Asymmetric bank lending channels and ECB monetary policy

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Abstract

The launch of the euro has prompted interest in the differences between financial systems and their consequences for monetary policy transmission. This paper analyses the case of a monetary union composed of countries with heterogeneous bank lending channels. In order to insulate the economies from the asymmetric effects produced by differences in national banking systems, a money supply process based on the interest rate on bonds and its spread with respect to the lending rate is proposed. Using a two-country rational expectations model, this study highlights the properties of the optimal monetary instrument. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

European monetary integration has prompted interest in the study of differences between financial systems among EU countries and their consequences for monetary transmission mechanisms (Dornbusch et al., 1998). In the spirit of Bernanke and Blinder (1988), heterogeneity in the structure of financial intermediation and
in the degree and composition of firms’ and households’ debt could imply differences in the effectiveness of the ‘credit channel’ (or, now, the ‘bank lending channel’) of monetary policy in the euro area (Borio, 1996; Kashyap and Stein, 1997; Guiso et al., 1999). Empirical studies seem to confirm the importance of these asymmetries. For example, the credit channel has been found to be present in Italy (Buttiglione and Ferri, 1994; Angeloni et al., 1995; Bagliano and Favero, 1995; Fanelli and Paruolo, 1999; Chiades and Gambacorta, 2000), but not in France (Bellando and Pollin, 1996), Germany (Barran et al., 1995) or the Netherlands (Garretsen and Swank, 1998). The analysis could also be extended to other UE countries, such as the United Kingdom, where there is evidence of a significant credit channel (Dale and Haldane, 1993a,b, 1995). Apart from their different conclusions, these econometric studies point out the substantial information content of the spread between bank and bond market rates in explaining loan market disturbances and their impact on real output (see also Kashyap et al., 1993).

The aim of this paper is to analyse the optimal monetary policy for a monetary union composed of countries with structural differences in credit channels. In order to better insulate the economies from the asymmetric effects produced by heterogeneity in national financial systems, the classical money supply process proposed by Poole (1970) is modified to consider the spread between the interest rate on loans and that on bonds as an additional feedback variable. In fact, while the interest rate on bonds embodies information mainly on money market equilibrium, the spread also indicates the state of the credit and goods markets.

The analysis is carried out with reference to the economic policy scenario for the EMU where the Governing Council sets its objective for the Union as a whole. Nevertheless, heterogeneity in the financial structures has great influence on the choice of monetary policy, because it affects the geographical distribution of the effects. The main finding of this study is that if the countries that make up the Union have asymmetric bank lending channels, an active monetary policy that responds to information from financial indicators produces very great benefits; in this case, the optimal monetary policy is influenced not only by the magnitude of the variance of the shock but also by its point of origin, since its propagation within the union depends upon the characteristics of the country that has been hit by the disturbance.

The remainder of the paper is organised as follows. Section 2 presents the analytical framework, based on a two-country rational expectations model. Section 3 analyses the characteristics of a money supply process that uses as feedback variables both the interest rate on bonds as in Poole (1970) and its spread vis-à-vis the bank lending rate. After discussing the objective function of the area-wide monetary authority (Section 4), Section 5 investigates the properties of the optimal monetary instrument. Section 6 summarises the main conclusions.

2. The analytical framework

The analysis is based on a two-country rational expectations model in which both
economies are subject to real and nominal disturbances. The specification is
log-linear and, in order to simplify the analytical forms, all variables are expressed
as deviations from their trend. The novelty of this framework with respect to the
existing literature Turnovsky and d’Orey, 1989; Monticelli, 1993, 2000; Gambacorta, 2001 is the introduction of the credit market.

The two economies are described by the following equations (asterisks indicate
variables pertaining to country 2; the list of symbols is reported in Section 7).

Country 1:

\[ m_t^d - p_t = \phi y_t - a i_t + u_{md} \quad (1) \]

\[ l_t^d - p_t = w y_t - h \tilde{p}_t + u_{ld} \quad (2) \]

\[ l_t^s - z m_t^s + q \tilde{p}_t + u_{ls} \quad (3) \]

\[ y_t^d = b y_t^* - f \left( i_t^* - E p_{t+1} + p_t \right) - d ( p_t - p_t^* ) - v \tilde{p} + u_{yd} \quad (4) \]

\[ y_t^s = g \left( p_t - E P_{t-1} \right) + u_{ys} \quad (5) \]

Country 2:

\[ m_t^* - p_t^* = \phi y_t^* - a i_t^* + u_{md^*} \quad (1') \]

\[ l_t^* - p_t^* = w y_t^* - h \tilde{p}_t^* + u_{ld^*} \quad (2') \]

\[ l_t^s - z m_t^s + q \tilde{p}_t^* + u_{ls^*} \quad (3') \]

\[ y_t^d = b y_t^* - f \left( i_t^* - E p_{t+1}^* + p_t^* \right) - d ( p_t^* - p_t ) - v ^* \tilde{p}^* + u_{yd^*} \quad (4') \]

\[ y_t^s = g \left( p_t^* - E P_{t-1}^* \right) + u_{ys^*} \quad (5') \]

Eqs. (1) and (1’) are standard money demand functions. If no interest is paid on
bank accounts, these equations also represent the demand for deposits. In the case
of a monetary union the equilibrium is unique, therefore \( m_t^s = m_t^d + m_t^d^* \).

Following Bernanke and Blinder (1988) and Kashyap and Stein (1995), the loan
market is characterised by imperfect substitutability between bonds and loans:
borrowers (households and firms) and lenders (banks) choose, respectively, their
liability and asset composition according to the spread between the rates on loans
(\( \rho \)) and on bonds (\( i \)). Credit demands (2) and (2’) are negatively influenced by the
spread and positively related to real output for transaction motives (working capital or liquidity considerations). Loan supplies (3) and (3') depend positively on money at the area level (which, ignoring currency in circulation, is equal to deposits) and the spread (it is implicitly assumed that the rate of return on excess reserves is zero). The loan market clears by quantities \( l_t^i = l_t^d \) and \( l_t^s = l_t^d \) and there is no credit rationing (Stiglitz and Weiss, 1981).

Eqs. (4) and (4') represent output demands, which depend upon the other country’s output (via exports) and the difference in price levels (‘foreign channel’).\(^1\) Moreover, output demands are influenced by the cost of financing for investment and consumption. The conditions of the capital market are captured by the real interest rate on bonds (‘money channel’), those of the credit market (‘bank lending channel’) by the spread \( \hat{\rho} = \rho - i \).\(^2\)

The parameter \( \nu \) has a special role in the model: it represents the only asymmetry in the economic structure of the two countries. It shows the strongest impact of monetary transmission on output due to the relative importance of intermediate vs. direct financing. In short, the value of this parameter is expected to be high if the private debt market is less developed or firms’ and households’ indebtedness is significant and dependent on the banking sector (Borio, 1996; Kashyap and Stein, 1997). In order to emphasise the source of divergence of a heterogeneous financial system on the monetary transmission mechanism described by the model, country 1 is posited to be more dependent on the credit channel (\( \nu > \nu^* \)).

The supply side of the goods market is represented by Eqs. (5) and (5'): deviations of output from trend are a positive function of unanticipated movements in the price level.

The two-country blocks are linked by the following equations:

\[
p_t = p_t^* + \alpha_t
\]  

\(^{1}\)Since the two countries form a monetary union, the logarithm of the exchange rate is fixed and, to simplify the analysis, it has been normalised to zero. Therefore the balance of trade is influenced only by the difference between price levels.

\(^{2}\)Some observations on the form used for output demand are in order. Eqs. (4) and (4') are equivalent to those that consider separately the influence of the two real interest rates on bonds and loans. In fact, if the other variables are fixed and for simplicity the interest rates are expressed in nominal terms, the relation \( Y = -f'i + \nu'\rho \) is equivalent to \( Y = -f'i - \nu(\rho - i) \) with \( Y_t = -f'i = -f + \nu < 0 \) and \( Y_t = -\nu' = -\nu < 0 \). The only restriction to impose is that, given \( Y_t < 0 \), it must be that \( f > \nu \). However, the interpretation of \( f' \) is different from that of \( f \). The former explains only the effects on output of the interest rate condition in the bond market, while the latter \( (f = f' + \nu') \) measures the overall effect of a change in \( i \), which is common to the bond and credit markets, assigning \( \nu \) the task of capturing the effect caused by the ‘peculiarity’ of the loan market with respect to the capital market. In general, the bank lending channel operates if the spread between the interest rate on loans and bonds widens in response to a monetary restriction. For an explanation of the information content of the spread in interpreting loan market disturbances and their impact on the evolution of real output, see among others, Kashyap et al. (1993) and Kashyap and Stein (1995).
\[ i_t = i_t^* \] (7)

The stochastic law of one price (6) assumes perfect substitutability in the output market, except for a random disturbance, \( u_p \), which incorporates market imperfections. The main implications of this hypothesis are two. First, there is a unique equilibrium at the area level, so \( y_t^d + y_t^s = y_t^s + y_t^s \). Second, the different competitiveness between the two countries influences outputs and prices directly by means of the stochastic variable \( u_p \), while the parameter \( d \) denoting the ‘foreign channel’ of monetary policy transmission does not enter the solutions (Monticelli, 1993).

Since the money market is perfectly integrated, Eq. (7) indicates that the nominal interest rate is unique (for simplicity, the same default risk is assumed between borrowers in the area). On the contrary, lending rates are different; loans are considered imperfect substitutes, not only because bank credit depends on customer relationships that facilitate concentration in local markets (Sharpe, 1990; Rajan, 1992), but also on account of the lack of an efficient secondary market for credit, which prevents arbitrage.

All the stochastic variables are assumed to be independently distributed with zero mean and finite variance \([u \sim \text{id}(0, \sigma_u)]\).

3. The money supply rule and the solution of the model

To close the model it is necessary to design the money supply rule of the monetary authority. The ECB monetary strategy is a mix of inflation and monetary targeting (ECB, 1999). Apart from the explicit definition of the primary objective of price stability, the ECB strategy is based on two ‘pillars’: the indication of a reference value (not binding) for M3 money growth and the analysis of a set of indicators that provides information about the state of the economy.

Taking into account the characteristics of this approach, the aim of this section is to analyse the following money supply process:

\[ m_t^s = m_t^s + k_{t} - c_{1} \hat{p}_{t} - c_{2} \hat{p}_{t}^* \] (8)

which considers not only the interest rate as in Poole (1970) but also national spreads as feedback variables. In Eq. (8), \( k, c_1, c_2 \) are policy instruments chosen jointly by the monetary authority to minimise its objective function.

In the presence of stochastic disturbances, which cannot be observed, movements in financial indicators embody information on the nature of current shocks, so that the optimal monetary instrument is defined by a feedback rule from changes in interest rates and spreads to the money stock. In particular, the inclusion in the rule of the spread between the interest rate on loans and bonds provides additional information about shocks on the credit and the output markets and their impact on prices and income (Kashyap et al., 1993; Bernanke and Gertler, 1995; Kashyap and Stein, 1995).
The analysis of the proposed money supply rule is particularly interesting because such a process considers all the elements of the ECB strategy. Eq. (8) coincides with monetary targeting (first pillar) only in special cases and takes into consideration the information obtainable from financial markets (second pillar). Moreover, on the hypotheses that (1) the monetary authority knows the structure of the economy; and (2) the objective variables are not immediately observable or influenced by monetary policy instruments, this process is isomorphic to inflation targeting (see McCallum, 1996; Svensson, 1996, 1997a,b; Bernanke and Mishkin, 1997; Kuttner and Posen, 1998).

Considering for simplicity that the two countries are equal in size, it is possible to analyse a policy instrument based on the average of national spreads \( \tilde{c} \). In this case, which greatly simplifies the algebra, the money supply process becomes:

\[
m_t^e = m_t' + k_i_t - \frac{\tilde{\rho}_t + \tilde{\rho}_t^*}{2}
\]

It is worth remembering that this rule determines the overall amount of money, while its distribution between the two countries is endogenously determined.

Assuming that the law of motion of the optimal policy \((\tilde{c}, \tilde{k})\) is constant over time, given that the model is in deviation form, all the expectations can be set to zero and there is no inflation bias (Turnovsky and d’Orey, 1989; Monticelli, 1993, 2000; Gambacorta, 2001).

\[
E_p_i = E_{p_i}^* = E_{p_{i+1}} = E_{p_{i+1}}^* = 0
\]

The model represented by Eqs. (1)–(10) determines the following solutions for prices and real outputs:

\[
p_t = A_1 m_t' + A_2 (u_{ls} - u_{ld}) + A_3 (u_{ls} - u_{ld}^*) + A_4 (u_{md} + u_{md}^*) + A_5 (u_{yd} + u_{yd}^*) + A_6 u_p + A_7 u_{ys} + A_8 u_{ys}^*
\]

\[
p_t^* = B_1 m_t' + B_2 (u_{ls} - u_{ld}) + B_3 (u_{ls} - u_{ld}^*) + B_4 (u_{md} + u_{md}^*) + B_5 (u_{yd} + u_{yd}^*) + B_6 u_p + B_7 u_{ys} + B_8 u_{ys}^*
\]

\[
y_t = C_1 m_t' + C_2 (u_{ls} - u_{ld}) + C_3 (u_{ls} - u_{ld}^*) + C_4 (u_{md} + u_{md}^*) + C_5 (u_{yd} + u_{yd}^*) + C_6 u_p + C_7 u_{ys} + C_8 u_{ys}^*
\]

\[
y_t^* = D_1 m_t' + D_2 (u_{ls} - u_{ld}) + D_3 (u_{ls} - u_{ld}^*) + D_4 (u_{md} + u_{md}^*) + D_5 (u_{yd} + u_{yd}^*) + D_6 u_p + D_7 u_{ys} + D_8 u_{ys}^*
\]

where: \( A_i = B_i = C_i = D_i \) for \( i = 1, \ldots, 5 \); \( A_6 = C_6 \); \( B_6 = D_6 \); \( A_i = B_i \) for \( i = 7,8 \).
All the coefficients (whose expressions are reported in Appendix A) depend on $c$ and $k$, which describe the optimal monetary policy. To simplify the algebra it has been assumed that $\phi = g = w = z = 1$. It can be shown that this hypothesis does not change the main results of the study.\(^3\)

The law of motion of the optimal monetary policy is constant over time and perfectly credible [see Eq. (10)], therefore, in the absence of shocks, the endogenous variables coincide with their trend since money stock does not deviate from the reference value ($m'_{t} = E m'_{t-1} = 0$).

4. The objective function of the area-wide monetary authority

The starting point for the analysis of the optimal monetary rule ($\hat{c},\hat{k}$) is to consider the economic policy scenario for the EMU: the Maastricht Treaty delegates monetary policy to an independent area-wide central bank whose main concern is the maintenance of price stability, while output and employment represent secondary targets.

The monetary instruments $c$ and $k$ are chosen so as to minimise the following loss function:

$$\min_{c,k} L = \lambda \text{var}(p + p^*) + (1 - \lambda) \text{var}(y + y^*) \quad (15)$$

This equation assumes that the Governing Council of the central bank is formed by two national members, with equal voting rights (their weight inside the objective function is the same), who are interested in the stabilisation of area-wide prices and income.\(^4\) Since the model is expressed in deviation form, the primary objective is equivalent to containing inflation, while the secondary objective is to limit deviations of output from the trend in order to stabilise the economic cycle.

Article 105 of the Maastricht Treaty opens the way for the ECB to have secondary objectives therefore it can be assumed that $0.5 < \lambda < 1$. Nevertheless, if strictly interpreted, this article would suggest a lexicographic preference ordering, with no substitution at the margin between the two objectives and $\lambda = 1$ (Terlizzese, 1999).

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\(^3\) In general, to give a traditional economic interpretation to the solution (for example an increase in the money stock determines an increase in prices, as quantity theory implies), it is necessary to impose an upper limit on loan supply elasticity with respect to deposits: $z < z' < \infty$ (Gambacorta, 1999). This means that in the case of a deposit expansion banks do not overreact, providing an infinite amount of loans, and an easy policy determines a decrease in the monetary interest rate. It is worth noting that $z$ influences the shifting coefficient of the CC curve in the Bernanke and Blinder model (joint equilibrium on credit and output markets) in response to a monetary shock; from a graphical point of view this means that when LM moves, the CC shift is limited and does not determine an unstable equilibrium.

\(^4\) These hypotheses are consistent with the Maastricht Treaty. The Governing Council, which formulates monetary policy, is composed of six members constituting the Executive Board plus the Governors of the national central banks. Each member of the Governing Council has one vote (see Art. 10 of the Maastricht Treaty). Decisions must be taken with reference to the developments for the euro area as a whole (ECB, 1999).
Following the basic idea in Rogoff (1985), common sense suggests that the formulation for the loss function given by Eq. (15) is more realistic.\footnote{For an analysis of policymakers’ revealed preferences and the output–inflation variability trade-off see Cecchetti and McConnell (1998). See also Gerlach and Schnabel (2000) and Peersman and Smets (1999) who estimate a Taylor rule for the whole Union to provide a benchmark for the future behaviour of the ECB.}

The solution for the optimal monetary policy ($\hat{c}, \hat{k}$) will be a function of all the structural parameters of the model, including $\lambda$, the relative weight attached to the primary objective of price stability. Therefore, when there is a trade-off between prices and income stabilisation, the properties of the optimal monetary rule are in general ambiguous since they depend crucially on the magnitude of $\lambda$. In these situations, the analysis has to be limited to two benchmarks: (1) the case in which the ECB strictly interprets its mandate from the Maastricht Treaty focusing only on area-wide price developments ($\lambda = 1$); (2) the implausible case in which output becomes the only variable of interest and the ECB totally ignores the repercussions on inflation ($\lambda = 0$).

The present analysis abstracts from issues of political economy and supposes that the Governing Council sets its objective for the Union as a whole. However, since the two countries are equal in size, it is possible to prove that in the case of perfect substitutability in the output market [see Eq. (8)], the loss function (15) is equivalent to that in which the two national members attach more importance to developments in their home country than to the Union as a whole. This means that if the output market is perfectly integrated the minimisation problem represented by (15) is equivalent to

$$\min L = \lambda[\text{var}(p) + \text{var}(p^*)] + (1 - \lambda)[\text{var}(y) + \text{var}(y^*)]$$

(Monticelli, 1993; Gambacorta, 2001).\footnote{The case of heterogeneous objectives among the members of the Governing Council of the ECB, which goes beyond the scope of this study, is the subject of an ongoing debate concerning inefficient equilibria as a possible outcome of the institutional game outlined in the Maastricht Treaty (von Hagen and Suppel, 1994; Brueckner, 1997; Monticelli, 1999; De Grauwe et al., 1999). Non-cooperative behaviours, due to different regional objectives, are also recognised in the voting mechanism of the Federal Reserve System (Tootell, 1991, 2000; Havrilesky and Gildea, 1995; Faust, 1996).}

Using the definition of variance and the assumption of independently distributed shocks, the loss function can be rewritten as:

$$L = 4A_2^2(\sigma_{uls}^2 + \sigma_{uld}^2) + 4A_3^2(\sigma_{uls}^2 + \sigma_{uld}^2) + 4A_4^2(\sigma_{umd} + \sigma_{umd}^*)$$

$$+ 4A_5^2(\sigma_{uyd}^2 + \sigma_{uyd}^2) + (A_6 + B_6)^2\sigma_{yt}^2 + \left[4\lambda A_7^2 + (1 - \lambda)(C_7 + D_7)^2\right]$$

$$\times \sigma_{ys}^2 + \left[4\lambda A_8^2 + (1 - \lambda)(C_8 + D_8)^2\right]\sigma_{ys}^2$$

where the expressions of the coefficients are identical to those reported in Appendix A. Given the hypothesis of perfect substitutability in the output market, a trade-off between price and income emerges only in the case of supply shocks. On the contrary, in the case of aggregate demand shocks the optimal rule is independent of the relative weight attached to the two objectives.
Asymmetric effects between the two countries arise only in the case of shocks to the ‘law of one price’ \( (A_i = C_i \neq B_i = D_i) \) and to the aggregate supply \( (C_7 \neq D_7 \) and \( C_8 \neq D_8) \). Given the hypothesis of a unique output market, in the other cases the distribution of losses is symmetric because the law of one price discharges the structural asymmetries in the stochastic component \( u_p \).

5. The optimal monetary policy

This section analyses the characteristics of the optimal monetary policy defining the values of \( c \) and \( k \) that minimise the loss function.\(^8\) The optimal combination between \( c \) and \( k \) will be a function of the structural parameters of the model and of the variances of the economic shocks that may hit the economies.\(^9\) Once the optimal relation between \( c \) and \( k \) is obtained, it is possible to substitute it into Eq. (9) to specify the optimal feedback rule from interest rate and spread movements to money stock changes. In general this rule is quite complicated and requires a very precise knowledge of the structure of the economy that the monetary authority can hardly achieve. Therefore, comparative static analysis of the optimal monetary instrument can only provide a benchmark case, which can give useful insight on how strictly pure policies should be applied in the face of changes in the economic environment.

In terms of the classical CC-LM AD-AS model of Bernanke and Blinder (1988), the optimal monetary policy proposed in this study, which uses two parameters, consists not only in fixing the optimal slope of the LM function by making money supply interest sensitive, as in Poole (1970), but also in limiting the effects of the spread on the credit and goods markets represented by the curve CC.

\(^7\) In general, solving the model without imposing Eq. (8), it is possible to prove that national losses are asymmetric and highly dependent on which country is hit by the stochastic shock \( (A_i \neq B_i \text{ for } i = 1, ..., 7) \). This outcome loses validity only if the countries have the same financial structure. In this case, national losses are independent of the origin of the shock and national interests coincide with those at the area level \( (A_i = B_i \text{ for } i = 1, ..., 7) \). The implication of this result is straightforward: a sufficient condition for national members of the Governing Council not to deviate from the statutory objective to limit inflation at the area level is represented either by a perfectly integrated output market or by an identical financial structure of the countries (Gambacorta, 1999).

\(^8\) In the analysis of this paper the policy variables \( c \) and \( k \) are assumed to be controlled without error while no use is made of the proximate target concept. This approach has been followed, on the one hand, to simplify the analysis and, on the other, because the treatment of the money stock as a stochastic function of the monetary base would not have changed the results of the study.

\(^9\) The structural VAR model of Bhattacharya and Binner (1998) tries to capture the relative importance of the different kind of shocks in five European countries. The results suggest that, at least in the last two decades, supply shocks have determined more than 75% of output variance in the United Kingdom. On the contrary, demand shocks have been predominant for France (55%), while the Netherlands, Italy and Germany have been more subject to money demand disturbances (more than 50%). For this last group of countries, shocks on the supply side have also been of considerable importance (20% of output variation in Germany and more than 30% in Italy and the Netherlands). For an analysis of the correlation between supply–demand shocks and output variations in Europe in the period 1962–1988 see, among others, Bayoumy and Eichengreen (1992).
To give a traditional economic interpretation to the solution (for example, an increase in the money stock determines an increase in prices, as the quantity theory implies) it is necessary to impose a condition between $c$ and $k$ that allows the stability of the equilibrium (Gambacorta, 1999).\textsuperscript{10}

The properties of the optimal policy are reported in Table 1. The first two columns describe, respectively, the nature of the shocks that can hit the economies and the size of the trade-off between price and income stabilisation.

The third column represents the general rule identifying a line in the two-dimensional space $(k, c)$ that minimises the ECB loss function with respect to each specific shock. For simplicity we assume unitary variance for each kind of disturbance.

The last two columns of the table represent two benchmark cases that are nested in the general rule. The first is Poole’s strategy revisited in the Bernanke–Blinder framework obtained setting $c$ equal to zero. In this case, the optimal policy described by Eq. (9) focuses only on the parameter $k$ and becomes a pure interest rate rule when $k = \infty$ (horizontal LM) and a pure money supply rule when $k = -2a$ (vertical LM).\textsuperscript{11} The introduction of the credit market in Poole’s set-up alters the plausibility of certain values of the policy instrument. For example, if the effectiveness of the credit channels exceeds a critical value $(\nu + \nu^* > f\delta_2 + \delta_1 \delta_2)$ the response of the money supply to interest rate variations has to be limited and pure interest rate pegging is no longer possible ($k < k' < \infty$).\textsuperscript{12}

The second benchmark, obtained setting $k = 0$, represents a money supply process that uses only the loan-bond spread as feedback variable. The value of the optimal policy instrument $c$ includes the ‘pure’ policies of money targeting ($c = 0$) and partial spread pegging ($c = c'$).\textsuperscript{13} The upper limit, $c' = \infty$, indicates that it is not optimal to provide infinite liquidity to obtain perfect average spread pegging. Indeed, the existence of credit market segmentations impose to the monetary

\textsuperscript{10} In particular, setting the model in the matrix form $AX = B$, where $X$ is the vector of the endogenous variables, $B$ is the vector of exogenous variables and $A$ is a square matrix of structural parameters, it has to be $\det[A] > 0$. This means that: $\Delta = 2\delta_2 [2f\delta_2 + a(\delta_1 \delta_2 + \nu + \nu^*)] + k[\delta_2 (f + \delta_1) - \nu - \nu^*] - 2c[f + a(f + \delta_1)] > 0$.

\textsuperscript{11} The slope of the LM is given by $1/(2a + k)$. Given $\det[A] > 0$ it has to be $k < 2a[(f + \delta_1)\delta_2 + \nu + \nu^*] + 4f\delta_2 + a(\nu + \nu^*) = k' < \infty$. Considering the Bernanke–Blinder model, where the IS line is replaced with the CC (Commodities and Credit) equilibrium, this means that a flat LM line, which necessitates complete accommodation of the quantity of money, determines CC shifts that are directly proportional to the effectiveness of the national credit channels. Therefore, if the latter are wide, banks could overreact causing to the equilibrium to become unstable.

\textsuperscript{12} Also in this case, for the solution to be economically meaningful, it is necessary to impose an upper limit on $c$. In particular, given the condition $\det[A] > 0$, it has to be that $c < (2f + a\delta_1)\delta_2 + a(\nu + \nu^*) = c' < \infty$. The sign of the influence that the spread has on the money supply stock depends on the nature of the shock and cannot be established a priori. For example, an increase in the spread could be caused by an autonomous reduction in loan supply (which implies the need for ‘easy’ money) or an increase in loan demand (which calls for ‘tight’ money).
Table 1
The properties of the optimal monetary policy

<table>
<thead>
<tr>
<th>Shocks</th>
<th>Objective</th>
<th>General rule ($c \neq 0$ and $k \neq 0$)</th>
<th>Poole rule ($c = 0$)</th>
<th>Spread rule ($k = 0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$u_{d,t},u_{l,t}$</td>
<td>Prices and income</td>
<td>$\dot{c} = -\frac{2a\partial_2 \nu}{f\partial_2 - a(\nu - \nu^*)}$</td>
<td>Money targeting: $\dot{c} = -\frac{2a\partial_2 \nu}{f\partial_2 - a(\nu - \nu^*)}$</td>
<td>$\dot{c} = -\frac{2a\partial_2 \nu}{f\partial_2 - a(\nu - \nu^*)}$</td>
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<td></td>
<td></td>
<td>$(0 \leq \lambda \leq 1)$</td>
<td>$\dot{k} = -2a$</td>
<td>$\dot{k} = -2a$</td>
</tr>
<tr>
<td>$u_{d},u_{l}$</td>
<td>Prices and income</td>
<td>$\dot{c} = -\frac{2a\partial_2 \nu^<em>}{f\partial_2 + a(\nu - \nu^</em>)}$</td>
<td>Money targeting: $\dot{c} = -\frac{2a\partial_2 \nu^<em>}{f\partial_2 + a(\nu - \nu^</em>)}$</td>
<td>Partial money targeting: $\dot{c} = -\frac{2a\partial_2 \nu^<em>}{f\partial_2 + a(\nu - \nu^</em>)}$</td>
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<td></td>
<td>$(0 \leq \lambda \leq 1)$</td>
<td>$\dot{k} = -2a$</td>
<td>$\dot{k} = -2a$</td>
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<tr>
<td>$u_{md},u_{md}$</td>
<td>Prices and income</td>
<td>$\dot{c} = \partial_2 + \frac{k}{2f} (\nu + \nu^*)$</td>
<td>Partial interest rate pegging: $\dot{c} = \partial_2$</td>
<td>$\dot{c} = \partial_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(0 \leq \lambda \leq 1)$</td>
<td>$\dot{k} = \frac{2f\partial_2}{\nu + \nu^*}$</td>
<td>$\dot{k} = \frac{2f\partial_2}{\nu + \nu^*}$</td>
</tr>
<tr>
<td>$u_{md},u_{md}$</td>
<td>Prices and income</td>
<td>$\dot{c} = \partial_2 + \frac{k}{2a} \frac{\partial_2}{\nu + \nu^*}$</td>
<td>Money targeting: $\dot{c} = \partial_2$</td>
<td>$\dot{c} = \partial_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(0 \leq \lambda \leq 1)$</td>
<td>$\dot{k} = -2a$</td>
<td>$\dot{k} = -2a$</td>
</tr>
<tr>
<td>$u_p$</td>
<td>Prices and income</td>
<td>$\dot{c} = \partial_2 + \frac{k}{2a} \frac{\partial_2}{\nu + \nu^*}$</td>
<td>Money targeting: $\dot{c} = \partial_2$</td>
<td>$\dot{c} = \partial_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$(0 \leq \lambda \leq 1)$</td>
<td>$\dot{k} = -2a$</td>
<td>$\dot{k} = -2a$</td>
</tr>
<tr>
<td>$u_{ys}$</td>
<td>Prices</td>
<td>$\dot{c} = \frac{2\partial_2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{f\partial_2 + 2a\partial_1 \partial_2 + a(\nu - \nu^*)}$</td>
<td>Partial spread pegging: $\dot{c} = \frac{2\partial_2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{f\partial_2 + 2a\partial_1 \partial_2 + a(\nu - \nu^*)}$</td>
<td>$\dot{c} = \frac{2\partial_2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{f\partial_2 + 2a\partial_1 \partial_2 + a(\nu - \nu^*)}$</td>
</tr>
<tr>
<td>$u_{ys}$</td>
<td>Prices</td>
<td>$(\lambda = 1)$</td>
<td>$\dot{k} = -\frac{2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{\partial_1 \partial_2 - \nu}$</td>
<td>$\dot{k} = -\frac{2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{\partial_1 \partial_2 - \nu}$</td>
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<tr>
<td></td>
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<td>$(\lambda = 1)$</td>
<td>$\dot{k} = -\frac{2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{\partial_1 \partial_2 - \nu}$</td>
<td>$\dot{k} = -\frac{2[f\partial_2 + a(\partial_1 \partial_2 + \nu)]}{\partial_1 \partial_2 - \nu}$</td>
</tr>
</tbody>
</table>
Table 1 (Continued)

<table>
<thead>
<tr>
<th>Shocks</th>
<th>Objective</th>
<th>General rule ((c \neq 0 \text{ and } k \neq 0))</th>
<th>Poole rule ((c = 0))</th>
<th>Spread rule ((k = 0))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(u_{ys})</td>
<td>Income</td>
<td>(\hat{c} = \frac{2\vartheta_{2}[f\vartheta_{2} + a(f\vartheta_{2} + \nu^{<em>})]}{f\vartheta_{2} + 2af\vartheta_{2} - a(\nu - \nu^{</em>})} + \frac{\hat{k}}{f\vartheta_{2} + 2af\vartheta_{2} - a(\nu - \nu^{*})})</td>
<td>(\hat{k} = -\frac{2[f\vartheta_{2} + a(f\vartheta_{2} + \nu^{*})]}{f\vartheta_{2} - \nu})</td>
<td>(\hat{c} = \frac{2\vartheta_{2}[f\vartheta_{2}(1 + a) + a\nu^{<em>}]}{f\vartheta_{2}(2a + 1) - a(\nu - \nu^{</em>})})</td>
</tr>
<tr>
<td>(\lambda = 0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(u_{ys}^{*})</td>
<td>Income</td>
<td>(\hat{c} = \frac{2\vartheta_{2}[f\vartheta_{2} + a(f\vartheta_{2} + \nu)]}{f\vartheta_{2} + 2af\vartheta_{2} + a(\nu - \nu^{<em>})} + \frac{\hat{k}}{f\vartheta_{2} + 2af\vartheta_{2} + a(\nu - \nu^{</em>})})</td>
<td>(\hat{k} = -\frac{2[f\vartheta_{2} + a(f\vartheta_{2} + \nu)]}{f\vartheta_{2} - \nu^{*}})</td>
<td>Partial spread pegging:</td>
</tr>
<tr>
<td>(\lambda = 0)</td>
<td></td>
<td></td>
<td></td>
<td>(\hat{c} = \frac{2\vartheta_{2}[f\vartheta_{2}(1 + a) + a\nu]}{f\vartheta_{2}(2a + 1) + a(\nu - \nu^{*})})</td>
</tr>
</tbody>
</table>

*Note: All the symbols are reported in Section 7.*
authority to limit money supply in order not to cause anomalous effects to the economic variables and to the stability of the system.

The partial average spread pegging policy can be interpreted as a means to diminish credit market imperfections (a spread reduction means that the cost of capital supplied by banks tends to be equal to the cost of financing in the bond market) and attenuate the differences between the credit systems of the two countries. In fact, given the existence of ‘monitoring’ and ‘screening’ costs, the spread cannot be negative and the average spread tends to zero only if both national spreads converge toward zero.

It is interesting to note that the inclusion of two feedback variables in the monetary rule allows one to calculate a unique solution not only when the shocks are symmetric $(u = u^*)$ or idiosyncratic $(u \neq u^*)$ but also when the economies are hit by two different kinds of shock.

5.1. Aggregate demand shocks

When aggregate demand shocks occur, given the hypothesis of perfect substitutability in the output market, there is no trade-off between the primary objective of price stability and the secondary objective of output stabilisation. This means that the optimal rule is independent of $\lambda$.

In the model there are four sources of aggregate demand disturbance (credit market, money demand, goods demand and price-wedge shocks) and the optimal rule depends greatly on the source. In particular, from Table 1 it emerges that, considering Poole’s rule, a vertical LM is preferable only when money demand shocks are negligible. This result is similar to the classic Poole finding (1970): in the case of high variability of the CC curve (shocks in the credit market and goods demand) a fixed money supply is optimal. The same optimal rule can be applied also in the case of a shock in the price difference, which modifies the terms of competitiveness between the two countries in the IS.

This means that in the case of CC shifts, money supply must remain fixed and not be influenced either by interest rate or spread variations. The economic intuition underlying this result is that CC movements determine significant changes in the financial variables that could cause overreaction of the money supply. In this case it is better to insulate the LM from this kind of feedback effect in order to prevent destabilising effects on output and prices. Therefore, when the variance of credit shocks is also taken into consideration, then as in Poole (1970), not only interest rate pegging but also spread pegging is sub-optimal for containing the variance of all these disturbances jointly.

When money demand shocks are the only source of instability, Poole’s result of interest rate pegging is no longer optimal. Using Poole’s rule $(c = 0)$ in the Bernanke–Blinder set up, it is preferable to fix the LM slope to a positive value that depends on the parameters that describe the credit market. The optimal value

$$\hat{k} = \frac{2f \theta_d}{\nu + \nu^*}$$

determines, in each country, an inelastic CC so that LM movements
have a limited effect on income and prices. With respect to Poole’s model, interest rate pegging ($\hat{k} \to \infty$) is optimal only in the particular cases of ineffective credit channels ($\nu + \nu^* \to 0$). Indeed, in the Bernanke–Blinder framework, if the monetary policy reacts to support variations in public’s liquidity preference with a change in money supply, this also determines an effect on the supply of loans, which shifts the CC. Only when CC movements are negligible ($\nu + \nu^* \to 0$) does Poole’s result hold because the CC tends to have the same characteristic of an IS.

Analysing the alternative money supply process based only on the spread ($k = 0$), the optimal monetary policy is partial spread pegging $\hat{c} = \partial_2 < c'$ except in the case of credit market disturbances. The interpretation of this result needs the computation of the partial equilibrium in the money and the credit market (which we call the ‘MC condition’; for more details see Chiades and Gambacorta, 2000). Since the slope of this line for the whole union is equal to

$$\frac{d\nu}{d\nu^*} = \frac{\partial_2 - c}{2}$$

the optimal rule $\hat{c} = \partial_2$ has the property of making MC perfectly vertical. Moreover, $\hat{c}$ maximises the sensitivity of MC shifts to money stock changes. Given these results, in the case of a variation in liquidity preferences, the quantity of money necessary to accommodate MC shifts is contained, while in the case of IS movements there are effects only on the interest rate, while income and prices do not change (the MC is vertical). This means that a spread rule becomes optimal in the case of high variance of output demand and price-wedge shocks that identify IS shifts (see Table 1).

On the other hand, spread pegging is not always optimal when the variance of credit shocks is also taken into consideration. In this case, given the asymmetry between national credit channels, the law of motion of the optimal monetary instrument is not univocally determined and also depends upon the origin of the shock. If the shock has origin in country 1, the optimal rule is given by $\hat{c} = \frac{-2a\partial_2\nu}{f\partial_2 - a(\nu - \nu^*)}$ so that, if the structural difference between the credit channels is relatively high ($\nu - \nu^* > \frac{f\partial_2}{a}$), $\hat{c}$ turns to be positive and partial spread pegging is preferable. On the contrary, if the disturbance hits the credit market of country 2, given the condition $\nu > \nu^*$, $\hat{c} = \frac{-2a\partial_2\nu^*}{f\partial_2 + a(\nu - \nu^*)} < 0$ so that a vertical LM becomes optimal. The economic intuition underlying these results is that if spread pegging tends to neutralise the effect of the credit channel on aggregate demand it also requires the money stock to adjust to credit market disequilibrium. In this case, only if the shock hits country 1, which has a more

\[\text{The slopes of the CC for country 1 and 2 are, respectively, } \frac{di}{dy} = -\frac{\partial_1\partial_2 - \nu}{2f\partial_2 - (\nu + \nu^*)k} \text{ and } \frac{di}{dy^*} = -\frac{\partial_1\partial_2 - \nu^*}{2f\partial_2 - (\nu + \nu^*)k}.\]
unstable CC, the benefit of containing CC shifts is greater than the cost deriving from the simultaneous money market changes. Indeed, since the CC of country 1 is relatively steep, the effect of LM movements is more limited. Obviously, if credit channels are completely ineffective the optimal strategy coincides with money targeting because credit market disturbances have no effect on aggregate demand (the CC curve does not move) and there is no need to change the quantity of money.

From this first step of the analysis it emerges that money targeting is preferable for containing the stochastic movements of aggregate demand, only when money demand disturbances are negligible. Spread pegging, meanwhile, can insulate IS and LM shocks but does not perform as well with respect to credit market disturbances spread pegging is optimal only when the credit shock hits country 1 and the difference between the bank lending channels is sensible.

5.2. Aggregate supply shocks

If the economies are hit by a supply shock, the optimal rule depends on the trade-off between price and output stabilisation (\(\lambda\)) and the degree of asymmetry between the bank lending channels (\(\nu - \nu^*\)). The optimal rule for price stabilisation (\(\lambda = 1\)) in the symmetric case (\(\nu = \nu^*\)) is independent of the origin of the shock. From the sixth and the seventh rows of Table 1 it is possible to obtain the following optimal combinations (\(\hat{k} = -\frac{2[f\hat{\theta}_2 + a(\hat{\theta}_1\hat{\theta}_2 + \nu)]}{\hat{\theta}_1\hat{\theta}_2 - \nu}, \hat{c} = 0\)), and (\(\hat{k} = 0, \hat{c} = \frac{2[\hat{\theta}_2(f + a\hat{\theta}_1) + a\nu]}{f + 2a\hat{\theta}_1}\)) whose economic intuition can be explained bearing in mind that the slope of the aggregate demand at the area level is given by:

\[
\frac{d(p + p^*)}{d(y + y^*)} = \frac{(\hat{\theta}_1\hat{\theta}_2 + \nu)(2a + k) + 2f\hat{\theta}_2 - 2\nu k - c(f + 2a\hat{\theta}_1)}{(f\hat{\theta}_2 + \nu)(2a + k) + 2f\hat{\theta}_2 - 2\nu k - cf(1 + a)}
\] (17)

By inspection of Eq. (17) it can be immediately verified that these rules determine a flat aggregate demand for the union so that any AS shifts do not have any impact on prices. In particular, if \(\nu = \nu^* > 0\), Poole rule \(\hat{k}\) becomes positive showing a preference for interest rate pegging. This means that if the sensitivity of the CC to the credit channel is high it is necessary to limit the slope of LM in order to contain the effect on the interest rate.

In the case of the alternative benchmark rule based on the spread, there is always a preference for partial spread pegging (\(\hat{c} > 0\)). The meaning of this condition is that even if there is no segmentation between national credit markets, in the case of supply shocks it is always preferable to neutralise the impact of the bank lending channels on aggregate demand by reducing national spreads.

If the structural asymmetries in the credit channels are not negligible, the optimal reaction of the monetary rule changes with the origin of the shock. In particular, when \(\nu > \hat{\theta}_1\hat{\theta}_2 > \nu^*\) and the supply disturbance has origin in country
1, which has a more effective credit channel, the optimal Poole rule favours a vertical LM ($\hat{k} < 0$). This result stresses the fact that it is important to consider the direct impact of money variation on national credit markets: if the supply shock hits country 1, which has a more effective credit channel, the adjustments of the money supply to keep the interest rate fixed cause a perceptible shift of the CC curve. On the contrary if the perturbation hits country 2, interest rate pegging is the sensible policy because allowing LM to be flat has lesser consequences.

These results change if the average spread is considered as feedback variable. In the case of a supply shock in country 1, the optimal monetary rule must always be oriented towards partial spread pegging, which is more effective in containing the effects caused by the banking sector. Conversely, if the disturbance has origin in country 2, there is less need to neutralise the destabilising effect determined by the credit channel and if the structural difference is relatively great ($\nu - \nu^*$ > $\frac{\partial_2(f + 2a\partial_1)}{a}$) there is a preference for money targeting.

When output becomes the only variable of interest of the ECB ($\lambda = 0$), analysis of the symmetric case shows that the optimal benchmark rules become ($\hat{k} = -\frac{2[f\partial_2 + a(f\partial_2 + \nu)]}{f\partial_2 - \nu}$, $\hat{c} = 0$), and ($\hat{k} = 0$, $\hat{c} = \frac{2f\partial_2(1 + a) + 2a\nu}{f(2a + 1)}$), which make the AD perfectly vertical [see Eq. (17)]. In the case of heterogeneous credit channels it is possible to prove that the optimal rule tends to have opposite characteristics to those obtained setting $\lambda = 1$ (see the last two rows of Table 1). From the analysis of the effects of supply shocks, the main results for price stabilisation are the following. If the countries that make up the union have homogeneous bank lending channels, the optimal monetary rule in the case of a high variance of supply shocks is independent of the origin of the disturbance and calls for control of the interest rate structure (spread and interest rate pegging are preferable to money targeting). On the contrary, in the case of heterogeneous credit channels, the benefits of an active monetary policy, which responds to information from financial indicators, are very great. This seems to be in line with the use of a large number of economic indicators so as in the ‘second pillar’ of the ECB monetary strategy.

In the presence of structural asymmetries, the optimal monetary policy is influenced not only by the nature of the shock but also by its provenance since its propagation within the union depends upon the characteristics of the country that has been hit by the stochastic shock. In particular a disturbance in country 1, where the bank lending channel is more powerful, calls for spread pegging, while if country 2 is hit by a supply shock interest rate pegging becomes preferable.

6. Conclusions

This paper has analysed the optimal monetary policy in a monetary union composed of countries with heterogeneous credit channels. In order to insulate
better the economies from the asymmetric effects produced by differences in national financial systems, the classic money supply process proposed by Poole (1970) has been modified to consider the spread between the interest rates on loans and bonds as an additional feedback variable. Using a two-country rational expectations model, this study has highlighted the properties of the optimal monetary instrument. The main conclusions can be summarised as follows.

In the case of perfect substitutability in the goods market, not only money and output demand shocks, but also credit market disturbances influence prices and income in an additive form and the monetary union, therefore, tends to reduce the effects of such shocks only if they are negatively correlated.

Asymmetric effects between the two countries are determined only in the case of shocks to the ‘law of one price’ and to aggregate supply. Only when these two kinds of disturbance are negligible does the stabilisation objective of each country coincide with that of the monetary area as a whole.

In the presence of stochastic disturbances that cannot be observed, the optimal monetary policy has to consider all information from movements in the financial indicators: the common interest rate on bonds embodies information mainly about money market disequilibria, the spread between the interest rate on loans and bonds ensure additional information about shocks on the credit market and output demand. Using the spread as a feedback variable in the money supply process determines, on the one hand, the reduction of asymmetric effects due to national credit market differences and, on the other, a better insulation of the economies from both money and output demand disturbances.

This result indicates the superiority of spread vs. interest rate pegging. Indeed, in contrast to Poole’s model, control of the interest rate can insulate the economies from money demand shock only in the extreme case of ineffective credit channels. The economic intuition underlying this result is that, in the Bernanke–Blinder framework, if monetary policy reacts to support variations in the public’s liquidity preference by changing the money supply, this also determines an effect on the supply of loans, which moves the CC. Therefore, only when these movements are negligible does Poole’s result hold.

In the face of credit market disturbances, money targeting is generally preferable, except in the case of a shock in country 1 associated with high asymmetry between national credit channels, which requires spread pegging to contain the effects on prices and output variability.

When random disturbances affect the supply side of the economies, the optimal monetary policy becomes highly sensitive to the effectiveness of credit channels and their degree of asymmetry. Moreover, the selected rule with respect to inflation tends to have opposite consequences on output variance.

The main message from this paper is that in the case of a monetary union among countries with different financial structures, monetary policy should respond by ‘leaning against the wind’ with more intensity than if the countries were identical. Each kind of shock changes the optimal rule in a specific direction with an intensity that is a function of the parameters of the model. Moreover, if the difference between national credit channels reaches a critical threshold value, with
credit market and supply disturbances, the law of motion of the optimal rule switches, depending upon the country in which the shock has originated.

Further research could be directed towards three additional issues. First, the general analytical framework of the model could be used to analyse the consequences for the monetary transmission process of structural and institutional differences in other markets (for example, the labour market). Second, the results of the optimal monetary rule proposed here could be improved using other economic indicators as feedback variables, in line with the ‘second’ pillar of ECB monetary policy. Third, an analysis of the monetary instrument problem should also take into account national fiscal policies. In this case, indeed, the optimal policy rule also depends on fiscal policy co-ordination at the area level and should include as feedback variable also an indicator of their degree of asymmetry.

7. Nomenclature

\( a \): elasticity of demand for money with respect to the interest rate on bonds
\( b \): elasticity of exports with respect to foreign real output
\( d \): elasticity of aggregate demand with respect to the difference between prices
\( E_t \): expectation operator, conditional on information at time \( t \)
\( \phi \): elasticity of demand for money with respect to real output
\( f \): measure of the overall effect on output of a change in the real interest rate on bonds (‘money channel’)
\( g \): measure of the ‘price surprise’ effect on real output
\( h \): elasticity of demand for loans with respect to the spread
\( i \): nominal interest rate, expressed in units
\( k, c \): policy instruments
\( \lambda \): weight attached to price stability
\( l^d \): nominal loan demand, expressed in logs
\( l^s \): nominal loan supply, expressed in logs
\( m^s \): nominal money supply, expressed in logs
\( p \): price of output expressed in logs
\( q \): elasticity of supply of loans with respect to the spread
\( \tilde{\rho} \): spread between the interest rate on loans (\( \rho \)) and bonds (\( i \)), expressed in units
\( u_{td} \): stochastic disturbance in the demand for loans
\( u_{ts} \): stochastic disturbance in the supply of loans
\( u_{md} \): stochastic disturbance in the demand for money
\( u_{p} \): stochastic disturbance in the ‘law of one price’ equation
\( u_{yd} \): stochastic disturbance in aggregate demand
\( u_{ys} \): stochastic disturbance in aggregate supply
\( \nu \): measure of the effect on real output of a change in the spread (‘bank lending channel’).
w: elasticity of demand for loans with respect to real output
y: real output, expressed in logs
z: elasticity of supply of loans with respect to money

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Appendix A: Coefficients of the model

\[ A_1 = B_1 = C_1 = D_1 = 2 \partial_2 [f \partial_2 + a(\nu + \nu^*)] / \Delta > 0 \]

\[ A_2 = B_2 = C_2 = D_2 = \{ \partial_2 (2a + k) \nu + c[f \partial_2 + a(\nu^* - \nu)] \} / \Delta \]

\[ A_3 = B_3 = C_3 = D_3 = \{ \partial_2 (2a + k) \nu^* + c[f \partial_2 + a(\nu - \nu^*)] \} / \Delta \]

\[ A_4 = B_4 = C_4 = D_4 = \partial_2 [-2f \partial_2 + k(\nu + \nu^*) + 2fc] / \Delta \]

\[ A_5 = B_5 = C_5 = D_5 = \partial_2 [2a(\partial_2 - c) + k \partial_2] / \Delta \]

\[ A_6 = C_6 = \{ 2f \partial_2 [(2 + a)f \partial_2 + a(\partial_1 \partial_2 + 2 \nu^*)] + k \partial_2 (f \partial_2 + \partial_1 \partial_2 - 2 \nu) \]
\[ -2c[a(\partial_1 \partial_2 - \nu + \nu^*) + f \partial_2 (1 + a)] \} / \Delta \]

\[ B_6 = D_6 = \{ -2f \partial_2 [(2 + a)f \partial_2 + a(\partial_1 \partial_2 + 2 \nu)] + k \partial_2 (f \partial_2 + \partial_1 \partial_2 - 2 \nu^*) \]
\[ +2c[a(\partial_1 \partial_2 + \nu - \nu^*) + f \partial_2 (1 + a)] \} / \Delta \]

\[ A_7 = B_7 = \{ -2f \partial_2 (f \partial_2 + a(\partial_1 \partial_2 + \nu)) - k \partial_2 (\partial_1 \partial_2 - \nu^*) \]
\[ +c[a(2\partial_1 \partial_2 + \nu - \nu^*) + f \partial_2 ] \} / \Delta \]

\[ A_8 = B_8 = \{ -2f \partial_2 (f \partial_2 + a(\partial_1 \partial_2 + \nu^*)) - k \partial_2 (\partial_1 \partial_2 - \nu) \]
\[ +c[a(2\partial_1 \partial_2 - \nu + \nu^*) + f \partial_2 ] \} / \Delta \]
\[ C_7 = \{2 \partial_2[3f + a(2f + \partial_1\partial_2 + \nu + 2\nu^*)] + k\partial_2[2f + \partial_1) - 2\nu - \nu^* \] 
\[ -c[a(2\partial_1\partial_2 - \nu + \nu^*) + f\partial_2(3 + 4a)]/\Delta \]

\[ D_7 = \{-2\partial_2[f\partial_2 + a(\partial_1\partial_2 + \nu)] - \partial_2k(\partial_1\partial_2 - \nu^*) \] 
\[ +c[a(2\partial_1\partial_2 + \nu - \nu^*) + f\partial_2]}/\Delta \]

\[ C_8 = \{-2\partial_2[f\partial_2 + a(\partial_1\partial_2 + \nu^*)] - \partial_2k(\partial_1\partial_2 - \nu) \] 
\[ +c[a(2\partial_1\partial_2 + \nu + \nu^*) + f\partial_2]}/\Delta \]

\[ D_8 = \{2\partial_2[3f + a(2f + \partial_1\partial_2 + 2\nu + \nu^*)] + k\partial_2[2f + \partial_1) - \nu - 2\nu^* \] 
\[ -c[a(2\partial_1\partial_2 + \nu - \nu^*) + f\partial_2(3 + 4a)]}/\Delta \]

\[ \Delta = 2\partial_2\{2[f\partial_2 + a(f\partial_2 + \partial_1\partial_2 + \nu + \nu^*)] + k[\partial_2(f + \partial_1) - \nu - \nu^* \] 
\[ -2c[f + a(f + \partial_1)] > 0 \]

0 < \partial_1 = 1 - b < 1 and \partial_2 = h + q > 0

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