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THE BANK LENDING CHANNEL OF MONETARY TRANSMISSION IN BRAZIL: A VECM APPROACH

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ABSTRACT/RÉSUMÉ

The bank lending chanêl of monetary transmission in Brazil: A VECM approach

This paper tests for the existence of a bank lending channel in the transmission of monetary policy in Brazil using monthly aggregate data for the period 1995:12 through 2008:6. The test is carried out in a VECM setting that allows for multiple cointegrating relationships among the variables of interest. We find evidence of two cointegrating vectors, which we identify as bank loan demand and supply functions by testing for a number of exclusion and exogeneity restrictions on the cointegrating relationships. Loan supply is negatively related to the interbank deposit certificate rate in the long term, which confirms the existence of a lending channel for monetary transmission. The VECM's short-term dynamics show that loan demand is equilibrium-correcting. But short-term disequilibria in the supply of loans are corrected through changes in the interbank deposit certificate rate, suggesting that monetary policy plays a role in restoring equilibrium in the credit market by affecting the borrowing rate faced by banks to raise non-deposit funds. This Working Paper relates to the 2009 *OECD Economic Survey of Brazil* (www.oecd.org/eco/surveys/brazil)

JEL classification: E10; E44; E52
Keywords: Vector error-correction model; bank lending channel; monetary transmission mechanism

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**Le crédit bancaire comme canal de transmission de la politique monétaire au Brésil :
Un modèle à correction d'erreur**

Ce document teste l'hypothèse de l'existence du crédit bancaire comme canal de transmission de la politique monétaire au Brésil à l'aide de données mensuelles agrégées pour la période décembre 1995 à juin 2008. Le test est effectué dans le cadre d'un modèle à correction d'erreur (VECM) qui permet plusieurs vecteurs de cointegration parmi les variables d'intérêt. L'analyse empirique révèle l'existence de deux vecteurs de cointegration, que nous identifions comme la demande et l'offre de crédit bancaire sur la base d'un certain nombre de restrictions d'exclusion et d'exogénéité imposées sur les vecteurs de cointegration. L'offre des prêts bancaires est inversement liée au taux de long terme des certificats de dépôt interbancaire, ce qui confirme l'existence du crédit bancaire comme canal de transmission de la politique monétaire. La dynamique de court terme du VECM montre que la demande des prêts s'ajuste à l'équilibre de long terme. Mais à court terme les déséquilibres dans l'offre des prêts sont corrigés par des changements dans le taux des certificats de dépôt interbancaire, ce qui suggère que la politique monétaire joue un rôle dans le rétablissement de l'équilibre sur le marché du crédit en affectant le taux d'emprunt des banques. Ce Document de travail se rapporte à l'Étude économique de l'OCDE du Brésil, 2009 (www.oecd.org/eco/etudes/brésil).

Classification JEL : E10 ; E44 ; E52
Mots clés : Modèle à correction d'erreur ; canal du credit bancaire ; mechanisme de transmission monétaire

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The bank lending channel of monetary transmission in Brazil: A VECM approach

Luiz de Mello and Mauro Pisu,[1]

1. Introduction

At close to 40% of GDP in mid-2008, Brazil's credit-to-GDP ratio is relatively low, even by emerging-market standards. Although the country has a sophisticated banking system, years of chronic inflation prior to macroeconomic adjustment in the mid-1990s, coupled with stubbornly high real interest rates since then, are considered the main culprits for a low credit-to-GDP ratio. As a result, it has often been argued that there should be limited scope for monetary policy to affect demand through a bank lending channel. But empirical evidence available to date shows that this is not the case (Souza Sobrinho, 2003; Takeda *et al.*, 2005). Against this background, this paper aims to shed additional light on this issue, motivated by a sharp rise in the stock of outstanding bank loans, especially to individuals, since 2003, which is likely to have strengthened the lending channel further. In particular, the paper focuses on three basic policy questions: *i*) Is there a lending channel for monetary policy in countries with low credit-to-GDP rations? *ii*) Do the credit dynamics provide information about the future path of inflation, therefore justifying regular monitoring of credit aggregates for the conduct of monetary policy, and *iii*) Is there a role for monetary policy is restoring short-term disequilibrium in loan demand and supply?

We use aggregate, rather than bank-level, data to estimate the long-term determinants of bank loan demand and supply in a VECM setting. This approach allows for multiple cointegrating relationships among the variables of interest, which is particularly appealing for the identification of supply and demand responses to changes in the monetary stance. A large literature pioneered by Bernanke and Blinder (1992), Kashyap and Stein (1993), Bernanke and Gertler (1995) and Walsh (1998) has highlighted the fact that the estimated supply response to monetary shocks may be overestimated to the extent that demand-side effects are not identified correctly. A number of identification strategies have been proposed, including through the use of bank-level data to account for heterogeneity in bank responses to monetary policy. Instead, we rely on an identification strategy based on the simultaneous estimation of supply and demand equations, coupled with the testing of a number of exclusion, exogeneity and homogeneity restrictions on the cointegrating parameters. Comparable identifications strategies have been pursued recently in Kakes (2000) for the Netherlands, Hülsewig *et al.* (2002) for Germany and Calza *et al.* (2006) for the Euro-area countries.

We use monthly data available from Brazil's banking survey and the central bank's dataset on a variety of credit instruments and associated lending rates. The VECM includes bank loans, the interbank deposit certificate rate, the pre-set lending rate (averaged across a host of credit modalities), CPI inflation, a proxy for economic activity and bank capital as endogenous variables. Attention is focused on private (domestic and foreign) banks and on the non-earmarked credit market segment over a period spanning 1995:12 through 2008:6.

Our findings are threefold. *First*, a low credit-to-GDP ratio does not preclude the existence of a lending channel for monetary transmission, at least as far as the Brazilian experience is concerned. We found evidence of the presence of two cointegrating vectors on the basis of the Johansen trace test. Based on our identification strategy, the long-run demand for credit is positively related to real activity and negatively related to the pre-set lending rate and inflation. The long-term supply of loans is negatively associated with the borrowing rate faced by banks to raise external funds, suggesting that banks do not have unlimited access to non-reservable sources of finance, and positively related to the lending rate, bank capital and inflation.

Second, the stock of outstanding loans offers limited information on the future trajectory of inflation. This is because inflation, as well as bank capital, was found to be weakly exogenous in the cointegrating vectors. This finding therefore casts doubt over the relevance of regular monitoring of credit aggregates for the conduct of monetary policy in an inflation-targeting setting.

Third, changes in the monetary stance play an important role in restoring short-term equilibrium in the supply of bank loans. This is because loan supply is equilibrium-correcting in the interbank deposit certificate rate, but not in the stock of loans. On the other hand, excess demand for loans is self-correcting, albeit slowly.

The paper is structured as follows. Section 2 reviews the empirical literature on the lending channel of monetary transmission. Section 3 presents the data and reports the unit root properties of the relevant series. Section 4 describes the methodology and identification hypotheses and reports the estimation results. Section 5 concludes.

2.   A survey of the literature

The early formulation of the bank lending channel problem dates back to Bernanke and Blinder (1988) within an IS/LM-type setting. Accordingly, the existence of a lending channel for monetary transmission is based on the premise that the supply of non-deposit sources of funding for banks is not infinitely elastic. Banks are not able to replace non-remunerated deposits, which contract in response to a monetary tightening, with alternative sources of funding, such as deposit certificates or new equity, or to decrease their bond holdings (Bernanke and Gertler, 1995). The existence of a lending channel also depends on the non-substitutability between loans and bonds, which violates the Modigliani-Miller proposition for banks. Stein (1998) provides micro-foundation of the bank lending channel in a model of bank asset and liability based on adverse selection. Kashyap and Stein (1993 and 2000), among others, provide a thorough review of the literature.

The early empirical literature aimed to test for the existence of a bank lending channel by estimating reduced-form equations of credit supply using aggregate data. The basic approach was pioneered by Bernanke and Blinder (1992). Nevertheless, this strand of literature was criticised on the grounds that it is difficult to identify credit supply responses, given that monetary shocks simultaneously affect the demand for loans (Romer and Romer, 1990). Failure to disentangle these separate effects leads to an overestimation of the impact of monetary policy on the supply of bank loans.

More recently, different identification strategies have been proposed, including the use of bank-level data to account for heterogeneity in the response of credit to monetary policy. The assumption that banks are price-takers (*i.e.* the demand for loans is infinitely elastic) is maintained. But banks are hypothesised to react differently to monetary policy depending on the extent of substitutability and access to alternative sources of non-deposit finance, which varies across banks. Information on bank characteristics, such as capitalisation, size and liquidity, is used to account for heterogeneity across banks (*e.g.* Kashyap and Stein, 1995 and 2000; Peek *et al.*, 2003; Ashcraft, 2006; Cetorelli and Goldberg, 2008, for the United States; Farinha and Marques, 2001, for Portugal; Angeloni *et al.*, 2002, for the Euro-area countries).

However, as emphasised by Kashyap and Stein (2000), even if the identification problem is solved by using bank-level data, aggregation problems make it difficult to quantify the impact of monetary policy on aggregate credit. To avoid this aggregation problem, a recent strand of literature has favoured the use of aggregate data and relied on the estimation of vector error-correction models (VECMs). Within this framework the supply and demand for loans can be identified by testing for the presence of multiple cointegrating relationships and exclusion, exogeneity and homogeneity restrictions on the cointegrating relationships. Loan supply and demand can therefore be modelled jointly, rather than in a one-equation reduced-form setting.

The VECM-based literature is growing fast. For example, Hülsewig *et al.* (2002) use quarterly data for Germany for the period 1975:1 through 1998:4 and find three cointegrating relationships, which the authors interpret as credit demand, credit supply and bank capital equations. Identification of the credit demand and supply equations relies predominantly on the sign of banks' borrowing and lending rates, as well as that of bank capital, coupled with exclusion and homogeneity restrictions imposed on the long-run VECM coefficients. Overall, their results support the existence of a bank lending channel, although the estimated effect of monetary shocks on loan supply appears to be small in magnitude.

In the same vein, Kakes (2000) tests for the existence of a bank lending channel in the Netherlands using quarterly data during 1979:1 and 1993:4. The author finds two cointegrating relationships and imposes a homogeneity restriction on the borrowing and lending rates in the supply equation; in doing so, the sensitivity of loan supply to the interest-rate spread can be quantified. Nevertheless, there does not appear to be strong evidence of a banking channel, at least on the basis of the short-term dynamics of the error-correction equation. Additional evidence is reported by Calza *et al.* (2006) for the Euro-area countries using quarterly data during 1981:4 and 2001:3. The authors find only one cointegrating vector, which they normalise as a loan demand equation on the basis of the signs of the long-term coefficients of interest.

The empirical literature on Brazil, although limited, supports the existence of a bank lending channel for the transmission mechanism of monetary policy. Most empirical evidence is in the tradition of Kashyap and Stein (2000). Bank-level data is used to estimate the sensitivity of credit to changes in the monetary stance through reduced-form equations for (non-earmarked) loan supply, while using bank heterogeneity (arising essentially from size and liquidity/capitalisation indicators) for identification. Takeda *et al.* (2005) analyse two separate monetary instruments: the policy interest rate and compulsory reserve requirements on bank deposits. On the basis of loan supply equations estimated by difference-GMM for the period end-1994 to end-2001, the authors show that changes in reserve requirements have a more potent impact on bank lending than changes in the policy interest rate, especially for larger banks.

Souza Sobrinho (2003) uses aggregate monthly data for the period 1996:10 through 2001:12 and follows the tradition of Bernanke and Blinder (1992). The author estimates a VAR on bank credit, industrial production, the policy interest rate, inflation and a monetary aggregate. He shows on the basis of impulse response functions that non-earmarked credit reacts sluggishly to a monetary tightening before contracting after two months and recovering after two years.

3.   Data and unit roots

Monthly data available from the Central Bank of Brazil are used for the period spanning 1995:12 through 2008:6. Total credit to the private sector is available from the banking survey (private financial system's claims on private non-financial agents). The banks' borrowing rate is the annualised monthly rate on interbank deposit certificates (CDI). We follow the literature (Takeda *et al.*, 2002; Souza Sobrinho, 2003) and define the lending rate as the annualised pre-set rate on loans financed through non-earmarked resources, which is a weighted average of a host of bank lending rates (for enterprises, including loans for working capital, discounts of promissory notes, overdraft facilities; and for individuals, including payroll-back loans). Bank capital is also available from the banking survey. The CPI (IPCA) is used as the price index. GDP is proxied by the industrial production index. Descriptive statistics of the dataset are reported in Table 1.

Table 1. **Descriptive statistics, 1995:12-2008:6**

|	Mean	St. Dev.	Min.	Max.
Borrowing rate (in %, annualised monthly rate)	20.3	7.0	11.1	44.8
Lending rate (in %, annualised monthly rate)	66.8	21.0	40.2	163.6
CPI inflation (in %, 12-month annual rate)	7.5	4.4	1.6	22.4
Industrial production index (in units)	101.7	13.3	74.9	136.8
Bank capital (in billions of *reais* of June 2008)[1]	342.3	116.0	224.7	694.9
Stock of bank loans (in billions of *reais* of June 2008)[1]	362.2	125.0	183.0	653.9

1.   Deflated by the CPI (IPCA).

Source: Data available from the Central Bank of Brazil, and authors' calculations.

Visual inspection of the data shows that the stock of private financial institutions' loans to the private sector grew sharply after early 2003, following a period of relative stability (Figure 1). Credit to individuals has led the way, and loans to enterprises started to rise in earnest after late 2006. The stock of credit accounted for about 38% of GDP in June 2008. Private financial institutions, including foreign banks operating in Brazil, accounted for two-thirds of total credit, with government-owned or controlled institutions accounting for the remainder. Bank credit to the government is negligible (less than 1% of total loans outstanding). About one-quarter of total credit is earmarked, benefiting predominantly the industrial sector, agriculture and housing, with public banks playing a dominant role in these operations.[2]

To test for the presence of unit roots in the data, the nominal series were deflated by the CPI (IPCA) and defined in logs. The Lee and Strazicich LM test, which allows for one or two endogenous breaks, was used (Lee and Strazicich, 2003 and 2004). This test has the advantage of allowing for breaks both under the null (unit root with breaks) and the alternative hypotheses (stationarity around breaks). The presence of

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2.   Earmarked credit operations refer to existing regulations on the allocation of savings and sight deposits in commercial banks to finance credit to selected sectors, especially agriculture and housing, including through mandated saving arrangements. See OECD (2005 and 2006) for a summary of directed credit requirements.

Figure 1. **Credit and interest-rate dynamics, 1995-2008**

A. Credit trends[1]
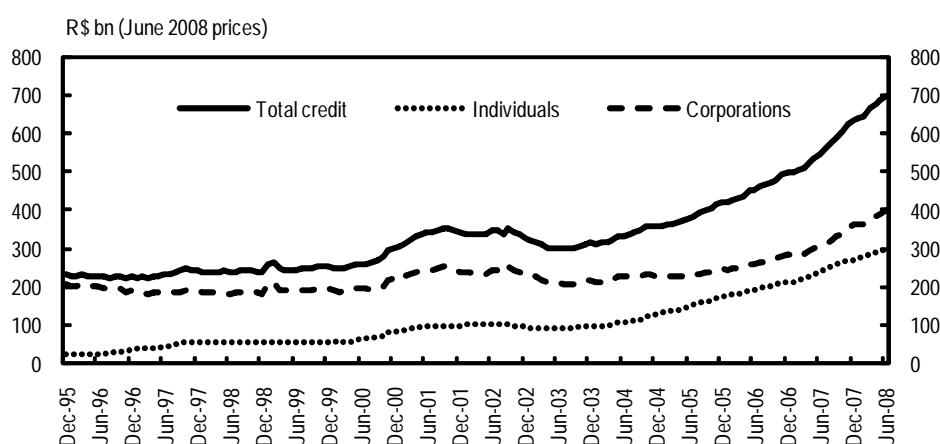
B. Borrowing and lending rates
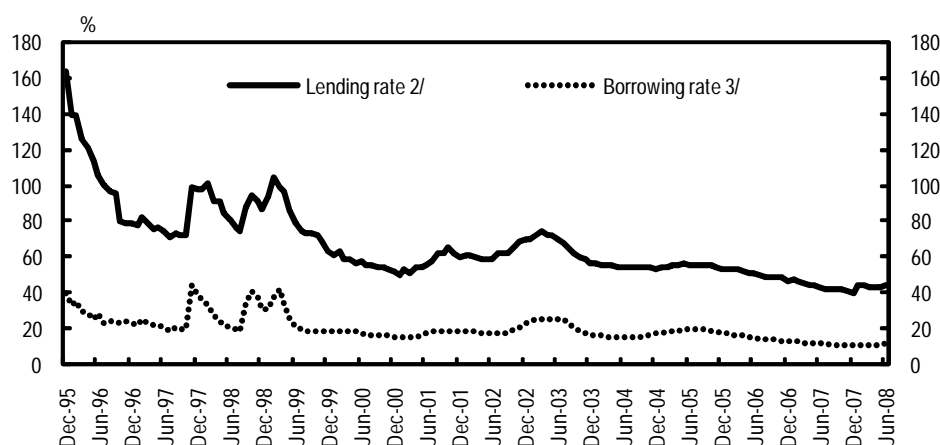
1. Deflated by the CPI (IPCA).
2. Refers to the average annualised monthly pre-set rate on non-earmarked loans.
3. Refers to the annualised monthly rate on interbank deposit certificates (CDI).

Source: Central Bank of Brazil.

breaks in the series is expected, because the time period under examination includes a change in the exchange-rate regime in January 1999, when the *real* was allowed to float freely, as well as the financial stress associated with the emerging-market crises of the second-half of the 1990s. On the basis of this test, there appears to be one or two endogenous breaks, depending on the variable in question, in the levels (but no trend) of bank capital and the lending and interbank deposit certificate rates. All breaks were identified between 1997:6 and 1999:2, a period that includes episodes of significant financial strain associated with the Asian and Russian crises, as well as the change in the exchange-rate regime. The hypothesis of integration could not be rejected at classical levels of significance for these three series. The test was also performed on the other series and the results also suggest that they follow I(1) processes.

With regard to industrial production, which does not appear to exhibit breaks, the Elliott, Rothenberg and Stock ADF-GLS test, which is more efficient than other tests under the hypothesis of normal residuals, was used (Elliott, Rothenberg and Stock, 1996). The optimal number of lags was selected on the basis of the Schwartz information criterion, starting with a maximum of 12 lags and testing for normality of the residuals. The results (not reported) show that the series follows an I(1) process. As for the CPI and the stock of credit to the private sector, which do not exhibit breaks, but appear to be trended and to have non-normal residuals, the Schmidt-Phillips test (SP) was used (lag truncation equal to 4) (Schmidt and Lee, 1991). In both cases, the null hypothesis of unit roots could not be rejected at classical levels.

The results of the unit root analysis indicate the need to test for cointegration among these variables. We therefore proceed to test for cointegration using the Johansen-Juselius methodology that allows for the existence of multiple cointegrating relationships. With six integrated variables, there may be at most five cointegrating relationships for the variables defined in levels.

4. Methodology and estimation results

The cointegrating relationships

We consider a simple aggregate model of loan supply (l^S) and demand (l^D). Loan demand depends on macroeconomic conditions, proxied by economic activity (y) and inflation (π), as well as the lending rate (r_l) offered by banks. The supply of loans depends on the sources of funds available to banks, including capital (c), the borrowing rate (r_b) paid by banks for external funds and inflation, which affects the real rate of return on credit operations. This simple model allows for the identification of loan supply and demand, thus avoiding the well-known identification problems that arise in the estimation of reduced-form credit supply equations. In particular, the model can be written as:

$$l^S = l^S(c, \pi, r_b, r_l), \text{ and}$$
$$l^D = l^D(\pi, y, r_l). \tag{1}$$

If the presence of two cointegrating relationships cannot be rejected by the data, identification of the supply and demand functions depends on the estimated sign of the lending rate, which should be negative in the demand equation and positive in the supply equation, and the sign of the borrowing rate, which should be negative in the supply equation. Identification also depends on testing for two exclusion restrictions: bank capital should not enter the demand equation (while being positively signed in the supply equation), and economic activity should not enter the supply equation (while being positively signed in the demand equation).[3]

We estimate Model (1) in a VECM setting including six variables: credit stock, CPI, industrial production, the interbank deposit certificate rate, the lending rate and bank capital. In line with the literature, we define all variables in logarithmic form, except for the interest rates and the CPI. The VECM can be defined, as usual, as $\Delta Y_t = A(L)\Delta Y_t + \Pi Y_{t-1} + \varepsilon_t$, for $Y = [c, \pi, r_b, r_l, y, l]$, where L is the lag operator, and ε is an error term. The rank of Π, which can be written as $\Pi = \alpha\beta'$, where α and β are $p \times r$ matrices, and p is the number of variables in Y, is denoted by r. β is a vector of cointegrating relationships and α is a loading matrix defining the adjustment speed of the variables in Y to the long-run

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3. The identification of the cointegration vectors requires r restrictions for each vector, where r is the number of cointegrating vectors. We impose one normalising and one exclusion restriction in the demand and supply equations.

equilibria defined by the cointegrating relationships. We also include an unrestricted constant and seasonal dummies in the VECM.[4] The optimal lag length was selected on the basis of the Schwarz (SC) and Hannan-Quinn (HQ) criteria, along with misspecification tests for the error terms. Both the SC and HQ criteria suggested the inclusion of two lags. However, this lag structure proved to be insufficient to eliminate serial correlation in the error terms. Thus, we experimented with increasing the number of lags until the errors were found to be serially uncorrelated, which was achieved with five lags.[5]

Table 2 reports the results of the Johansen trace test for cointegration.[6] The null hypothesis is of cointegrating rank of at most r (*i.e.* the VECM has at most r cointegrating relationships). On the basis of this test, the null is rejected for $r=0$ and $r \leq 1$ (at the 1 and 5% levels, respectively), suggesting the presence of two cointegrating relationships. In addition, all characteristic roots lie inside the unit circle; as a result, the system is stable and converges to its long-term equilibrium.

Table 2. **Johansen's trace test**

Null hypothesis	Eigenvalue	Trace statistics	5% *p*-value
r=0	0.351	135.15	0.000
r≤1	0.219	71.98	0.031
r≤2	0.098	35.93	0.405
r≤3	0.080	20.85	0.377
r≤4	0.049	8.71	0.399
r≤5	0.009	1.379	0.240

Source: Data available from the Central Bank of Brazil, and authors' estimations.

The estimated unrestricted cointegrating vectors are reported in the top panel of Table 3. Based on the signs of the relevant parameters, it appears that vectors β_1 and β_2 could be interpreted as demand and supply relationships, respectively.[7] The bottom panel of the table reports the hypothesis tests conditional on the selected rank. Consistently with the univariate tests, the hypothesis of stationarity can be rejected for all variables in the system (at least at the 10% level). The long-run exclusion tests suggest that none of the variables included in the VECM can be omitted from the long-run relationships.

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4.   We also have conducted the estimation including a constant restricted in the cointegration space in addition to the unrestricted constant. The results are similar to those reported in the paper.

5.   The multivariate LM tests with the null of no serial correlation of orders one and five were not rejected (*p*-values of 0.235 and 0.163, respectively). The multivariate LM tests for ARCH effects were rejected, but, as shown by Rahbek *et al.* (1999), the rank test is robust to moderate ARCH effects. Also, including additional lags did not produce error terms free of ARCH effects. For this reason, we kept the more parsimonious specification including five lags.

6.   We were unable to use the small-sample correction for the trace statistics proposed by Johansen (2000, 2002a and 2002b) due to a lack of degrees of freedom.

7.   We experimented with including dummy variables to identify the abandonment of the exchange-rate regime in January 1999 and a sharp monetary tightening in the run-up to the presidential election of October 2002. But neither dummy was found to be statistically significant at classical levels.

Table 3. **Unrestricted cointegration vectors and restriction tests**

	y	c	l	r_b	r_l	π
	Unrestricted vector					
β_1	13.203	-4.203	-0.577	0.263	-0.137	-0.124
β_2	-16.648	-0.046	5.45	0.315	-0.134	-0.028
	Hypothesis tests[1]					
Stationarity	7.611	5.72	4.722	22.207	30.305	18.307
	[0.022]	[0.057]	[0.094]	[0.000]	[0.000]	[0.000]
Long-run exclusion	33.42	32.147	33.336	22.15	27.314	24.598
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Weak exogeneity	8.435	1.208	40.681	12.204	11.631	3.886
	[0.015]	[0.547]	[0.000]	[0.002]	[0.003]	[0.143]

1. The test statistics are distributed as χ^2 with 2 degrees of freedom (*p*-values are reported in brackets).

Source: Data available from the Central Bank of Brazil, and authors' estimations.

Finally, the hypothesis of weak exogeneity cannot be rejected for both capital and inflation. A joint exogeneity test also fails to reject the null that both variables are weakly exogenous ($\chi^2(4) = 5.11$, *p*-value = 0.28). This finding is interesting for the conduct of monetary policy. It implies that disequilibria in loan supply and demand do not contain information about future inflation. This is at odds with the evidence reported by Calza *et al.* (2006) for the Euro-area countries that inflation reacts to a credit demand overhang/shortfall.

To identify the supply and demand equations, we imposed the following joint exclusion and exogeneity restrictions on the cointegration parameters: $H_0 : \beta_{1c} = \beta_{1r_b} = \beta_{2y} = \alpha_{1c} = \alpha_{2c} = \alpha_{1\pi} = \alpha_{2\pi} = 0$. If the null hypothesis is not rejected, loan demand is unaffected by bank capital and the interbank deposit certificate rate, loan supply is unaffected by activity, and capital and inflation are weakly exogeneous (in line with the findings reported above). The null hypothesis could not be rejected at classical levels on the basis of a LR test ($\chi^2(5) = 7.875$, *p*-value = 0.163). As a result, the parameters of the demand and supply equations normalised in *l* are the following (absolute t-statistics in parentheses):

$$l^d = \; 2.164 \; y \; - \; 0.011 \; r_l \; - \; 0.031 \; \pi, \tag{2}$$
$$\quad\;\; (6.69) \qquad (4.69) \qquad\;\; (4.68)$$

$$l^s = \; 0.942 \; c \; - \; 0.097 \; r_b \; + \; 0.040 \; r_l \; + \; 0.007 \; \pi.$$
$$\quad\;\; (7.88) \qquad (7.20) \qquad\; (7.20) \qquad\;\; (0.82)$$

These parameter estimates show that economic activity is a powerful determinant of the demand for bank loans. Comparable studies have also estimated the income elasticity of bank loan demand to be greater than one, including Calza *et al.* (2006), for the Euro area (1.48); Kakes (2000), for the Netherlands (1.75); and Fase (1995), for the Netherlands (2-2.5). Moreover, the demand for loans appears to be negatively related to the lending rate and inflation. There is no prior on the sign of the relationship between the demand for loans and inflation. A negative coefficient might suggest that, as in de Gregorio and Sturzenegger (1997), firms reduce their demand for credit as inflation rises, because inflation is negatively related to productivity and the demand for labour.

As for the supply equation, there is a positive association between bank capital and loans. The point estimate suggests that, as capital increases by 1%, the supply of loans increases by around 0.9%. This

finding is consistent with the existence of bank capital channel as proposed by Van de Heuvel (2002 and 2006): when the value of their capital falls, banks cut back lending in line with capital adequacy requirements or to finance the cost of issuing new capital. In addition, inflation is positively related to loan supply, although the estimated semi-elasticity is not statistically significant. Moreover, as expected, the supply of loans is positively related to the lending rate and negatively related to the interbank borrowing rate. Both estimates are highly significant. This provides *prima facie* evidence of the existence of a bank lending channel, since monetary policy moves affect the supply of loans. In particular, if the interbank deposit rate were to fall by 10 percentage points, a variation that is of the same magnitude as the one that took place between the July 2005 peak and the January 2008 trough, loan supply would rise by approximately 1% over the long term. This semi-elasticity is about three times as high as that estimated by Kakes (2000) for the Netherlands in a VECM that excludes bank capital and inflation, and twice as high as that estimated by Hülsewig *et al.* (2002) for Germany in a VECM that includes bank equity but excludes inflation.

The signs and magnitudes of the point estimates of the lending and borrowing rates might suggest that the interest-rate spread may be an important determinant of loan supply. To be sure, we tested an additional homogeneity restriction $H_0 : \beta_{2r_b} = -\beta_{2r_l}$, jointly with the exclusion and exogeneity restrictions defined above ($H_0 : \beta_{1c} = \beta_{1r_b} = \beta_{2y} = \alpha_{1c} = \alpha_{2c} = \alpha_{1\pi} = \alpha_{2\pi} = 0$). But the null hypothesis could be rejected at classical levels of significance ($\chi^2(6) = 21.73$; p-value = 0.000). Therefore, contrary to the findings reported by Kakes (2000) and Hülsewig *et al.* (2002), the interest-rate spread does not seem to be an important determinant of loan supply in Brazil.

The short-term dynamics

The short-run dynamics of loan supply and demand can be assessed using the loading matrix (α) in conjunction with the normalised restricted cointegrating vectors reported in Equation (2). As underlined by Juselius (2006), if α_{ij} and β_{ij} (as expressed in Equation (2), which is normalised in l) are of the same sign, then variable i adjusts towards the equilibrium defined by the cointegrating relationship j. On the other hand, if they have opposite signs, then variable i does not converge to that equilibrium; in this case, convergence is achieved through movements in the other variables included in the VECM.

Based on the loading matrix presented in Table 4, the demand equation is equilibrium-correcting in the volume of loans, whereas this is not true for the supply equation (α_{l2} is low and insignificant). As a result, all else equal, short-term disequilibria in the demand for loans are self-correcting, albeit slowly,given the magnitude of the estimated loading coefficient. Activity and lending rates are also equilibrium-correcting in the long-run demand equation: a demand overhang will cause activity to rise and the lending rate to decrease. On the other hand, short-term disequilibria in the long-run supply equation are corrected through changes in the interbank rate only. All in all, monetary policy plays an important role in restoring equilibrium in the credit market in a situation of excess supply of loans by affecting the borrowing rates faced by banks to raise non-deposit funds. The adjustment coefficients of the other variables are insignificant in the long-run loan supply.

Table 4. **Loading matrix[1]**

|	Demand (α_1)	Supply (α_2)
Δy	0.036 (2.749)	0.007 (0.595)
Δc	0 (-)	0 (-)
Δl	-0.043 (6.049)	0.009 (1.430)
Δr^b	-4.412 (2.898)	-5.085 (3.600)
Δr^l	-6.544 (3.491)	-0.961 (0.552)
$\Delta \pi$	0 (-)	0 (-)

1. Absolute t-statics in parentheses.

Source: Data available from the Central Bank of Brazil, and authors' estimations.

To assess the reliability of our estimates, Figures 2 and 3 depict the long-term parameters α and β, respectively, obtained through recursive estimations of the VECM, while imposing the identifying restrictions tested above. All parameters appear to be reasonably stable, despite some fluctuation at the beginning of the sample. The fact that the coefficients of the borrowing and lending rates estimated in the supply equation increased in absolute value over time (Figure 3) suggests that loan supply became progressively more responsive to monetary policy.

Figure 4 shows the recursive statistics of the stability test for the cointegrating vectors, as proposed by Hansen and Johansen (1999). We performed two tests: one based on re-estimating the long- and short-term parameters for each sub-sample and the other based on re-estimating the long-term parameters only, while setting the short-term parameters at the values estimated for the entire sample. Both test statistics suggest that the cointegration vectors are stable. Only at the beginning of the recursive period is there evidence of parameter instability on the basis of the statistics obtained by re-estimating the short-term parameters for all sub-samples. Finally, Figure 5 plots the time path of the LR test statistics for the identifying restrictions on α and β (Hansen and Johansen, 1993). Again, the tests were carried out by re-estimating the short-term parameters for all sub-samples or setting them equal to their full-sample estimates. Overall, the identifying restrictions are rejected only for a short period during 2005, according to the test statistic computed by re-estimating the short-term coefficients for each sub-sample.

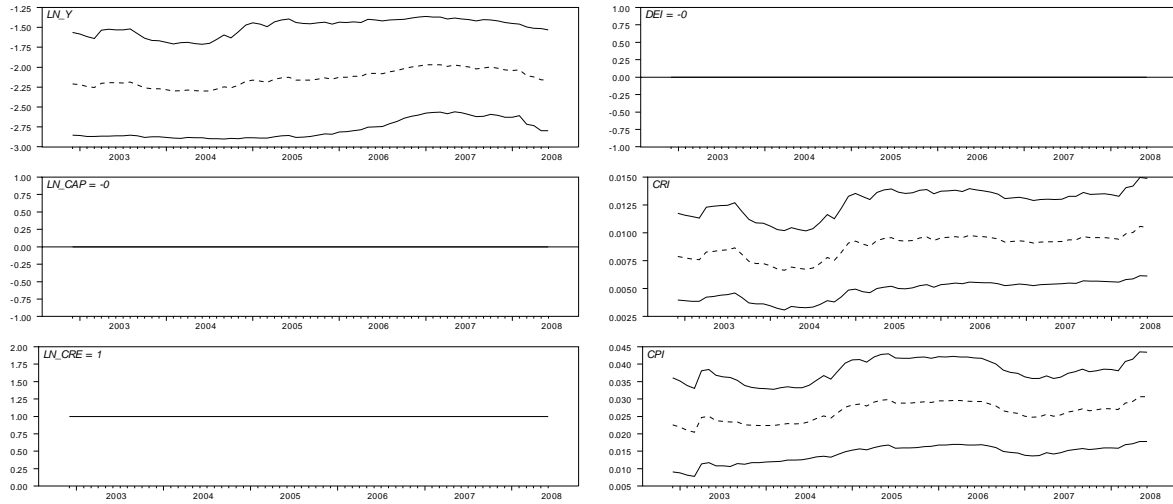Figure 2. **Parameter constancy tests: Loading matrix**

A. Loading coefficients of the demand equation (α_1)
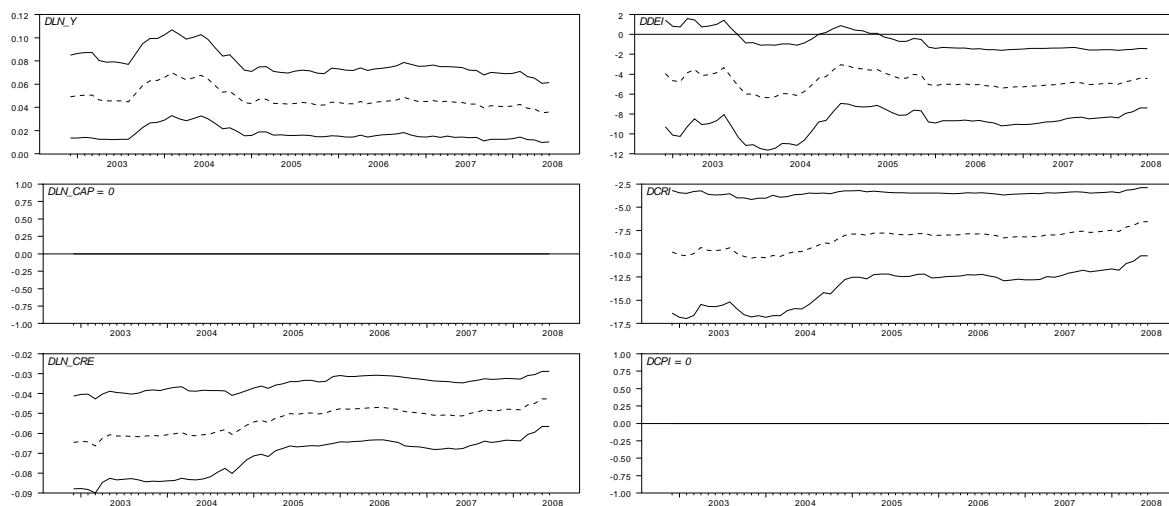
B. Loading coefficients of the supply equation (α_2)
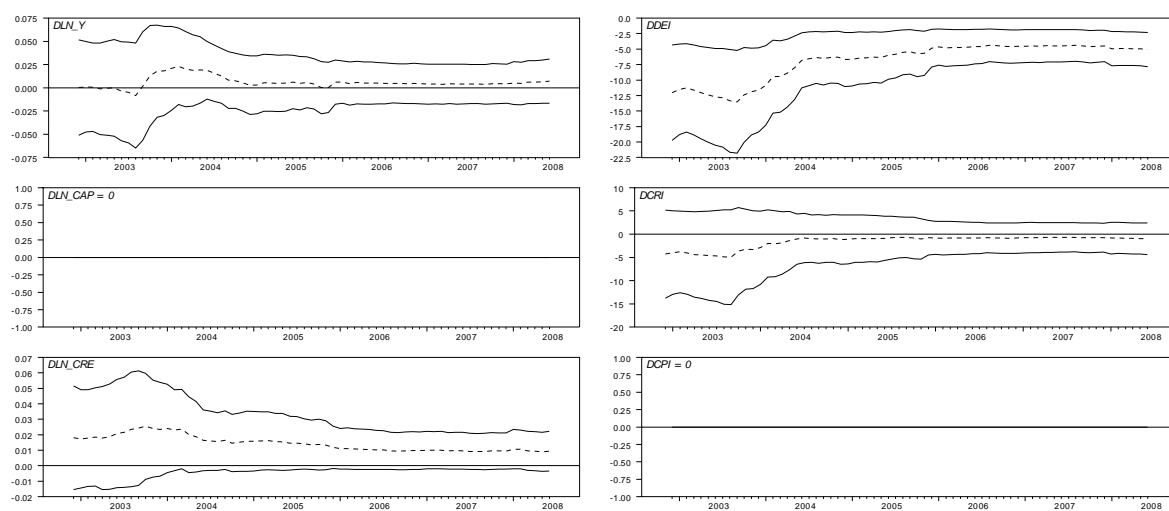
Source: Data available from the Central Bank of Brazil, and authors' estimations.
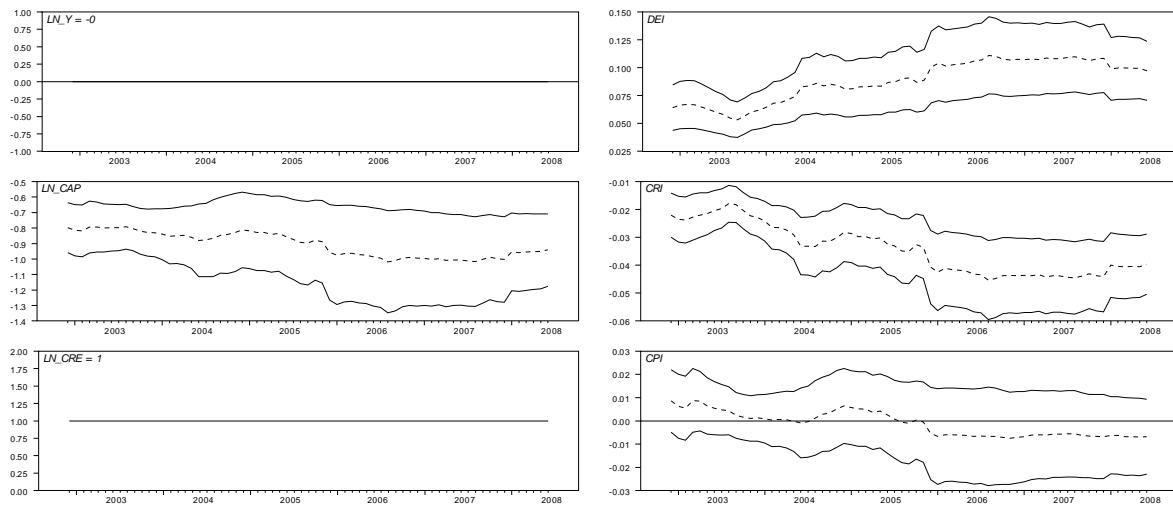
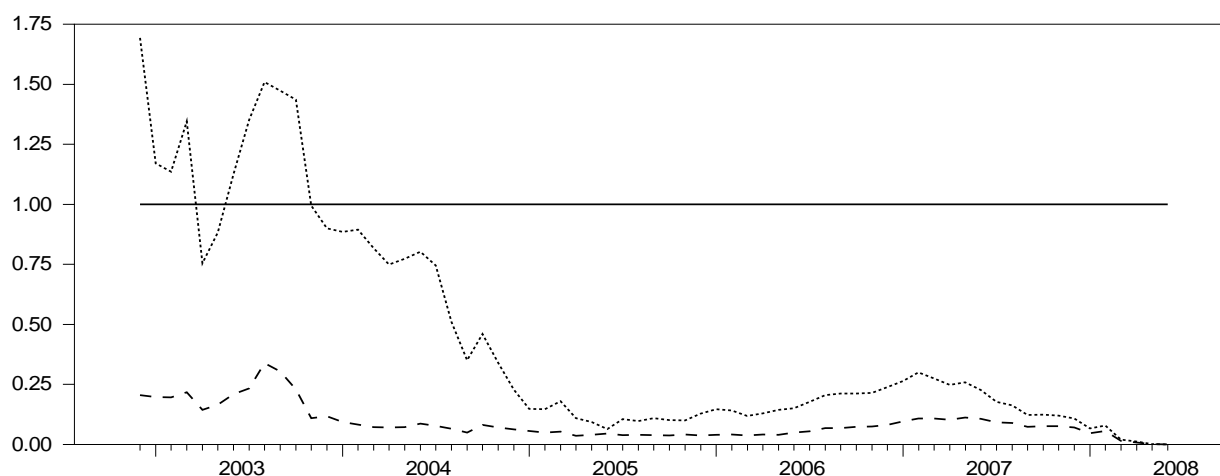Figure 3. **Parameter constancy test: Cointegrating vectors**

A. Demand equation (β_1)
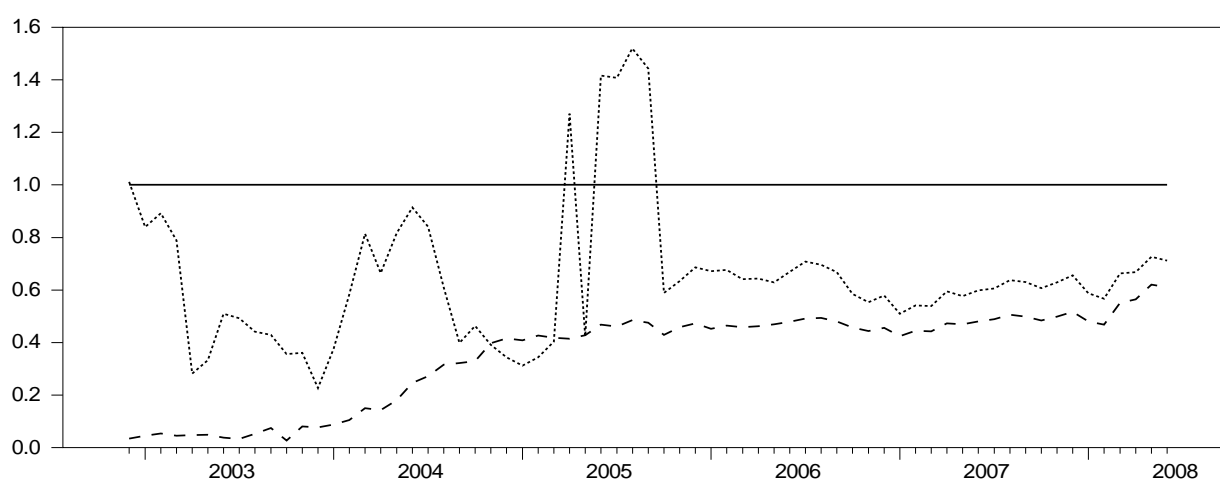

B. Supply equation (β_2)

Source: Data available from the Central Bank of Brazil, and authors' estimations.

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Figure 4. **Constancy test for β[1]**

1.   The dotted line refers to the test statistic obtained by re-estimating the long- and short-term parameters for each sub-sample. The dashed line is based on re-estimating the long-term parameters only and setting the short-term parameters at the values estimated for the entire sample. The 5% critical value was rescaled and set equal to 1.

Source: Data available from the Central Bank of Brazil, and authors' estimations.

Figure 5. **Time path of the LR test statistics of restrictions on α and β[1]**

1.   The dotted line refers to the test statistic obtained by re-estimating the long- and short-term parameters for each sub-sample. The dashed line is based on re-estimating the long-term parameters only and setting the short-term parameters at the values estimated for the entire sample. The 5% critical value was rescaled and set equal to 1.

Source: Data available from the Central Bank of Brazil, and authors' estimations.

5.   Conclusions

An important difficulty in testing for the existence of a bank lending channel for monetary transmission is to disentangle the loan supply and demand effects of monetary-policy moves. Different identification strategies have been proposed, including the use of bank-level data to estimate reduced-form supply equations and the testing of exclusion/homogeneity restrictions on multiple cointegrating vectors in

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a VECM setting on the basis of aggregate data. This paper adopted the latter strategy in recognition of the fact that estimation of reduced-form supply equations using bank-level data may not be very informative about the strength of the bank lending channel due to aggregation problems.

The estimation of a VECM using Brazilian aggregate monthly data for a period spanning December 1995 through June 2008 yields two cointegrating vectors, which could be identified as loan supply and demand equations on the basis of exclusion restrictions on the cointegrating vectors and exogeneity restrictions on the VECM's loading parameters. The estimation results reported in the paper complement previous empirical evidence using bank-level data and suggest that a comparatively low credit-to-GDP ratio does not preclude the transmission of monetary policy through a bank lending channel. The empirical findings also show that changes in credit aggregates are a poor predictor of inflation, casting doubt over the relevance of regular monitoring of loan stocks for the conduct of monetary policy within an inflation-targeting framework, and that monetary policy plays a role in restoring short-term disequilibria in the supply of loans through its impact of the cost of non-deposit sources of finance for banks.

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