

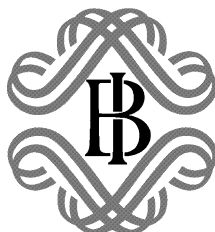
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**Is money informative? Evidence from a large model used
for policy analysis**

by F. Altissimo, E. Gaiotti and A. Locarno



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IS MONEY INFORMATIVE? EVIDENCE FROM A LARGE MODEL USED FOR POLICY ANALYSIS

by Filippo Altissimo^{*}, Eugenio Gaiotti^{*} and Alberto Locarno^{*}

Abstract

In this paper we assess whether monetary variables, which are observed with little delay, conveyed marginal information on the state of the Italian economy in the 1990s, taking as a benchmark the forecasting errors generated by the quarterly model used by the Bank of Italy. We follow two approaches. First we map monetary surprises into estimates of the structural disturbances using a Kalman filter approach, in order to improve the forecasts. Then we look at the sample correlations among forecasting errors in monetary and real variables, thereby taking into account links that may not be accounted for by the model's structure. We find that bank interest rates have a strong information content. Monetary aggregates play no role according to the first approach; according to the second approach they do, but the economic interpretation of this finding is not straightforward. All in all, the results highlight the role of financial prices and quantities as indicators of the state of the economy. However, they do not imply a mechanical policy reaction to this information, as both the strength and the sign of the relationship between the surprises in monetary and real variables depend on the source of the shocks.

JEL classification: C53, E52, E58, E65.

Keywords: monetary aggregates, information variables, Kalman filter, forecasting.

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1. Introduction

Is money useful to the monetary policymaker? The role of monetary variables in guiding policy choices was downgraded by most academics and central bankers in the 1990s, in the face of unexpected shifts in the velocity of money. Money also ceased to play an explicit role in mainstream macro models. Most modern models (both large macromodels and small, micro-founded structural models) feature a stable long-run relationship between money and prices, but monetary variables fail to serve a useful purpose for implementing policy, since they are post-recursively demand-determined, after the fundamental macro variables are set.¹

Recently, however, the role of monetary and credit variables has returned to the spotlight of policymaking and academic interest.

At the policy level, the strategy adopted by the European Central Bank since it started operating in 1999 draws an explicit distinction between approaches that assign a central role to money and those that rely on a set of indicators, including projections obtained with econometric techniques;² the ECB uses both approaches. At the academic level, a number of recent quantitative studies have re-examined the issue of the information content of money, finding a meaningful role for financial variables as predictors of future inflation (Nicoletti-Altamari, 2001, Trecroci and Vega, 2000).³

One of the reasons for assigning a role to monetary variables is that they may convey information on the underlying state variables of the economy, which are observed with lag of several months. This is because “monetary data are measured relatively more accurately than many other economic indicators and are typically available in a more timely fashion” (European Central Bank, 2000). In this vein, a number of recent studies have used small, micro-founded structural models in order to assess whether, under specific assumptions on the structure of information lags, monetary variables possess any information content

¹ See the review and discussion in Meyer (2001).

² See European Central Bank (2000) and Issing *et al.* (2001).

³ Dotsey and Otrok (1994) question the reliability of the evidence provided by Granger-causality tests and argue that the issue of the information content of money can only be addressed within structural models.

(Dotsey and Hornstein, 2000, for the US, and Coenen, Levin and Wieland, 2001, for the euro area).

Another strand of the literature argues that money may be useful as a proxy for effects that are otherwise not well measured or, more fundamentally, that it has a direct role in the transmission mechanism, which is not captured by existing models.⁴ In a different perspective, the emphasis is sometimes placed on the role of money as a guidepost for avoiding major mistakes rather than on its short-run contribution to overcoming information lags in other variables.⁵

In this paper we focus on the first set of issues and assess whether monetary variables had non-negligible information content in the 1990s. To answer this question, we rely on a large macro model, the quarterly model of the Italian economy at the Bank of Italy, which is extensively used for actual policymaking. The main reason for this choice, which contrasts with the attention paid by the recent literature to small models, is the practical relevance of the experiment: large macro models may have a number of theoretical shortcomings compared with the recent stream of smaller models built on solid microfoundations, but they remain a prominent tool used by central banks for forecasting and policy evaluation.⁶ The issue of whether more timely information on monetary variables may deliver an improvement in their forecasting performance is therefore relevant. The experiment amounts to asking whether closer consideration of monetary variables would improve on what forecasters in many central banks *actually* do.

The paper analyzes the properties of the forecasting errors generated by the quarterly model; we refer to surprises to the final targets of policy (GDP and prices) as well as to innovations to monetary variables (both quantities or prices). How surprising are these surprises? Can we do marginally better by considering monetary variables more carefully?

⁴ Meyer (2001) lists the main explanations proposed to justify the direct impact of money on inflation and economic activity: (i) money affects demand; (ii) money proxies for the broad range of interest rates and asset prices through which monetary policy operates; (iii) monetization causes changes in expectations about the course and effects of future policy. Among the proxy roles, Longworth (2002) also argues that money may pick up non-linear responses of output to interest rates.

⁵ This underlies the position in European Central Bank (2000), according to which “the analysis conducted under the second pillar [projections and other indicators] focuses on .. factors ... which influence price developments in the shorter term”, while “the analysis under the first [monetary] pillar offers particularly useful guidance over a medium-term horizon”. See also Dotsey, Lanz and Santucci (2000).

We assess the information content of surprises in monetary variables following two distinct but complementary routes: one approach requires filtering the new information contained in financial variables by mapping surprises into estimates of the structural disturbances impinging on the variables of interest and then starting a new forecasting round of the model; the other looks directly at the correlations among surprises. It is worth stressing that the two approaches are complementary rather than competing. The former rests on the transmission mechanism built into the model and addresses the problem of measuring the gain in predictive accuracy achievable by exploiting the information contained in monetary surprises. The latter tries to answer the same question simply by looking at historical correlation among surprises. Both methods have pros and cons: the former is more efficient and informative, the latter more robust.

We depart from the previous literature in several respects. In contrast with Angeloni and Cividini (1990), who assess the information content of monetary variables only on the basis of the properties of the quarterly model of the Italian economy and measure it by means of stochastic simulations, we take our model to the data and assess the relevance of money as an information variable in terms of the actual forecasting performance over the 1990s. Whereas Friedman (1984) looks at the “surprises” generated by a small econometric model in order to assess the information content of money, we rely on a large model routinely used for monetary policy purposes and on structural assumptions to filter information. Unlike Dotsey and Otrok (1994), we provide a unified framework for combining both structural and reduced-form approaches to estimate unobserved variables.

The results highlight the potential role of financial prices and quantities as measures of unobserved state variables and suggest that the effort required to implement structural filters has its own pay off. However, the policy implications of this finding are not straightforward, since the relationship between the financial and real sides of the economy are far from time-invariant and highly dependent on the source of the shocks.

The paper is organized as follows. Section 2 describes how monetary and credit aggregates entered the policy strategy of the Bank of Italy in the two decades preceding European Monetary Union. Section 3 discusses how surprises in monetary variables may be

⁶ For a survey, see the special issue of *Economic Modelling*, July 1998 (Vol. 15, No. 3).

used by the policymaker and compares two different ways of reaping the full benefits of the timely availability of financial statistics. In Section 4, an extended Kalman filter approach is applied to the Bank of Italy's quarterly model to gauge the gain in forecasting accuracy associated with optimally extracting the information contained in monetary variables. Section 5 addresses the same issue by studying the historical correlation among surprises generated by the quarterly model. Section 6 concludes.

2. The background: monetary policy in Italy

Two features make the quarterly model of the Bank of Italy a promising reference for our experiment. First, the model was extensively used for policy-making, both in a period when the announcement of monetary reference paths played an important role and when they were somewhat de-emphasized, leaving room for targeting inflation forecasts. Second, it features a post-recursive role for monetary and credit variables, which is very much in line with current macroeconomic practice.⁷

The monetary policy framework of the Bank of Italy in the last two decades employed several reference variables: target ranges for money (M2) were announced from 1985 to 1998, although with varying emphasis; the exchange rate also played a pivotal role in the EMS period, from 1979 to 1992; inflation forecasts played a major role from 1994 to 1998.⁸ The common, clearly specified theoretical framework of the quarterly model ensured that the multiple objectives pursued by the monetary authority could be set in a mutually consistent way. It helped the central bank to evaluate the information content of real and monetary variables and to present and explain its actions to the general public, with a logically consistent account of the developments of the real and monetary indicators.

When M2 growth rates were announced, the model, as a forecasting tool, provided values for the M2 profile consistent with the desired path for the final targets. A normative scenario derived from a main forecasting exercise, usually performed every autumn, was

⁷ The quarterly model of the Italian economy is described in Banca d'Italia (1986) and Galli, Terlizzese and Visco (1989). Its current version includes 96 stochastic equations and 790 identities. A detailed description of the monetary transmission mechanism in the model is in Nicoletti-Altimari *et al.* (1995). The money demand equation (in the official definition used by the Bank of Italy until 1998) is presented in Angelini, Hendry and Rinaldi (1994).

⁸ See Altissimo *et al.* (2001) for details and references.

used as an input for the profiles for the main financial aggregates, interest rates and monetary instruments. The use of monetary aggregates for day-to-day policy evaluation was based on monitoring and assessing their deviations from the benchmark scenario and on analysis of the causes of such deviations.⁹

However, from the mid-1990s onwards, the focus of monetary policy switched towards inflation forecasts, although the target path for M2 continued to be announced. Beginning in 1995, the Governor of the Bank of Italy announced upper limits for inflation in the following year and stated explicitly how the management of official rates would be linked to the behaviour of actual and expected inflation. The model retained an essential role, as it was the tool used to produce the internal inflation forecasts that would be announced to the public.¹⁰

Currently, the model is still extensively used, in particular during the macroeconomic projection exercises carried out jointly with the ECB and the other national central banks of the Eurosystem (see European Central Bank, 2001). The theoretical framework underlying the monetary and financial block is to a large extent the one outlined in Ando and Modigliani (1975) and conforms to the methodology that used to underlie the MPS econometric model for the US.¹¹ Monetary and credit aggregates essentially play a post-recursive role, similarly to most existing macro-models.¹²

⁹ A detailed analysis of the role played by monetary indicators in different episodes is in Altissimo *et al.* (2001). The paper also discusses of the role played by the quarterly model in policy making.

¹⁰ Siviero *et al.* (1999) discuss the role of inflation forecasts over the period and provide econometric evidence of the role of internal forecasts in the Bank's reaction function.

¹¹ The introduction of forward-looking elements in such a framework is discussed by Nicoletti-Altimari *et al.* (1995) and Gaiotti and Nicoletti-Altimari (1996).

¹² The monetary and financial section of the model is composed by more than two hundred equations, of which some thirty are stochastic. It describes the financial position of seven categories of economic agents (central bank, banks, government, households, firms, mutual funds and rest-of-the-world) and how their assets and liabilities are allocated among eight groups of instruments (currency, deposits, compulsory reserves, repos, short-term securities, long-term securities, loans and mutual funds and shares). Each market is described by a demand function and an inverted supply equation, in which the endogenous variable is the relevant interest rate. The determination of interest rates is based on banks' behavioural equations and equations for the term structure. Banks have monopolistic power and can set both the lending and the borrowing rate, but take the price of interbank deposits as given. In both cases, the size of the spread depends on the elasticity of demand and on the structure of marginal costs.

3. Money, information and surprises

Even when money and credit do not have a direct impact on aggregate supply or demand, responding to their unexpected movements could be appropriate if they signal contemporaneous, but still unobservable, changes in real income or prices. Thanks to the shorter lags with which monetary and credit data become available, surprises in the behaviour of money with respect to a benchmark profile may be used as soon as they materialize to infer something about likely forthcoming surprises in policy targets and to react accordingly.¹³ The question is how to exploit this information effectively. In this section we employ a simple mainstream model to assess the relative performance of two approaches which can be used for this purpose.

The way in which the flow of new information is used for policy purposes can be described within a simple “passive money” macro-model (e. g. Clarida *et al.*, 1999, and Galí, 2000). A forward-looking aggregate demand curve is coupled with a forward-looking price equation and a money demand schedule appended. The system is closed with a policy rule.

$$(1) \quad \begin{aligned} x_t &= E_t x_{t+1} - \frac{1}{s} (r_t - E_t \mathbf{p}_{t+1} - rr_t) \\ \mathbf{p}_t &= \mathbf{b} E_t \mathbf{p}_{t+1} + \mathbf{1} E_t x_t + u_t \\ m_t &= p_t + y_t - \mathbf{h} r_t + v_t \end{aligned}$$

where $x_t \equiv y_t - \bar{y}_t$ is the output gap, \mathbf{p}_t is inflation, m_t money and r_t the monetary policy instrument.¹⁴ The cost-push term is assumed to be an AR(1) process, $u_t = ru_{t-1} + \mathbf{e}_t$, with $\mathbf{e}_t \sim IID(0, \mathbf{s}_e^2)$, while the velocity shock, v_t , is assumed to be white noise, with variance \mathbf{s}_v^2 ; \bar{r}_t , the flexible-price equilibrium real interest rate, is exogenous to this model.¹⁵

We assume that at time t current prices and inflation are not observed. Correspondingly, we assume that the cost-push shock, which is the variable driving the

¹³ The vast literature on the information content of money dates from the 1970s (a survey is in Friedman, 1990). Here, we briefly summarize the main features of this approach in a simplified model, in order to clarify our subsequent analysis.

¹⁴ All variables are in logs, except the interest rate.

¹⁵ Galí (2000) shows that \bar{r}_t , the flexible-price equilibrium real interest rate, depends on the discount factor, productivity and government consumption.

equilibrium path of output and inflation, and the money-demand shock are known with a one-period lag, while we assume no uncertainty about the parameters of the model and the probability distribution of the shocks.

The central bank optimizes every period by choosing the interest rate which minimizes its current-period loss function, which is assumed to be a quadratic function of both inflation and the output gap: $1/2(\mathbf{p}_t + \mathbf{a}x_t)^2$. The optimal policy requires that $E_t x_t = (\mathbf{1}/\mathbf{a})E_t \mathbf{p}_t$.

In each period, the estimate of inflation can be optimally revised by applying the Kalman filter to extract information on the unobserved state variables. The revision in the estimate will depend on the “surprises” in money and in past inflation, yielding (see Appendix I for a derivation):

$$(2) \quad \mathbf{p}_{t/t} - \mathbf{p}_{t/t-1} = \left[\frac{1}{1+\mathbf{x}} \quad \vdots \quad (\mathbf{j} + \mathbf{r}) - \frac{\mathbf{y}}{1+\mathbf{x}} \right] \begin{bmatrix} (m_t - p_{t-1}) - (m_{t/t-1} - p_{t-1/t-1}) \\ \mathbf{p}_{t-1} - \mathbf{p}_{t-1/t-1} \end{bmatrix}$$

where $\mathbf{x} \circ \mathbf{s}_m / \mathbf{s}_e$. Money is informative insofar as velocity shocks are not too volatile: as $\mathbf{x} \otimes \mathbf{y}$, money surprises play no role at all; were the volatility of the velocity shock equal to zero, inflation would be predicted with no error.

Equation (2) sets a relation among “surprises” of endogenous variables. To exploit it for policy purposes, two approaches may be used.

A first approach relies on the econometric model describing the working of the economy and uses the model’s estimated multipliers and covariance matrix to filter the information contained in monetary and credit data, by means of the same filtering procedure used to obtain (2). We apply this approach to the quarterly model of the Italian economy in Section 4. This solution is theoretically appealing, since it provides an approximation to the optimal filter and explicitly attempts to attribute to structural shocks the innovation to previous-period forecasts. In this sense, it is also related to what, less formally, is usually done in day-to-day monetary analysis, when the behaviour of money is interpreted to gain insight into the underlying economic phenomena. However, a drawback of this approach is that it is strongly model-dependent, as only the dynamic correlations among forecast errors

that are built into the structure of the model are taken into account: one may not find any information content for money if the model is misspecified.

A second approach, which we apply to the quarterly model in Section 5, gauges the informative content of surprises in financial variables by analyzing the correlation between forecast errors, by means of regressions among the surprises in endogenous variables obtained from a simulation of the model.¹⁶ In the model described above, this would require regressing $\mathbf{p}_t - \mathbf{p}_{t|t-1}$ onto $[(m_t - p_t) - (m_{t|t-1} - p_{t|t-1})]$ and $(\mathbf{p}_{t-1} - \mathbf{p}_{t-1|t-1})$. The resulting estimates (as shown in the Appendix I) would asymptotically yield the coefficient:

$$(3) \quad \mathbf{d} = \begin{bmatrix} \frac{1}{1+\mathbf{x}} \\ (\mathbf{j} + \mathbf{r}) - \frac{\mathbf{y}}{1+\mathbf{x}} \end{bmatrix}$$

which is clearly identical to the one in (2).

While the two approaches are equivalent under perfect knowledge of the structural coefficients in the system, the equivalence breaks down if either an incomplete set of surprises is used or model uncertainty is allowed for. In the first case, the estimates of the second method could be biased and inefficient because of an omitted variables problem. In the second case, by contrast, no general conclusion can be drawn concerning the relative performance of the two methods. The advantage of using a much larger set of variables in the estimates of the structural model may be offset by the bias caused by imposing incorrect over-identifying restrictions on the reduced-form. The magnitude of these contrasting effects will depend on the source of misspecification.

All in all, the second approach is simpler and may possibly account for relationships among variables which are not embodied in the structure of the model. But it is also inefficient and more likely to arbitrarily constrain the information set used to evaluate the signalling role of financial variables. Though the balance of these two effects may go either way, model uncertainty is a reason for comparing the two approaches to extracting information from monetary data.

¹⁶ Friedman (1984) provides an example of this approach.

4. Information lags and monetary variables: a filtering approach

An example of the use of a filtering technique to exploit the information contained in new observations and update the estimates from a large model is found in Kalchbrenner and Tinsley (1976), who blow up the forecast errors of the indicators into estimates of the structural disturbances. Angeloni and Cividini (1990) and Angeloni and Passacantando (1991) present results obtained from the quarterly model of the Bank of Italy, concluding that monetary aggregates provide some information on present and future values of nominal GDP. However, their experiment, which contributed to justifying the role attributed to monetary aggregates in Italy in the 1980s, is based on the “theoretical” information content built into the model’s properties, i. e. on the reduction of the forecast error variance obtained from a set of stochastic simulations of the model. By contrast, we aim to measure the forecasting improvement for actual data over a specific period (the 1990s).

Incorporating the additional information from new observations on money and credit variables in a full-scale simulation requires that a few steps be followed. First, surprises for financial indicators must be computed; second, such surprises must be mapped into structural shocks; finally, forecasts conditional on the information set augmented with the updated estimate of the structural shocks must be generated.

The linearized version of the quarterly model of the Bank of Italy can be represented by the following set of equations:

$$(4) \quad Ay_t \equiv A \begin{bmatrix} y_t^T \\ y_t^M \\ y_t^O \end{bmatrix} = B(L)y_{t-1} + C(L)x_t + \begin{bmatrix} \mathbf{e}_t^T \\ \mathbf{e}_t^M \\ \mathbf{e}_t^O \end{bmatrix}$$

where y_t , the vector of modelled variables, is partitioned into three subsets, y_t^M , y_t^T and y_t^O corresponding respectively to policy targets, monetary indicators and other endogenous variables; \mathbf{e}_t is the vector of structural white-noise disturbances, with covariance matrix \mathbf{S}_e ; x_t and y_t represent the vectors of exogenous and endogenous variables respectively, with $B(L)$ and $C(L)$ matrix polynomial of order $p-1$ and q .

The corresponding reduced form is:

$$(5) \ y_t \equiv \begin{bmatrix} y_t^T \\ y_t^M \\ y_t^O \end{bmatrix} = A^{-1}B(L)y_{t-1} + A^{-1}C(L)x_t + A^{-1}\mathbf{e}_t \equiv \mathbf{P}(L)y_{t-1} + \mathbf{G}(L)x_t + u_t$$

Equation (5) may be re-written as:

$$(6) \quad y_t = \Pi^n(L)y_{t-n} + \sum_{i=0}^{n-1} \Pi^i(L)\Gamma(L)x_{t-i} + \sum_{i=0}^{n-1} \Pi^i(L)u_{t-i}$$

Consequently, one obtains:

$$(7) \quad y_t - y_{t-n} = \sum_{i=0}^{n-1} \Pi^i(L)[A^{-1}(\mathbf{e}_{t-i} - \mathbf{e}_{t-i|t-n})] \equiv \begin{bmatrix} g' \underline{\mathbf{e}}_t \\ h' \underline{\mathbf{e}}_t \\ f' \underline{\mathbf{e}}_t \end{bmatrix}$$

where $(\mathbf{e}_{t-i} - \mathbf{e}_{t-i|t-n})$ is equal to \mathbf{e}_{t-i} if $i < n$, zero otherwise. Here $\underline{\mathbf{e}}_t$ represents the vector formed by stacking the current and lagged (up to order $n-1$) structural disturbances \mathbf{e}_t and g , h and f are matrices obtained from the reduced form multipliers i periods ahead. Equation (7) makes clear that surprises in endogenous variables are a complex combination of the shocks buffeting the economy.

Our experiment amounts to using the mapping from structural to reduced-form errors described in equation (7) to blow up the surprises in the financial indicators, u_{t-n}^M , into estimates of the disturbances of the structural equations \mathbf{e}_t , which may then be transformed into estimates of the unobserved states y_t^T (and y_t^O).¹⁷ The matrices appearing in (7) are functions of the reduced-form parameters and the covariance matrix of the shocks, and can be estimated via simulations, by shocking the structural errors and computing the dynamic multipliers up to order $n-1$, where n is the information lag. As the structure of the quarterly model includes some non-linearity, the reduced-form multipliers are recomputed in each period.

It is worth stressing that the filter uses the information contained in u_{t-n}^M only in a way which is coherent with the causal links coded in the identities and stochastic equations

¹⁷ The procedure has a straightforward interpretation in terms of the Kalman filter, as shown in Appendix II.

built into the quarterly model. Hence, the experiment is based on the assumption that the quarterly model is a reliable description of the working of the economy. We are constraining ourselves to detect only the information which is consistent with the theoretical structure of the model.

The procedure is implemented in three steps. First, l -step ahead forecasts are obtained from simulating the quarterly model. Assuming that the information lag, n , is common to all endogenous variables, the model in t is simulated conditional on the observations of endogenous variables up to time $t-n$ and on the actual path of the exogenous ones.¹⁸ The time index t ranges from 1989Q1 to 1999Q2, so that for each forecast horizon, 42 observations are available. The l -step-ahead forecast variance of the i^{th} element of the vector y_t^T is estimated and defined as $\mathbf{s}_{i,l}^2$.

Second, a new forecast is made, assuming that one more observation of monetary data is available. For example, for $n=1$, the value of the variables collected in y_t^T , unobserved as of time t , are now estimated conditional on the enlarged information set $\tilde{I}_t = I_t \cup \{y_t^M\}$. The surprise $y_t^M - y_{t-1}^M$ is mapped into the structural disturbances based on (7); the latter are then used as add-factors. The model is then simulated again to obtain a new set of projections; forecast error variances $\tilde{\mathbf{s}}_{i,l}^2$ are computed:

$$(8) \quad \tilde{\mathbf{s}}_{i,l}^2 = \frac{1}{42} \sum_t \left(y_{i,t+l}^T - \tilde{y}_{i,t+l|t-n}^T \right)^2$$

Third, an additional set of projections is generated by assuming that at time t all variables dated t (not only y_t^M) are known. The corresponding l -step-ahead forecast error variances, $\bar{\mathbf{s}}_{i,l}^2$, which are conditional on $\bar{I}_t = \tilde{I}_t \cup \{y_t^T, y_t^O\} = I_{t+1}$, are computed. Notice that since $I_t \subset \tilde{I}_t \subset \bar{I}_t$, it is clearly the case that $\mathbf{s}_{i,l}^2 \geq \tilde{\mathbf{s}}_{i,l}^2 \geq \bar{\mathbf{s}}_{i,l}^2$: $\bar{\mathbf{s}}_{i,l}^2$ provides a lower bound to the forecast error variance and represents the appropriate scaling factor for gauging the contribution to the forecasting accuracy of the news about monetary and financial variables.

¹⁸ That is, time- t projections are conditional on $I_t = \{y_j\}_{j=t-p}^{t-n} \cup \{x_j\}_{j=t-q}^{t+l}$. Simulation runs from $t-n+1$ to $t+l$, where l is the forecast horizon and n the information lag.

The outcome of the experiment is reported in Tables 1 and 2, which show and compare the mean square forecast errors (MSFE) which are obtained under different assumptions concerning the information set available to the econometrician. Projections, which ranges from 1 to 4 steps ahead, refer to nominal and real GDP. Six variables, representing either monetary and financial aggregates or prices, are alternatively used as information variables. Two indices, which are used to assess the information contained in y_t^M , are reported in Table 1: the first, $\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$, measures the extent of the deterioration in forecast accuracy due to the existence of information lags; the second, $\Lambda_{u^M \rightarrow u^T} \equiv (\mathbf{s}_{i,l} - \tilde{\mathbf{s}}_{i,l})/\bar{\mathbf{s}}_{i,l}$, determines how much of this loss of precision can be avoided by incorporating financial surprises. We consider innovations in financial variables one at a time.

Among the financial variables we select currency, M2,¹⁹ credit to firms and credit to households and bank and market interest rates. Since, by construction of the experiment, there are no surprises in the policy rate (which is treated as an exogenous variable), the information in the unexpected movements of bank and market rates corresponds to the information in the movements of the spread of these rates vis-à-vis the policy rate.

The results do not lend support to the view that, given the model's structure, timely information on monetary and credit aggregates may help reduce the uncertainty originating from information lags on other variables. Rather, they seem to confirm that in the 1990s monetary and credit aggregates lost the informative value they had in the previous decade. Neither M2 nor currency nor credit to the private sector contributes to reducing forecast uncertainty on nominal GDP, as is shown by the negligible value reported in Table 1 of the improvement in predictive accuracy.

By contrast, bank interest rates prove effective in estimating the current unobserved values of real variables.²⁰ Compared with the benchmark case in which there is a one quarter

¹⁹ The pre-EMU definition of Italian M2 is used, since most of the sample period predates the start of Stage Three.

²⁰ Changes in the premium component of (bank and non-bank) interest rates are the amplification mechanism typically advocated by supporters of the credit channel view. Shifts in monetary policy or cyclical conditions alter the efficiency of financial markets in matching borrowers and lenders and raise the extent to which borrowers face rationing in credit markets: a deterioration in financing conditions causes firms and

information lag for all variables, the lending rate reduces the MSFE by nearly one half; the deposits rate performs only marginally worse. Even when the forecast horizon is increased from $l = 1$ to $l = 4$, the improvement obtained by including financial data in the information set remains noticeable.

Similar results are obtained when real GDP is considered (Table 2): the extent of the decrease in the MSFE is roughly the same and the improvement in predictive accuracy due to the use of the information in interest rates extends to all forecast horizons. This outcome suggests that news on the external finance premium mostly affect real activity and only marginally prices, which is quite consistent with the common view that changes in financing conditions are transmitted first to aggregate demand and only with a delay of several quarters to inflation. When aggregate demand components are considered, the outlook changes, though not in an unexpected way: innovations in bank interest rates appear to convey significant information about the prospective path of investments but seem silent about future consumption expenditure and trade flows.

All in all, this evidence has a straightforward interpretation. Interest rate surprises appear to contain significant information because two conditions are met: first, the model accounts for a set of channels through which bank interest rates are related to the real sector; second, the economy works in a way which is not at variance with the description provided by the model. Monetary and credit aggregates appear not to meet these requirements or to meet them only in part: they do not exert a causal influence on non-financial variables in the model, nor is the existing reverse causation from consumption/investment choices to portfolio decisions strong enough to be exploitable, since it is obscured by financial and institutional innovations and velocity shocks.

5. Information lags and monetary variables: looking at surprises

The above analysis is conditional on the structure of the model. The results could, then, be an artefact, due to the limited role assigned to monetary variables in the model. The alternative strategy we follow is to estimate univariate regressions in the spirit of (3) above,

households to revise down their spending plans and thus amplifies the effects of the initial shock.

in order to directly map surprises in y_t^M into revisions in y_t^T . The logic is the same as in the experiment run in the previous section. There is, however, an important difference. Here, by directly addressing the empirical correlations across surprises, we allow all empirical correlations between monetary variables and target variables to play a role beyond the assumed structure of the quarterly model.

Friedman (1984) tested the information content of monetary variables by means of a dynamic simulation of a small (six-equation) macroeconomic model over a long horizon. He derived forecast errors for nominal income growth an indefinite number of quarters ahead and estimated equations relating these forecast errors to the corresponding surprises in money growth, allowing for a rich dynamics in the both variables. He found that movements of money growth contained additional information about future income growth, which, however, was statistically but not economically significant.

This approach was criticized on two grounds (Goldfeld, 1984). First, when dynamic simulations over a long horizon are used to generate forecast errors, the estimated equations should include the lagged surprises for all the endogenous variables in the model, with a lag structure determined by the structure of the original model and the assumptions on the information lags. Moreover, the estimated parameters in the surprise equations are just a simple combination of parameters in the underlying model (unless the dynamics of the initial model is mis-specified), so they can simply be written down rather than estimated.

We follow the logic of the approach, but with substantial modifications. Since we run the experiment on a large model, the parameters in the surprise equations could hardly be recovered directly from the structure of the model itself. We also confine ourselves to surprises over a fixed horizon and keep the lag structure of the regressors consistent with the assumptions on information delays. Specifically, we assume that an initial l -period ahead forecast for the all the variables is made; then, new data for the monetary variable are released, while information on the other variables in the model is still missing. The surprise in the target variables obtained from the first forecast is regressed on the monetary surprises in the immediately subsequent period to the one when the forecast was made. More specifically, we run the experiment under the assumption that monetary data are known one

or two quarters in advance compared with other variables, which is admittedly an extreme hypothesis, as it imposes that provisional national accounts data are not informative.²¹

We ran simulations of the quarterly model over the period 1989Q1-1999Q2, under the assumption of no uncertainty concerning exogenous variables, model coefficients and functional form specification. We compute the l -step-ahead ($l=1,2,4$) forecast error of the same endogenous variables considered in the previous section. We report the properties of the one-step-ahead surprises generated by the experiment in Table 3 (all surprises are defined as percentage deviations from the baseline). As one would expect, they exhibit reasonable properties: stationarity, normality, homoscedasticity and absence of autocorrelation.

For each horizon, we choose one monetary variable at a time, and we run the following regression:

$$(9) \quad y_{i,t}^T - y_{i,t|t-n}^T = \mathbf{a} + \sum_{j=1}^k \mathbf{g}_j (y_{k,t-n+j}^M - y_{k,t-n+j|t-n}^M) + \mathbf{h}_t$$

(note that $y_{i,t}^T$, $y_{k,t}^M$ indicate a single component of the corresponding vector of variables). We test the statistical significance of \mathbf{Sg} in each equation by allowing for heteroscedasticity and serial autocorrelation in the error term. We evaluate the decrease in the forecast error variance.²² Alternatively, we also estimate the variant:

$$(10) \quad y_{i,t}^T - y_{i,t|t-n}^T = \mathbf{a} + \sum_{j=1}^k \mathbf{g}_j (y_{k,t-n+j}^M - y_{k,t-n+j|t-n}^M) + \sum_{j=0}^h \mathbf{I}_j y_{k,t-n-j}^M + \mathbf{h}_t$$

²¹ Monetary data usually become available before national accounts data are released. In Italy, in the period under consideration the first estimates of M2 (monthly average) were released by the last ten days of the month, while final data were available by the following month, with usually only small revisions. National account data would be available only after one or two quarters, and still subject to substantial revisions thereafter. More timely information was available on consumer prices, whose first estimates were also available by the end of the same month, as well as consumer sentiment, wholesale prices, survey data on inflation expectations and industrial production.

²² This is proxied by the R2 of the regression.

where lagged values of the monetary indicator are introduced in the regression, to test whether some omitted monetary link in the model would have helped forecasting the surprise from the model.²³

Table 4 reports the results for (10), respectively considering as a dependent variable the l -period-ahead forecast error of real GDP, the GDP deflator and nominal GDP (with $l=1, 2, 4$). In turn, it reports the R-squared from the regression (which proxies the information content), the sum of the coefficients on the monetary surprise \mathbf{Sg} , the F-test that lagged values of the monetary variable do not enter the regression. One or two stars indicate that the assumption that the null (respectively, $\mathbf{Sg}=0$ and $I_i=0, "i$) is rejected (at the 5 per cent or 1 per cent level).

As in the preceding experiment, the behaviour of bank interest rates (both current surprises and past values) has information content for real and nominal GDP, especially at the shorter horizons (1 and 2 quarters), with the expected (negative) sign. The percentage of variance explained by the equation is not negligible (between 30 and 40 percent for real GDP).

The results for monetary aggregates depart from the findings of the previous experiment. In particular, M2 surprises now have some information content for real GDP, as the sum of the coefficients is statistically significant and the share of explained variance is around 20 percent (with slight differences according to the forecasting horizon). In contrast, past values of M2 do not significantly enter the regression, suggesting that no major misspecification of the money-GDP link affects the model.

However, a closer inspection of the results shows that the sum of the coefficients on monetary surprises, although significant, always has a negative sign. This finding proved to be rather robust to the introduction of other explanatory variables in the equation or to estimation over different sub-samples. Conceptually, this is not in contrast with the analysis presented in this paper; the relation between surprises is a reduced form result whose relation

²³ Equation (14) was also estimated after adding the term $(y_{t-n}^T - y_{t-n|t-n-1}^T)$ on the right-hand side, to take into account the fact that, in actual forecasting practice, the recent forecasting errors in the dependent variable may also be used to update the initial conditions. The results were substantially the same as in the text.

to the structural parameters may be complex enough. In particular, it is conceivable that particular values of the sample covariances among different shocks are driving our result.²⁴

A plausible interpretation of these findings is related to the main features of the Italian business cycle in the 1990s. In a number of major episodes, an increase (or decrease) in uncertainty may have determined both an adverse effect on aggregate demand and an increase (or decrease) in the liquidity preference. In 1992-93, the lira abruptly abandoned the EMS, causing a marked portfolio shift towards money and a sharper contraction in GDP and economic activity; in 1994, a more climate expectations fostered a shift from money to bonds, while the reduction in risk premia partially contributed to the economic recovery; in 1996, market tensions linked to uncertainty about the sustainability of the government debt determined a new shift towards money and possibly contributed to the contraction in activity; finally, in 1997-98, the successful convergence to EMU prompted optimism among economic agents, which was reflected in a new reduction of risk premia, a shift to more liquid assets and a (mild) recovery of GDP. In all these cases, the larger (smaller) than expected growth in money M2 was not signalling excess demand; rather, it was anticipating a decrease (increase) in activity.

Although not inconsistent with an economic interpretation, this finding stands in contrast with a simplistic interpretation of the role that new information on money can play for the policymaker, as the latter is usually based on a positive correlation between the behaviour of money and output. It shows that monetary data can be useful as indicators, but they call for a careful interpretation. Their information role is heavily dependent on the source of shocks hitting the economy, which could vary over time.

6. Conclusions

We tested whether data on monetary and credit variables, thanks to their prompt availability and higher reliability, had marginal information content for output or inflation with respect to the mainstream paradigm of the working of the Italian economy, as summarized by the quarterly model of the Italian economy.

²⁴ Should one allow for a negative covariance between the cost-push and the money-demand shocks in the

In a first experiment we filtered data on monetary and credit aggregates based on the structure of the model, to assess whether they could be used to gather information on the underlying shocks and consequently to improve upon the forecasting performance in the 1990s. We found they could not. On the other hand, we found that timely data on lending and deposit rates did provide such information and could be usefully exploited by the policymaker.

Interest rate surprises appear to contain significant information because the model accounts for a set of channels through which bank interest rates are related to the real sector. By contrast, monetary and credit aggregates do not exert a causal influence on non-financial variables in the model, while their role as signals of unobservable state variables is obscured by the variance of velocity shocks embodied in the model's structure.

In a second experiment we tested whether the forecasting errors in monetary variables (and their past values) could help explain the forecast errors for output and inflation. This approach is complementary to the first one, as it also considers links not accounted for by the model structure. We found that the information content of monetary aggregates is higher than that implied by the previous experiment. However, its interpretation is difficult; in our sample, in the equation explaining the forecast errors in real GDP, monetary surprises have the opposite sign than expected, reflecting the kind of shocks hitting the Italian economy in the 1990s.

The results highlight the potential role of financial prices and quantities as measures of unobserved state variables. However, the policy implication of this finding are not straightforward, since the relationship between the financial and real sides of the economy are complex, far from time-invariant and highly dependent on the source of the shocks. Even if the behaviour of money and credit could give useful information to the policymaker, a very careful interpretation is needed and no mechanical reaction to monetary developments is warranted.

model in Section 3, it could be shown that the coefficient on money surprises in equation (2) could turn negative.

Appendix I

The model we refer to is similar to the one presented in Clarida *et al.* (1999) and Galí (2000).²⁵ An aggregate demand curve and a forward-looking Phillips curve describe the equilibrium in the goods market, while a policy interest rate rule summarizing the behaviour of the central bank. Within this framework, the quantity of money is demand-determined at the interest rate set by the monetary authority and the stock of money is not relevant for the determination of macroeconomic activity. To allow for a role for money as an information variable, we assume that the cost-push shock, which is the variable driving the equilibrium path of output and inflation, is known with a one-period lag with respect to the other disturbances. In addition, we assume that no uncertainty exists about the parameters of the model and of probability distribution of the shocks.

The solution of system (1) is obtained by applying the method of undetermined coefficient. The minimal state variable solution is provided by the following equations:²⁶

$$(A1) \quad p_t = u_t + \frac{\mathbf{r}(\mathbf{a}\mathbf{b}\mathbf{r} - \mathbf{I}^2)}{\mathbf{a}(1 - \mathbf{b}\mathbf{r}) + \mathbf{I}^2} u_{t-1} = u_t + \mathbf{j} u_{t-1}.$$

$$(A2) \quad x_t = E_t x_t = -\frac{\mathbf{I}}{\mathbf{a}} (\mathbf{r} + \mathbf{j}) u_{t-1}$$

$$(A3) \quad m_t - p_{t-1} = (\bar{y}_t - \mathbf{h}\bar{r}_t) + u_t + \underbrace{\left(\mathbf{j} - \left(\frac{\mathbf{I}}{\mathbf{a}} + \mathbf{h}\mathbf{r} \right) (\mathbf{r} + \mathbf{j}) \right)}_y u_{t-1} + v_t.$$

All three variables, once multiplied by the polynomial $(1 - \mathbf{r}L)$, with L being the lag operator, become ARMA(1,1) processes and can be easily cast into state-space form, which allows using the Kalman filtering technique for revising projections of the variables of interest to the monetary authority.²⁷ The Kalman filter is the minimum mean square linear

²⁵ We refer readers to these two papers for a more detailed description of the model and of its micro foundations.

²⁶ It is convenient to express real money balances in terms of previous-period prices because $m_t - p_{t-1}$ is included in the information set I_t . Notice that $m_t - p_{t-1} = \mathbf{p}_t + x_t + \bar{y}_t - \mathbf{h}(\bar{r}_t + E_t \mathbf{p}_{t+1}) + \mathbf{n}_t$, where the equilibrium real interest rate and potential output are exogenous variables, so that the solution is immediately obtained by replacing inflation and the output gap with their representation in terms of fundamental shocks.

²⁷ The transition equation of the Kalman-filter reflects the final-form solution of the endogenous variables

estimator of the unobserved state vector and therefore represents the obvious benchmark for assessing the relative merits of alternative filtering procedures.²⁸

The minimal state space representation is given by the following transition equation:

$$(A4) \quad \mathbf{a}_t \equiv \begin{bmatrix} \mathbf{p}_t \\ m_t - p_{t-1} \\ \mathbf{e}_t \\ v_t \\ \mathbf{p}_{t-1} \end{bmatrix} = \begin{bmatrix} \mathbf{r} & 0 & \mathbf{j} & 0 & 0 \\ 0 & \mathbf{r} & \mathbf{y} & -\mathbf{r} & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{p}_{t-1} \\ m_{t-1} - p_{t-2} \\ \mathbf{e}_{t-1} \\ v_{t-1} \\ \mathbf{p}_{t-2} \end{bmatrix} + d_t + \begin{bmatrix} 1 & 0 \\ 1 & 1 \\ 1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{e}_t \\ v_t \end{bmatrix}$$

where \mathbf{a}_t is the vector of state variables and d_t collects the exogenous components of the system. On the basis of the maintained assumptions about the flow of information, the cost-push shock and the velocity shock (equivalently, inflation and the price level) are observed only with a one-period lag. The measurement equation corresponding to the above transition equation is therefore equal to

$$(A5) \quad w_t \equiv \begin{bmatrix} m_t - p_{t-1} \\ \mathbf{p}_{t-1} \end{bmatrix} = \mathbf{Z} \mathbf{a}_t \equiv \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mathbf{p}_t \\ m_t - p_{t-1} \\ \mathbf{e}_t \\ v_t \\ \mathbf{p}_{t-1} \end{bmatrix}$$

Expression (A5) shows that the information set evolves according to the following recursive equation: $I_t = I_{t-1} \cup \{\mathbf{p}_{t-1}, \mathbf{e}_{t-1}, v_{t-1}, m_t\}$. When new data on inflation and money balances are released, the estimate of the state vector $\mathbf{a}_{t|t-1} \equiv E(\mathbf{a}_t / I_{t-1})$ may be updated according to the Kalman filter recursive equation, which states that $\mathbf{a}_{t|t} = \mathbf{a}_{t|t-1} + P_{t|t-1} \mathbf{Z}' F^{-1} (w_t - \mathbf{Z} \mathbf{a}_{t|t-1})$, where $\mathbf{a}_{t|t} \equiv E(\mathbf{a}_t / I_t)$, $P_{t|t-1}$ is the covariance matrix of the estimation error one-step-ahead and $F = \mathbf{Z} P_{t|t-1} \mathbf{Z}'$. In terms of the above model, the revision to the estimate of the state vector is:

and the coefficients of the transition matrix are a one-to-one mapping to the parameters of the structural model. The Kalman filter may therefore be viewed as a structural approach for updating the estimate of the unknown vector of state variables.

²⁸ The application of the Kalman filter to forward-looking models with symmetric information is discussed by Svensson and Woodford (2000).

$$(A6) \mathbf{a}_{t|t} - \mathbf{a}_{t|t-1} = \underbrace{\begin{bmatrix} [1+\mathbf{y}(\mathbf{j} + \mathbf{r})]\mathbf{s}_e^2 & (\mathbf{j} + \mathbf{r})\mathbf{s}_e^2 \\ (1+\mathbf{y}^2)\mathbf{s}_e^2 + \mathbf{s}_v^2 & \mathbf{y}\mathbf{s}_e^2 \\ \mathbf{s}_e^2 & 0 \\ \mathbf{s}_v^2 & 0 \\ \mathbf{y}\mathbf{s}_e^2 & \mathbf{s}_e^2 \end{bmatrix}}_{P_{t|t-1}Z'} \underbrace{\begin{bmatrix} \frac{1}{\mathbf{s}_e^2 + \mathbf{s}_v^2} & -\frac{\mathbf{y}}{\mathbf{s}_e^2 + \mathbf{s}_v^2} \\ -\frac{\mathbf{y}}{\mathbf{s}_e^2 + \mathbf{s}_v^2} & 1 + \mathbf{y}^2 + \frac{\mathbf{s}_v^2}{\mathbf{s}_e^2} \end{bmatrix}}_{F^{-1}} \underbrace{\begin{bmatrix} \mathbf{e}_t + \mathbf{y}\mathbf{e}_{t-1} + v_t \\ \mathbf{e}_{t-1} \end{bmatrix}}_{w_t - Z\mathbf{a}_{t|t-1}}$$

The above equation implies that

$$(A7) \quad \mathbf{p}_{t|t} - \mathbf{p}_{t|t-1} = \begin{bmatrix} \frac{1}{1+\mathbf{x}} & \vdots & (\mathbf{j} + \mathbf{r}) - \frac{\mathbf{y}}{1+\mathbf{x}} \end{bmatrix} \begin{bmatrix} \mathbf{e}_t + \mathbf{y}\mathbf{e}_{t-1} + v_t \\ \mathbf{e}_{t-1} \end{bmatrix}$$

where $\mathbf{x}^o \mathbf{s}_v / \mathbf{s}_e$. Two things are worth stressing: first, as expected, money is informative insofar as velocity shocks are not too volatile; second, both surprises enhance the estimate of current period inflation, since $\mathbf{p}_{t-1} - \mathbf{p}_{t-1|t-1}$ makes it possible to identify the previous-period cost-push innovation, while $(m_t - p_{t-1}) - (m_{t|t-1} - p_{t-1|t-1})$ helps to estimate \mathbf{e}_t .²⁹

The same result would be achieved by means of a regression of $\mathbf{p}_t - \mathbf{p}_{t|t-1}$ onto $[(m_t - p_{t-1}) - (m_{t|t-1} - p_{t-1|t-1}); (\mathbf{p}_t - \mathbf{p}_{t|t-1})]'$, as done in the text. Under complete knowledge of the structure of the model, OLS would yield the same vector of loading, namely

$$(A8) \quad \mathbf{d} = \begin{bmatrix} (1+\mathbf{y}^2)\mathbf{s}_e^2 + \mathbf{s}_v^2 & \mathbf{y}\mathbf{s}_e^2 \\ \mathbf{y}\mathbf{s}_e^2 & \mathbf{s}_e^2 \end{bmatrix}^{-1} \begin{bmatrix} [1+\mathbf{y}(\mathbf{j} + \mathbf{r})]\mathbf{s}_e^2 \\ (\mathbf{j} + \mathbf{r})\mathbf{s}_e^2 \end{bmatrix} = \begin{bmatrix} \frac{1}{1+\mathbf{x}} \\ (\mathbf{j} + \mathbf{r}) - \frac{\mathbf{y}}{1+\mathbf{x}} \end{bmatrix}$$

Under linearity and perfect knowledge of the parameters of the system, this result holds in general and is by no means related to specific features of the model used; indeed, F and $ZP_{t|t-1}$ in the Kalman filter updating equation coincide with the second moment matrices which define the OLS estimator.

²⁹ It is a matter of simple algebra to check that, in the sample model, $E_t(\mathbf{p}_t - \mathbf{p}_{t-1})^2 = [1 + (\mathbf{j} + \mathbf{r})^2] \mathbf{s}_e^2$ and $E_t(\mathbf{p}_{t|t} - \mathbf{p}_{t|t-1})^2 = \{[1 + (1 + \mathbf{x})(\mathbf{j} + \mathbf{r})^2] \mathbf{s}_e^2\} / (1 + \mathbf{x})$. As $\mathbf{x} \rightarrow 0$, the two variances coincide, meaning that $\mathbf{p}_{t|t}$ provides an exact estimate of the current-period inflation rate.

Appendix II

In order to be useful for revising forecasts, surprises must be transformed into the structural shocks entering the stochastic equation in model (4). The way in which this mapping is implemented may be described in terms of the updating equations of the Kalman filter, which, for models with Gaussian innovations, provides the minimum mean-square-error predictor (with non-Gaussian disturbances, it is optimal only within the class of linear predictors).

By suitably defining the vector of state variables, expression (5) can be transformed into the transition equation of a state-space model, namely:

$$(B1) \quad \begin{bmatrix} y_t^T \\ y_t^M \\ y_t^O \\ \vdots \\ y_{t-p+1}^T \\ y_{t-p+1}^M \\ y_{t-p+1}^O \end{bmatrix} = \begin{bmatrix} \Pi_1 & \dots & \Pi_p \\ I & & 0 \end{bmatrix} \begin{bmatrix} y_{t-1}^T \\ y_{t-1}^M \\ y_{t-1}^O \\ \vdots \\ y_{t-p}^T \\ y_{t-p}^M \\ y_{t-p}^O \end{bmatrix} + \begin{bmatrix} \Gamma_0 & \Gamma_q \end{bmatrix} \begin{bmatrix} x_t \\ \vdots \\ x_{t-q} \end{bmatrix} + \begin{bmatrix} u_t^T \\ u_t^M \\ u_t^O \\ \vdots \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

where \mathbf{P}_i , \mathbf{G}_i are the terms of the respective matrix-polynomials. By redefining the variables, (B1) may be written as:

$$(B2) \quad \mathbf{a}_t = \mathbf{T}\mathbf{a}_{t-1} + \mathbf{d}_t + \mathbf{u}_t$$

where \mathbf{d}_t summarizes the influence of exogenous factors and \mathbf{u}_t is a vector of white-noise disturbances, with covariance matrix \mathbf{S}_u . The corresponding measurement equation implies that only the subset y_t^M of the endogenous variables is observed without delay and is therefore included in the vector of observables w_t :

$$(B3) \quad w_t = Z\mathbf{a}_t$$

where

$$(B4) \quad w_t \equiv \begin{bmatrix} y_t^M \\ y_{t-1}^T \\ y_{t-1}^O \end{bmatrix}; \quad Z \equiv \begin{bmatrix} 0 & I & 0 & 0 & 0 & 0 & \dots \\ 0 & 0 & 0 & I & 0 & 0 & \dots \\ 0 & 0 & 0 & 0 & 0 & I & \dots \end{bmatrix}$$

According to the Kalman recursive equations, the optimal (linear) predictor of the state vector and the corresponding second-moment matrix are given by the following equations:

$$(B5) \quad \begin{aligned} \mathbf{a}_{t|t-1} &= T\mathbf{a}_{t-1|t-1} + d_t \\ P_{t|t-1} &= TP_{t-1|t-1}T' + S \end{aligned}$$

$$(B6) \quad \begin{aligned} \mathbf{a}_{t|t} &= \mathbf{a}_{t|t-1} + P_{t|t-1}Z' \left(ZP_{t|t-1}Z' \right)^{-1} (w_t - Z\mathbf{a}_{t|t-1}) \\ P_{t|t} &= P_{t|t-1} - P_{t|t-1}Z' \left(ZP_{t|t-1}Z' \right)^{-1} ZP_{t-1|t-1} \end{aligned}$$

Expressions (B5) and (B6) provide, respectively, the recursive formulae for the prediction and the updating step. According to the latter, the best way to update forecasts of the unobserved variables is to extract from the incoming information³⁰ the component that is orthogonal to the previous-period information set, which is essentially the same procedure underlying the least-squares estimator.³¹

Given the size of the model, however, it is not possible to work directly on the y_t vector: the alternative adopted is to use surprises to estimate structural shocks, treat them as add-factors and simulate the model to generate new forecasts of the whole set of endogenous variables.

³⁰ In equation (B4), $(w_t - Z\mathbf{a}_{t|t-1})$ represents current-period surprises in financial indicators and previous-period surprises in the remaining variables. On the LHS, $(\mathbf{a}_{t|t} - \mathbf{a}_{t|t-1})$ is the revision in the expected value of the components of the state vector which is obtained by exploiting the newly-arrived data. Notice that since many elements of \mathbf{a}_t are in the information set, $(\mathbf{a}_{t|t} - \mathbf{a}_{t|t-1})$ is mostly formed by zeros.

³¹ It is in fact easy to see that $ZP_{t|t-1}Z'$ is the (conditional) covariance matrix of the one-step-ahead forecast errors of the vector of observables, $(w_t - Z\mathbf{a}_{t|t-1})$, which plays the role of the set of regressors, while $P_{t|t-1}Z'$ represents the covariance matrix of $(\mathbf{a}_t - \mathbf{a}_{t|t-1})$ – the endogenous variables – and $(w_t - Z\mathbf{a}_{t|t-1})$.

To illustrate the procedure, one can re-define the state vector \mathbf{a}_t in (B2) as the vector stacking time- t surprises and structural shocks up to the $n-2^{\text{th}}$ lag.³² The matrix Z in (B3) is constructed in order to define w_t by selecting from the state vector only the subset of surprises in monetary variables, $u_{t|t-n}^M$. The blocks in the T matrix in (B2) providing the vector moving average representation of $u_{t|t-n} = [u_{t|t-n}^M, u_{t|t-n}^T, u_{t|t-n}^O]'$ are estimated by means of model multipliers;³³ correspondingly, the matrix P in (B6) is derived. The recursive equations in (B6) then provide the tool for extracting estimates of the \mathbf{e}_t .

Once such estimates of the current-period structural disturbances have been obtained, the model is simulated and $\tilde{\mathbf{s}}_{i,t}$ is computed and compared with its lower bound $\bar{\mathbf{s}}_{i,t}$ and upper bound $\mathbf{s}_{i,t}$.

³² n represents the information lag. $n-2$ lags of the structural shocks need to be included in the state vector because forecast errors are $VMA(n-1)$ processes.

³³ Equation (7) shows that, for linear models, structural shocks and forecast errors (surprises) are linked by the relation $u_{t|t-n} = \sum_{k=0}^{n-1} \Pi^k(L) A^{-1} \mathbf{e}_{t-k} = M_0 \mathbf{e}_t + \dots + M_{n-1} \mathbf{e}_{t-n+1}$. For the general case, this relation holds only as an approximation. In the experiment described in the paper, the matrices $\{M_k\}$, $k=0, 1, \dots, n-1$, have been estimated via simulation, using dynamic multipliers. In particular, the i - j^{th} element of the matrix M_k has been set equal to $\mathbb{1}_{y_{i,t+k}/\mathbb{1}_{e_{j,t}}}$.

Tables

Tab. 1

**FINANCIAL VARIABLES
AND ACCURACY IN FORECASTING NOMINAL GDP**

		<i>l=1</i>	<i>l=2</i>	<i>l=3</i>	<i>l=4</i>
Credit to households	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.62	1.44	1.30	1.27
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.03	0.01	0.01
Total credit to private sector	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.62	1.43	1.30	1.28
	$\Lambda_{u^M \rightarrow u^T}$	0.01	0.00	0.00	0.00
M2	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.61	1.44	1.30	1.27
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.00	0.00	0.05
Currency	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.62	1.44	1.30	1.27
	$\Lambda_{u^M \rightarrow u^T}$	0.01	0.02	0.00	0.00
Interest rate on loans	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.62	1.44	1.30	1.27
	$\Lambda_{u^M \rightarrow u^T}$	0.26	0.21	0.15	0.14
Interest rate on deposits	$\mathbf{s}_{i,l}/\bar{\mathbf{s}}_{i,l}$	1.62	1.44	1.30	1.27
	$\Lambda_{u^M \rightarrow u^T}$	0.24	0.12	0.11	0.11

The table reports two statistics for the money/credit variables specified in the first column: (1) the standard deviation of the forecast error *l*-step ahead (*l=1,2,3,4*) obtained when all variables are assumed to have the same information lag (i.e. one quarter); (2) the index measuring the efficiency gain obtained when financial variables are used to update initial conditions. Figures in both columns are expressed as ratios to the standard deviation of the forecast error obtained under the assumption of no information lags.

**FINANCIAL VARIABLES
AND ACCURACY IN FORECASTING REAL GDP**

		l=1	l=2	l=3	l=4
Credit to households	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.03	0.00	0.00
Total credit to private sector	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.00	0.00	0.00
M2	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.00	0.00	0.00
Currency	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.00	0.02	0.00	0.00
Interest rate on loans	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.14	0.19	0.10	0.12
Interest rate on deposits	$s_{i,l}/\bar{s}_{i,l}$	1.35	1.42	1.25	1.21
	$\Lambda_{u^M \rightarrow u^T}$	0.11	0.16	0.09	0.06

The table reports two statistics for the money/credit variables specified in the first column: (1) the standard deviation of the forecast error l -step ahead ($l=1,2,3,4$) obtained when all variables are assumed to have the same information lag (i.e. one quarter); (2) the index measuring the efficiency gain obtained when financial variables are used to update initial conditions. Figures in both columns are expressed as ratios to the standard deviation of the forecast error obtained under the assumption of no information lags.

Tab. 3

ONE-STEP AHEAD FORECAST ERRORS: DIAGNOSTIC TESTS

Variables	AR(1)	AR(2)	HET(1)	JB	ADF
Nominal GDP	0.52	0.93	0.59	0.63	-6.80 (**)
Real GDP	0.73	0.27	0.99	0.83	-6.30 (**)
GDP deflator	0.03 (*)	0.10	0.61	0.59	-4.40 (**)
Currency	0.92	0.02	0.81	0.70	-6.10 (**)
M2	0.15	0.26	0.07	0.20	-5.00 (**)
Credit	0.00 (**)	0.00 (**)	0.21	0.59	-3.20 (*)
Bank lending rate	0.49	0.49	0.01 (*)	0.93	-5.60 (**)
Bank deposit rate	0.05 (*)	0.26	0.05	0.98	-4.60 (**)

Diagnostic tests on the one-step ahead forecast error generated by the quarterly model of the Italian economy over the period 1989-1999. AR(*i*): LM test for autocorrelation of order *i*. HET(1): test for heteroscedasticity of order 1. Norm: Jarque-Bera test for normality. ADF: advanced Dickey-Fuller test for the presence of a unit root (the lag length was determined with an AIC criterion). The table reports probability levels (except for the ADF test).

Tab. 4

THE INFORMATION VALUE OF MONETARY SURPRISES (1989-1999)

Dependent variable: Nominal GDP									
	<i>horizon=1 quarter</i>			<i>horizon=2 quarters</i>			<i>horizon=4 quarters</i>		
	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ
Currency	0.20	-0.15	0.66	0.05	0.00	0.90	0.21	0.04	0.79
M2	0.14	-0.19 (*)	0.24	0.15	-0.15	0.44	0.09	-0.13	0.35
Credit	0.20	0.12 (*)	0.06	0.22	0.10	0.47	0.38	0.07	0.75
Bank lending rate	0.25	-0.16 (*)	0.51	0.35	0.30 (**)	0.01 (*)	0.47	-0.09	0.00 (**)
Bank deposit rate	0.13	-0.08 (*)	0.40	0.22	-0.12 (*)	0.09	0.41	-0.17	0.06
Long term rate	0.13	0.04	0.36	0.14	0.10 (*)	0.04 (*)	0.26	-0.05	0.04 (*)
Dependent variable: Real GDP									
	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ
Currency	0.35	-0.18 (**)	0.32	0.38	-0.17	0.86	0.39	-0.38 (**)	0.57
M2	0.14	-0.14 (*)	0.71	0.27	-0.17 (*)	0.57	0.17	-0.22 (*)	0.88
Credit	0.23	-0.05	0.01 (*)	0.17	-0.06	0.14	0.32	-0.25	0.60
Bank lending rate	0.34	-0.13 (*)	0.00 (**)	0.34	-0.22 (*)	0.15	0.36	-0.01	0.01 (**)
Bank deposit rate	0.28	-0.08 (**)	0.03 (*)	0.33	-0.11 (**)	0.02 (*)	0.47	-0.18	0.00 (**)
Long term rate	0.36	0.03 (*)	0.00 (**)	0.39	0.06 (*)	0.03 (*)	0.51	-0.01	0.00 (**)
Dependent variable: GDP deflator									
	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ	R2	$\Sigma\gamma$	F-test on λ
Currency	0.06	0.03	0.11	0.17	0.16	0.78	0.31	0.41	0.91
M2	0.08	-0.04	0.66	0.08	0.02	0.49	0.06	0.09	0.56
Credit	0.35	0.17 (*)	0.00 (**)	0.47	0.16	0.72	0.66	0.31 (*)	0.37
Bank lending rate	0.27	-0.03	0.73	0.56	-0.08	0.00 (**)	0.83	-0.07	0.00 (**)
Bank deposit rate	0.30	-0.01	0.32	0.55	-0.01	0.00 (**)	0.79	0.02	0.00 (**)
Long term rate	0.23	0.01	0.43	0.35	0.03	0.00 (**)	0.70	-0.05	0.00 (**)

Estimated equation (for $n=1, 2, 4$):

$$y_{i,t}^T - y_{i,t-n}^T = \mathbf{a} + \sum_{j=1}^k \mathbf{g}_j (y_{i,t-n+j}^M - y_{i,t-n+j|t-n}^M) + \sum_{j=0}^h \mathbf{l}_j y_{i,t-n-j}^M + \mathbf{h}_t$$

“R2”: R-squared of the regression. “ \mathbf{Sg} ”: sum of the \mathbf{g} coefficients, where (*) and (**) indicate rejection of the null $\sum_{j=1}^k \mathbf{g}_j = 0$, at the 5% and 1% level.. “F-test on λ ”: p-value of the null $\sum_{j=0}^h \mathbf{l}_j = 0$.

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