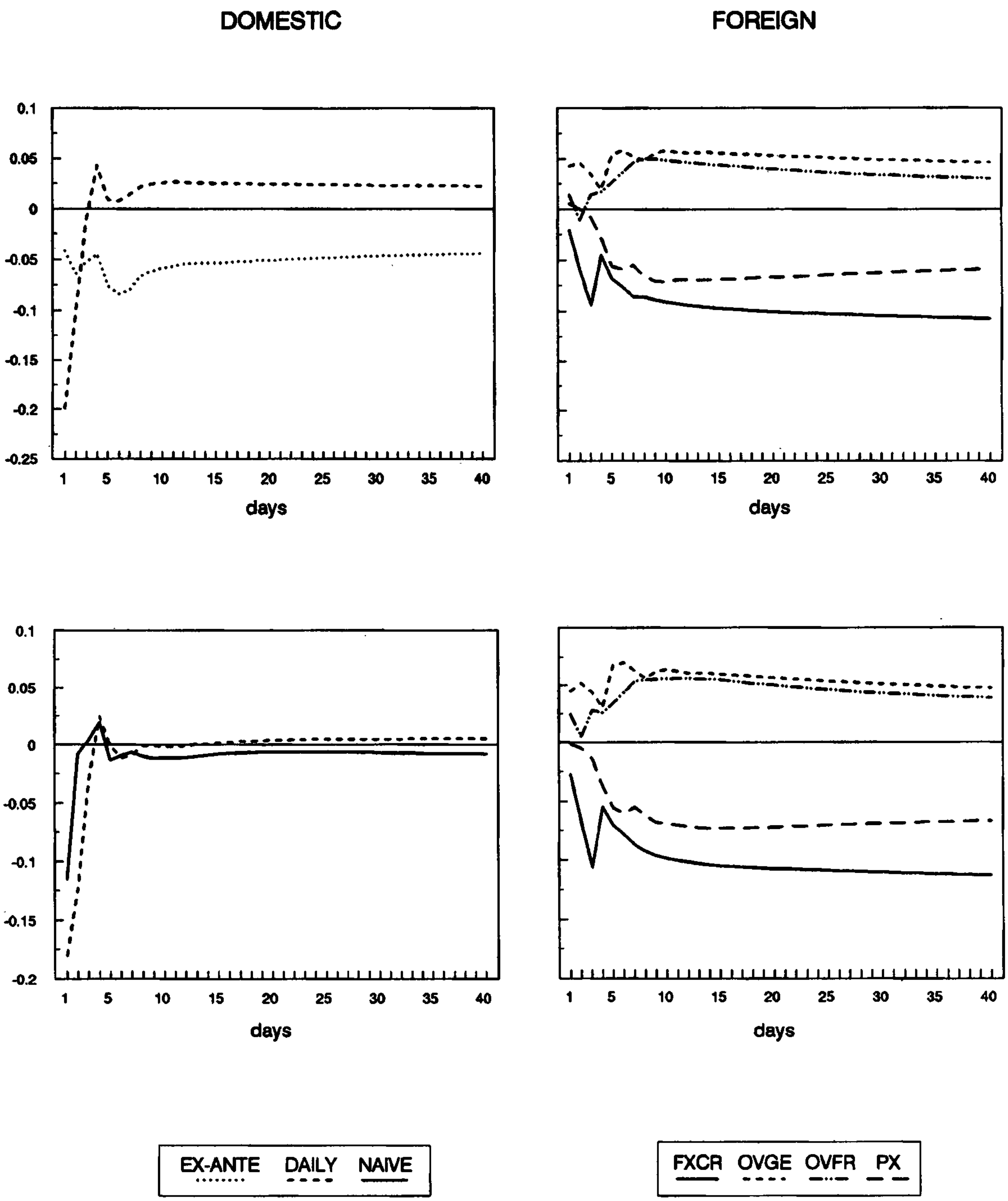


Table 4

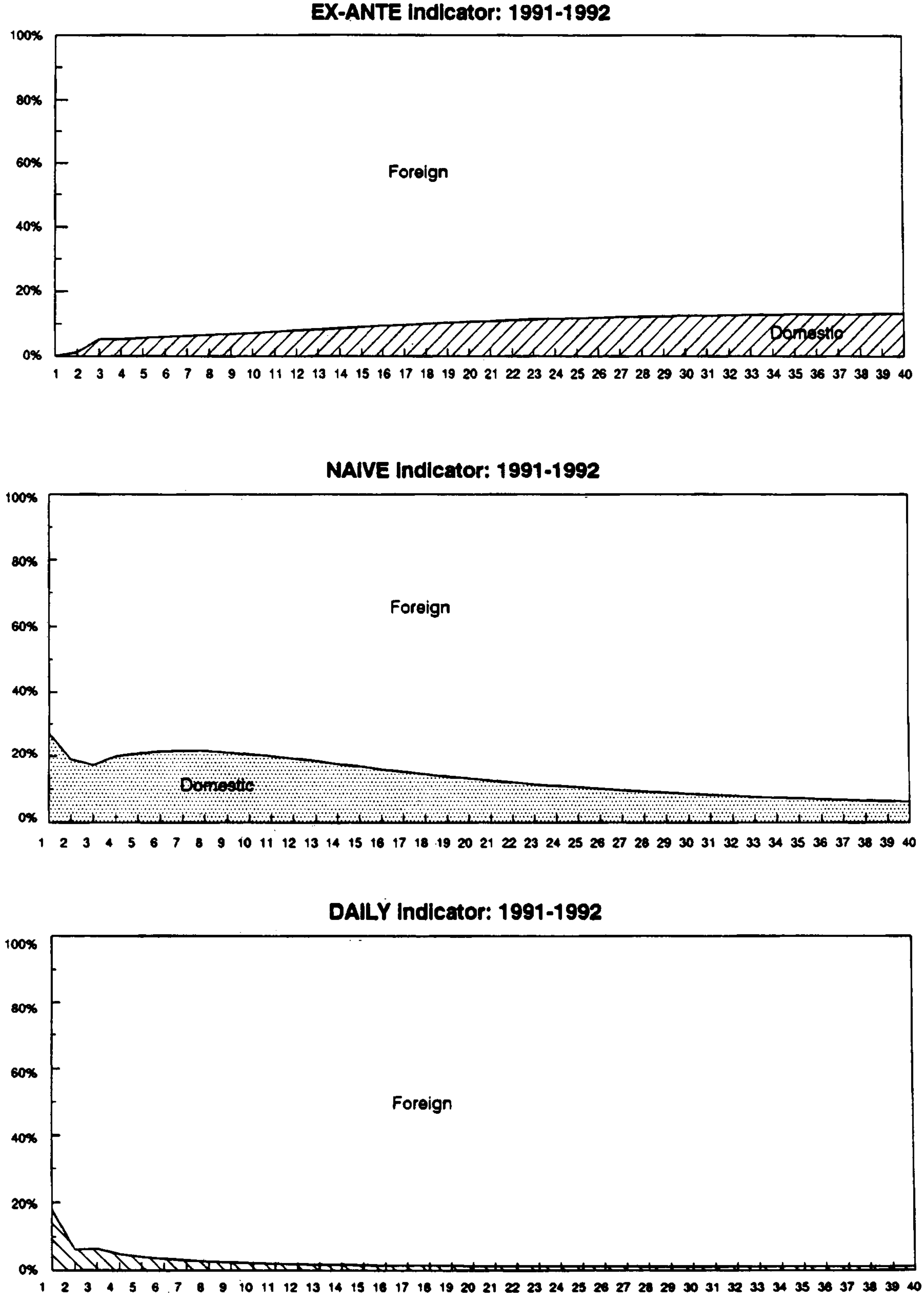
3 MONTH INTERBANK RATE, OVERNIGHT, LIQUIDITY AND FOREIGN EXCHANGE

	OLS							GMM						
	Lagged 3 month	Lagged overnight	Monthly indicator	Daily	FXCR	PXIT	R^2_c	Lagged 3 month	Lagged overnight	Monthly indicator	Daily	FXCR	PXIT	R^2_c
EX-ANTE	.81** (17.6)	.12** (4.00)	.0037* (2.05)	.0096 (1.31)	.0012 (.44)	-.10** (-3.34)	.948	.82** (33.6)	.12** (7.83)	.0033** (2.76)	.013** (3.61)	.0017 (.81)	-.10** (4.42)	.947
NAIVE	.83** (17.6)	.11** (3.38)	-.0077 (-.59)	.016* (2.41)	-.0007 (-.29)	-.087** (-2.85)	.948	.84** (27.6)	.098** (5.93)	-.0075 (-.72)	.011* (1.96)	.0004 (.20)	-.089** (-4.85)	.947
FOR1	.81** (17.4)	.13** (4.02)	.0041* (2.27)	.0095 (1.30)	.0012 (.44)	-.10** (-3.32)	.948	.82** (35.0)	.13** (8.37)	.0043** (3.29)	.013** (3.64)	.0018 (.85)	-.11** (-4.61)	.947
FOR2	.82** (18.0)	.12** (4.14)	.0017 (1.07)	.010 (1.47)	-.0002 (-.08)	-.076* (-2.38)	.948	.83** (28.9)	.12** (6.27)	.0026 (1.41)	.012** (3.24)	.0000 (.03)	-.078** (-3.58)	.947

Sum of the lagged coefficients; White (1980) t-statistics robust to heteroskedasticity in parentheses.
One star (*) indicates significance at the 5% level.
Two stars (**) indicate significance at the 1% level.
All regressions include 6 lags of the independent variables (lag length selected using Akaike's information criterion). The order of moving average disturbances in the GMM estimates is 20.

Fig. 17

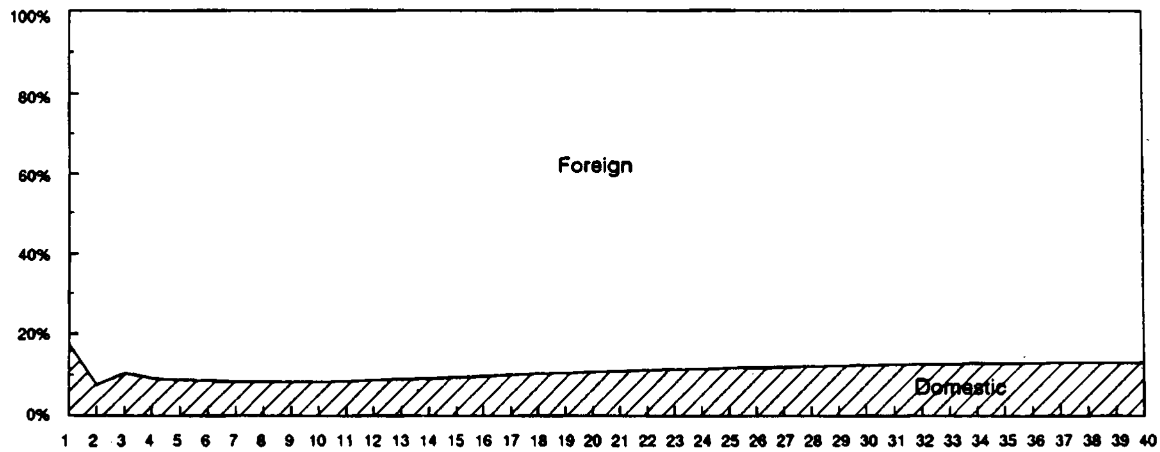
Variance decomposition of the 3 month interbank rate



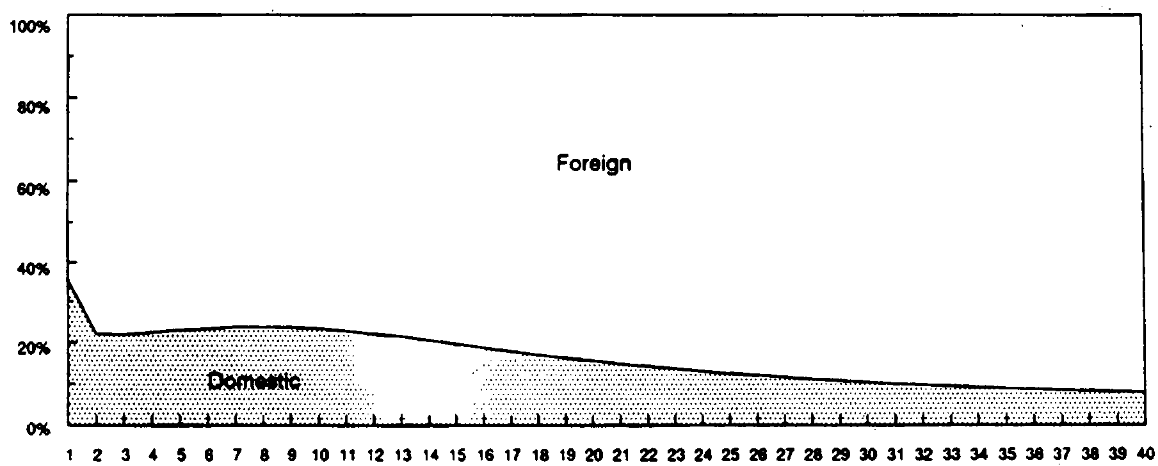
Variance decomposition of the 3 month interbank rate

Fig. 18

EX-ANTE + DAILY indicators: 1991-1992



NAIVE + DAILY indicators: 1991-1992



overnight rate indicators like DAILY and NAIVE were able to explain a very high variance share at short lags, this is not the case for the three-month rate. An extreme result is obtained using the EX-ANTE indicator, which is unable to explain any of the short-term variability of the three-month rate, but accounts for about 14 per cent in after two months. NAIVE and DAILY perform better than EX-ANTE in the short run (respectively, 27 and 30 per cent), but worse in equilibrium (6 and 2 per cent).

6. Conclusions

Our analysis of the relation between bank liquidity and interest rates, based on Italian data for 1991-92, strongly supports the existence of liquidity effects on money market interest rates. The best indicators of liquidity appear to be those embodying forward looking information on reserve flows within the reserve requirement computation period, consistent with an intertemporal optimizing behavior on the part of commercial banks.

The high quality of the data allows us to identify liquidity effects and to separate domestic from foreign sources of interest rate variability. We found that in the time period examined, unlike in the one before 1990, interest rate movements were almost entirely driven by foreign exchange factors, either directly or through the liquidity effects of central bank intervention. This suggests that monetary policy in Italy was, in the period examined, concentrated on maintaining a stable exchange rate within the ERM narrow band, and that other domestic objectives did not interfere with this target in a significant way. During this period, the adoption of a narrow band and the removal of foreign exchange controls drastically reduced the scope for an independent monetary policy, as predicted by the "asymmetric view" of the EMS.

Appendix 1: Liquidity and interest rates under average required reserves computation.[31]

Consider the demand for reserves by a perfectly competitive and risk neutral bank, in the <u>absence</u> of average reserve computation. Suppose that the daily cash flow is composed by a random part x, with zero mean and frequency distribution f(x), and a net balance of interbank transactions, b; the bank can borrow (b > 0) or lend (b < 0) without limit at the interest rate r. Excess liquidity at the end of the day is remunerated at the (low) interest rate r_L, while shortages have to be financed at the (high) rate r_H.

Expected profit at the end of the day is given by:

$$(1) \qquad r_H\int_{-\infty}^{-b}(b+x)f(x)dx + r_L \int_{-b}^{\infty}(b+x)f(x)dx - br$$

and the first order condition for a maximum is:

$$(2) \qquad r = r_H P + r_L(1-P); \qquad P = \int_{-\infty}^{-b} f(x)dx$$

where P is the probability of a liquidity shortage for any given b. Equation (2) represents the demand for liquidity as a function of r: an increase in r induces the bank to choose a lower value of b, i.e. of liquidity; a similar result is produced by a decrease in r_L and/or r_H.

Suppose now that the bank is subject to a reserve requirement computed on average over N days. r_L and r_H are the remuneration and the penalty rates applied to the excess or shortage computed at the end of the period. On each day n, the bank knows its cumulated reserve position up to n, α_n. On

---

31. This Appendix draws on Poole's (1968) and Baltensperger's (1980) models of bank reserve management.

each future day, there is a random cash flow element x_j, $j = n+1, \ldots, N$, and a possibility of daily borrowing in the interbank market, b_j at the current rate r_j. The expected value of the cumulated reserve position at the end of the period is:

$$(3) \qquad \alpha_n + \sum_{j=n+1}^{N} [b_j + x_j(N - j)]$$

Let x_j be a white noise with zero mean and variance equal to σ^2_x; then the stochastic part of (3), $x \equiv \Sigma x_j(N-j)$, has zero mean and variance $\Sigma(N-j)^2\sigma^2_x$. The expected value of profit at the end of the computation period (neglecting the constant term α_n) is:

$$(4) \qquad r_H\int_{-\infty}^{-\Sigma bj}(\Sigma b_j+x)f(x)dx + r_L\int_{-\Sigma bj}^{\infty}(\Sigma b_j+x)f(x)dx - \Sigma b_j r_j$$

where $f(x)$ is the frequency distribution of x_n. First order conditions for a maximum of (4) are:

$$(5) \qquad r_H P + r_L(1-P) = r_j, \quad j = n+1, \ldots, N,$$

where

$$P \equiv \int_{-\infty}^{-\Sigma bj} f(x)dx$$

is the probability of a liquidity shortage at the end of the period and r_j is the expected short-term interest rate.

Note that (5) implies that r_j must be constant for every j; the reserve averaging mechanism offers an unlimited arbitrage possibility to a risk neutral bank if expected short-term interest rates are not constant within the computation period.[32] Substituting r for r_j in (5), the demand

32. A fortiori, all forward and "long-term" (multi-day) rates must be identical within the period, even without risk neutrality.

for net interbank funds, $b = \Sigma b_j$ can be represented as in Figure A1. The shape of the curve is that of the cumulative function P. For $r=r_1$, the net supply of funds on the interbank market is b_1. An exogenous shock on reserves, or a different value of α_n, leads to a horizontal shift in the curve, with a corresponding change in the net supply of interbank funds. As the end of the computation period gets closer, the variance of x is reduced and the curve tends to the broken line $Ar_H r_L B$, becoming more inelastic to interest rate changes.

Let us now consider the market equilibrium. For each bank, k, (5) can be written as a function $g_k(m_k+b_k)$, where m_k is the expected value of x (not necessarily equal to zero) and b_k is the net demand for interbank funds. The equilibrium interest rate is determined by the Walrasian system:

(6.1) $g_k(m_k+b_k) = r$ for $k = 1, \ldots, K$

(6.2) $\Sigma b_k = 0$

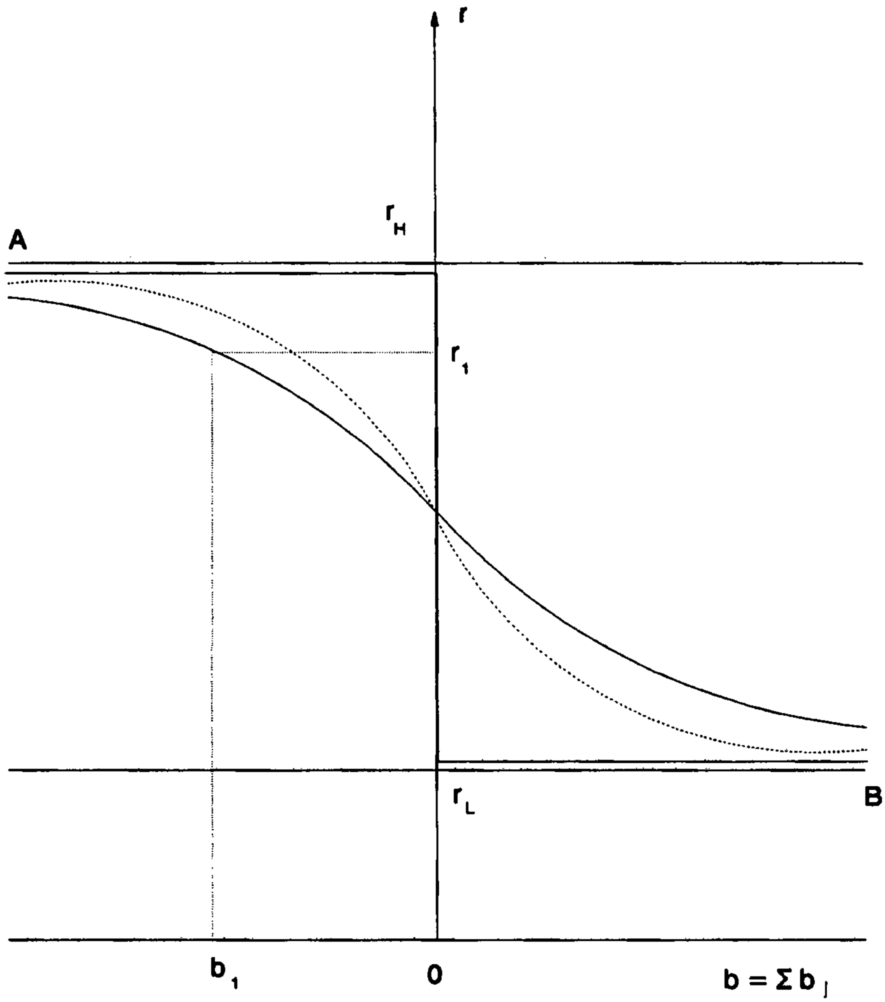
which also determines the reserve and interbank position of each individual bank. Differentiating (6) and solving for the change in r we obtain:

(7) $dr = (\Sigma dm_k)/[\Sigma(g'_k)^{-1}]$.

The numerator, (Σdm_k) can be interpreted as an aggregate liquidity shock; the denominator as an aggregate demand elasticity (with a negative sign). Thus the liquidity shock affects the interest rate by an amount that depends on the sum of individual demand elasticities.

As in the individual case, the aggregate schedule tends to a kinked curve like $Ar_H r_L B$ as time approaches the end of the averaging period. This means that, in (7), the

Fig. A1: Demand for net interbank funds



denominator gets smaller, and the unitary impact of a liquidity shock on r is an inverse function of the number of days remaining before the end of the computation period.

Appendix 2: Identification of causality in a block recursive VAR

A VAR can be written as:

$$Ay = By_{-1} + n$$

where $E(nn') = I$ and B is a matrix which may contain polynomials in the lag operator up to an arbitrary order. Suppose A is a lower block triangular matrix, i.e. A_{12} is a matrix of zeros in :

$$A = \begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix}$$

Variance decomposition in the VAR requires computing orthogonal "innovations", w, such that:

$$w = H^{-1}A^{-1}n; \; E(ww') = I;$$

where H is the so-called Choleski decomposition of the covariance Σ of the reduced form:

$$\Sigma = (A^{-1})(A^{-1})'; \; HH' = \Sigma.$$

In order to show that under the stated assumption on A the variance decomposition of w in two blocks is equivalent to the variance decomposition of the structural errors, we need to show that $Z \equiv H^{-1}A^{-1}$ is block diagonal. The lower-left block can be written as:

$$\underline{H}_{21}\,\underline{A}_{11} + \underline{H}_{22}\,\underline{A}_{21},$$

where the underscore denotes blocks of the corresponding inverse matrices. The lower-left block of ZZ', equal to zero by construction, is given by

$$\left(\underline{H}_{21}\,\underline{A}_{11} + \underline{H}_{22}\,\underline{A}_{21}\right)\left(\underline{H}_{11}\,\underline{A}_{11}\right) = 0;$$

postmultiplying by $\underline{A}_{11}\underline{H}_{11}$ proves our statement.

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