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SPECIAL ISSUE

An equilibrium approach to financial stability analysis: the Colombian case

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Abstract This paper studies in detail the performance of a general equilibrium model of the financial system when applied to the case of Colombia. This model was designed following closely the work by Goodhart et al. (Ann Fin **2**, 1–21, 2006b). The results suggest that the model performs satisfactorily, especially in the prediction of short-run trends (2 years). A shortcoming of the results is a slight overestimation of several trends in the medium to long-term. There is however room to progress, particularly in terms of the incorporation of idiosyncratic features of the Colombian financial system into the model.

Keywords Financial stability · General equilibrium · Regulation · Colombian financial system

JEL Classification Numbers D58 · E44 · E58 · G1 · G2

1 Introduction

During the last three decades, central banks have been successful in achieving low levels of inflation and in keeping them under close control. At the same time

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as achieving inflationary success, however, central banks have been increasingly concerned with financial stability.[1] This is understandable in face of the huge costs of recent financial crises experienced almost worldwide.

According to Bårdsen et al. (2006), central banks use several methods in order to assess the stability of the financial system, and to evaluate the corrective actions that must be put in place. Among the methods, structural macroeconomic models, complex frameworks that allow interactions between a variety of economic agents, are increasingly common.

During the last couple of years, economists at the Bank of England have pioneered the design and implementation of general equilibrium models that are useful to assess financial stability and to understand the complex relationships between banks, depositors, borrowers and economic authorities that determine the state of financial stability. Moreover, the models put forward by the economists at the Bank allow evaluation of different policy actions. The works by Tsomocos (2003a,b) and Goodhart et al. (2006b) summarize this effort.

The Central Bank of Colombia has recently recognized the importance of financial stability as a pillar for the well-functioning of the payments system and, therefore, for the correct implementation of monetary policy.[2] In particular, the Financial Stability wing of the Banco de la República has engaged in the implementation of a model in the spirit of those proposed by the Bank of England's economists.

The objective of this paper is to study in detail the practical performance of a general equilibrium model when applied to financial stability analysis in Colombia. The results are encouraging insofar as the model performs satisfactorily, especially in predicting short-run (2 years) trends. The paper is divided into six sections. The first provides a brief justification of the use of a finite horizon general equilibrium model (FHGEM) for financial stability analysis. The second presents the main features of the the model. The third section considers the strategies for implementation and calibration of the model, while the fourth and the fifth evaluate its performance when compared against Colombian data. Some concluding reflections are provided in the sixth section.

2 Why use such a model?

Amongst the set of methods currently employed to analyze the state of financial stability, probably none is comprehensive enough to answer all the questions and solve all the puzzles that may arise during the analysis. A thorough analysis must depend crucially on a complementary use of several methods. In this sense, the use of macroeconomic models (and in particular, of the general-

[1] For an interesting account of the emergence of financial stability as a major policy concern, alongside inflation, see Borio and Lowe (2002), and Garcia Herrero and del Rio (2003).

[2] From a peak of 32.4% in 1990, inflation in Colombia has fallen gradually to 4.9% in 2005.

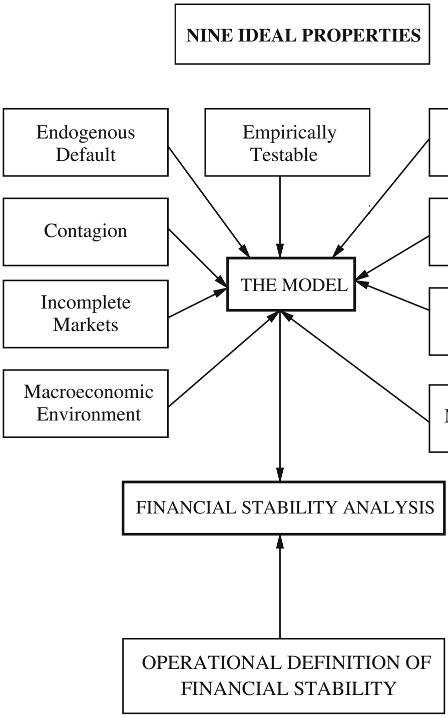

Fig. 1 Desirable characteristics in a macroeconomic model for the analysis of financial stability

equilibrium type) is increasingly common insofar as they encompass the endogenous interactions between the financial system and the rest of the economy.

The work by Bårdsen et al. (2006) contains an useful and detailed analysis of the comparative performance of several types of macroeconomic models. The following paragraphs summarize their main results.

According to the authors, although no model is able to answer all the questions, some of them share some *desirable* features that make them useful for financial stability analysis. Figure 1 presents those nine characteristics (identified by those authors) and the way in which they relate to the model and, therefore, to the analysis.

These nine characteristics are not, however, sufficient in order to do a good financial stability analysis. Previously, it is necessary to reach an agreement about what does financial stability mean, at least as far as the model is concerned. The authors conclude that the analysis depends on the combined result of the features of the model and what they define as an *operational* definition of financial stability. This definition allows numerical simulation of the model to be translated into estimates about the extent of financial stability.

Following these ideas, a FHGEM -such as that employed in this paper- not only features the aforementioned desirable characteristics but also allows us to use the following definition of financial stability: a situation characterized by

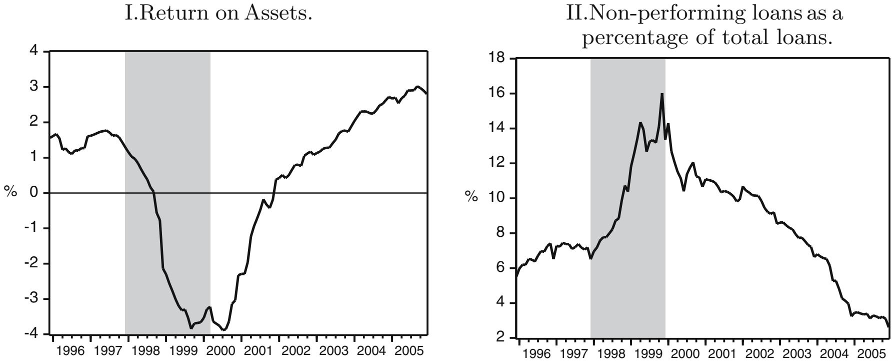

Fig. 2 Colombian financial system

low profits in financial institutions and a high probability of default in markets.[3] In order to justify the use of this particular definition in Colombia (and the use of a FHGEM at the Central Bank of Colombia) it is necessary to explore whether it can be applied to the Colombian case.

2.1 The case of the financial crisis of 1998–1999 in Colombia

To analyze its potential applications, it is useful to study a particular case in Colombian economic history, namely the financial crisis of the late nineties. According to information provided by the financial regulatory agency of Colombia (National Financial Superintendent's Office), from December 1997 to July 1999, the assets of the financial system fell 15,8% in real terms. Further, total loans as a percentage of GDP fell from 42.9% in 1997 to 35.5% in 1999. These facts suggest that the financial crisis of this period was one of the most damaging economic events of the twentieth century in Colombia.

Figure 2 shows the recent evolution of the profitability of the financial institutions and of non-performing loans as a percentage of total loans (which is a proxy of default in credit markets). From this it is clear that the period of financial instability of 1998–1999 was associated with huge losses to credit institutions and a poor repayment of credits.

These facts justify the use of the above *operational* definition for the analysis of financial stability in Colombia. So, the results of the simulations of the FHGEM, in terms of at least these two variables, might be used at the Financial Stability Department of the Central Bank of Colombia to evaluate financial stability.

[3] This definition does not solve the problem of *how* much is *very* much. Indeed, it is not possible to discern, from the simulation of the model, when profits are so low or default so high as to threaten financial stability. Nevertheless, the simulation of the model does allow us to discern if financial stability has improved or worsened. In other words, rather than in terms of states (stocks), this definition is useful for assessing changes in states (flows).

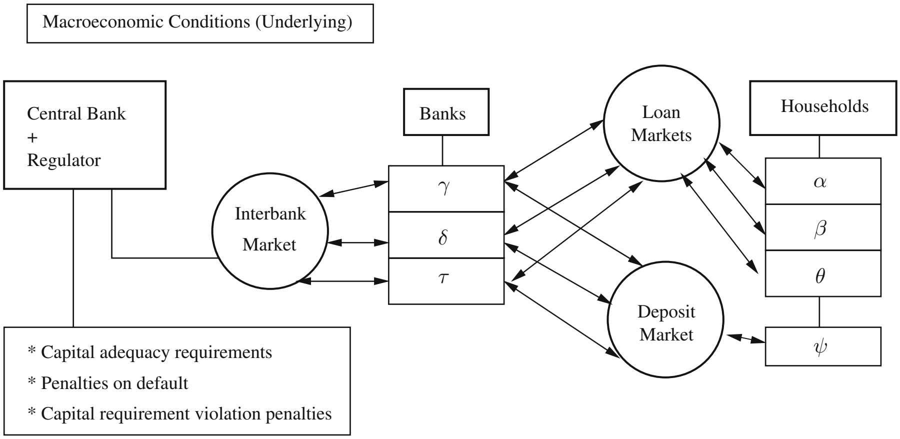

Fig. 3 Agents and interactions

3 The framework

This model, intended to serve as a tool for assessing financial stability at the Central Bank of Colombia, was designed following closely the work by Tsomocos (2003a,b) and Goodhart et al. (2006b). The model has three heterogeneous banks $b \in B = \{\gamma, \delta, \tau\}$, four private sector agents $h \in H = \{\alpha^{\gamma}, \beta^{\delta}, \theta^{\tau}, \phi\}$, a regulator and a Central Bank. All agents interact in financial markets. The time horizon is infinite $T = \{0, 1, \ldots, \infty\}$, and at each future date there are two possible states of nature $s \in S = \{i\ (\text{normal}), ii\ (\text{extreme})\}$. At time $t \in T$, the probability that state $s = i$ will happen at $t + 1$ is denoted by p. This probability is assumed to be known by all agents and constant over time. Each bank at $t \in T$ maximizes its expected profit taking into consideration the immediate future.[4] In other words, at the end of time t the bank maximizes its expected profits for time $t + 1$, and the expectation is taken over the two possible states of nature.

The agents interact in several financial markets, as shown in Fig. 3. As in Goodhart et al. (2006b), we assume limited participation in the credit market. At the beginning of each period the bank borrowers are assigned to borrow from a single bank, by information constraints or history. For each bank there exists a credit market in which the bank and its client interact: households α, β and θ borrow from banks γ, δ and τ, respectively. The agent ϕ represents the pool of depositors of this economy. Each bank in its respective deposit market interacts with the agent ϕ, who supplies funds to the banking system.

[4] In this model, the bank manager has the alternative of leaving the bank for a better contract elsewhere if he has attained a profitability above a certain benchmark. In other words, he has an opportunity cost for working in the bank and, under certain conditions (see Goodhart et al. 2006b), the manager will maximize the expected profits over a finite horizon.

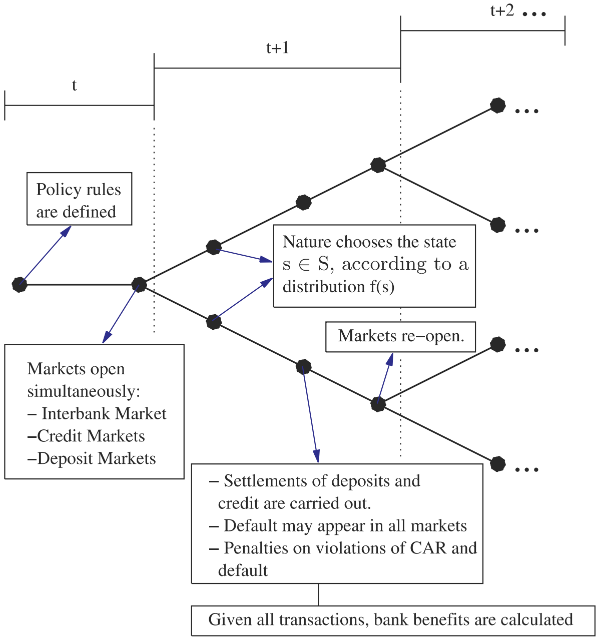

Fig. 4 Time structure

Additionally there exists an interbank market in which banks may borrow from each other. In this market the Central Bank conducts open market operations (OMOs).

The time structure of the model is as shown in Fig. 4.[5] By the end of period t, deposit markets, credit markets, and interbank market open simultaneously. Each bank decides rationally how much credit to offer and the amount of deposits it demands from the respective markets, forming expectations over the two possible future states of nature. Meanwhile, households decide their demands for loans and deposit offers, and the Central Bank conducts OMOs in the interbank market.

At the beginning of period $t + 1$, one of the possible states $s \in S$ occurs. According to which state s happens, the financial contracts signed at the previous period are settled and some level of default may happen. Banks are subject to default and capital requirements' violation penalties. Given this, bank profits are realized, after which all markets re-open.

[5] Figure 4 is taken from Goodhart et al. (2006b).

3.1 Banks' objective function

As already noted, the banking sector consists of three heterogeneous banks $b \in B = \{\gamma, \delta, \tau\}$, each one has a distinctive portfolio, capital endowment, and risk preferences.

In each period $t \in \{0, \ldots, \infty\}$, the bank $b \in B$ maximizes its expected payoff subject to balance sheet constraints. The objective function is a quadratic function of profitability in the immediate future $(t+1)$, minus penalties it will incurre if it defaults on its liabilities (deposits and interbank loans), and minus a penalty proportional to capital adequacy violations.

Each bank forms its expectations rationally, considering two possible states of nature $s \in S = \{i - normal, ii - extreme\}$. Bank b decides how much credit to offer at time t $(\overline{m}_t^b)$, the amount of deposits it seeks $(\mu_{d,t}^b)$, its interbank lendings (d_t^b), and its interbank debt (μ_t^b). Bank $b \in B$ also decides endogenously the repayment rate for $t+1$ $(\nu_{t+1,s}^b, s \in S)$.

The optimization problem of bank $b \in B$ at time $t \in \{0, \ldots, \infty\}$ is formalized as follows:

$$\begin{aligned}\mathrm{Max}_{m_t^b, \mu_t^b, d_t^b, \mu_{d,t}^b, \nu_{t+1,s}^b s \in S} E_t[\Pi_{t+1}^b] = &\sum_{s \in S} p_s \left\{\pi_{t+1,s}^b - c_s^b (\pi_{t+1,s}^b)^2\right\} \\ &- \sum_{s \in S} p_s \Bigg(\lambda_{ks}^b \max\left[0, \overline{k}_{t+1,s}^b - k_{t+1,s}^b\right] \\ &+ \lambda_s^b \left(1 - \nu_{t+1,s}^b\right) \left(\mu_t^b\right) + \lambda_s^b \left(1 - \nu_{t+1,s}^b\right) \left(\mu_{d,t}^b\right)\Bigg).\end{aligned} \tag{1}$$

Subject to balance sheet constraint:

$$\overline{m}_t^b + d_t^b + A_t^b = \frac{\mu_t^b}{1 + \rho_t} + \frac{\mu_{d,t}^b}{1 + r_{d,t}^b} + e_t^b + \mathrm{others}_t^b, \tag{2}$$

and subject to positive expected profitability:

$$\begin{aligned}&(1 + \rho_t)\nu_{t+1,s}^b \mu_d^b + (1 + r_{d,t}^b)\nu_{t+1,s}^b \mu_{d,s}^b + \mathrm{others}_t^b + e_t^b \\ &\leq \nu_{t+1,s}^{h^b}(1 + r_{d,t}^b)\overline{m_t^b} + (1 + r_t^A)A_t^b + \widetilde{R}_{t+1,s} d_t^b (1 + \rho_t), \quad s \in S,\end{aligned} \tag{3}$$

where

$$\begin{aligned}\pi_{t+1,s} = &\ \nu_{t+1,s}^{h^b}(1 + r_{d,t}^b)\overline{m_t^b} + (1 + r_t^A)A_t^b \\ &+ \widetilde{R}_{t+1,s} d_t^b (1 + \rho_t) - ((1 + \rho_t)\nu_{t+1,s}^b \mu_d^b \\ &+ (1 + r_{d,t}^b)\nu_{t+1,s}^b \mu_{d,s}^b + \mathrm{others}_t^b + e_t^b), \quad s \in S,\end{aligned} \tag{4}$$

$$e_{t+1,s} = e_t^b + \pi_{t+1,s}^b, \quad s \in S. \tag{5}$$

Capital adequacy ratio:

$$k^b_{t+1,s} = \frac{e^b_{t+1,s}}{\overline{\omega}v^{h^b}_{t+1,s}(1+r^b_t)\overline{m^b_t} + \widetilde{\omega}(1+r^A_t)A^b_t + \omega\widetilde{R}_{t+1,s}d^b_t(1+\rho_t)}, \quad s \in S \quad (6)$$

and

μ^b_t : bank b's debt in the interbank market in period t
d^b_t : bank b's interbank lendings
$\mu^b_{d,t}$: bank b's deposits
$v^b_{t+1,s}$: repayment rate of bank b in $t+1, s$
$\overline{m}^b_t$: amount of credit that bank b offers in the period t
A^b_t : Other assets of bank b
e^b_t : bank b's capital
r^b_t : lending rate offered by b
$r^b_{d,t}$: deposit rate offered by b
ρ_t : interbank rate in period t
$v^{h^b}_{t+1,s}$: repayment rate of h^b in $t+1, s$
$\widetilde{R}_{t+1,s}$: repayment rate expected by banks from their interbank lending in t+1
$k^b_{t+1,s}$: Capital adequacy ratio
$\overline{k}^b_{t+1,s}$: Capital adequacy requirement (CAR)
p_s : probability that state s $\in$ S occurs in $t+1$
c^b_s : risk aversion coefficient in the utility function
λ^b_s : default penalties for bank b at state s
$\lambda^b_{k,s}$: capital adequacy violation penalty for bank b at state s

3.2 Private agents: households

As already noted, in each period t household $h^b \in \{\alpha^\gamma, \beta^\delta, \theta^\tau\}$ seeks loans from bank b. Additionally, h^b decides the repayment rate (1 − *default*) on his obligations for each of the possible states of nature that may occur. The agent ϕ, on the other hand, decides the amount of deposits it supplies to each bank $b \in B$.

As in Goodhart et al. (2006b), we do not model explicitly the private agents' objective functions, mainly because it is not possible to obtain disaggregated data. Instead, the following reduced-form equations are assumed.

3.2.1 Demand for loans

In period t, h^b's demand for loans is a negative function of the lending rate offered by bank b, and depends positively on the expected GDP of the following period. In other words, the household anticipates rationally the level of GDP, which determines its expected level of future income. Using that information, he chooses his demand for loans to smooth his consumption.

$$\begin{aligned}\ln(\mu_t^{h^b}) = a_{h^b,1} + a_{h^b,2}\text{trend} + a_{h^b,3}\ln[p(\text{GDP}_{t+1,i}) \\ + (1-p)(\text{GDP}_{t+1,ii})] + a_{h^b,4}r_t^b,\end{aligned} \tag{7}$$

where $\mu_t^{h^b}$ is the amount of credit household h^b demands from bank b at time t.

3.2.2 Households' repayment rates

Household $h^b \in \{\alpha^\gamma, \beta^\delta, \theta^\tau\}$ decides at time t the repayment rate (1-default) on his loan obligation in $t+1$ for each state of nature. As in Goodhart et al. (2006b), the repayment rate is assumed to be a positive function of GDP at $t+1$. The repayment rate in $t+1$ is also a function of the aggregate credit supply at time t. In the case of the Colombian financial system, this relationship is expected to be negative. An increase in the aggregate credit supply at time t is associated with an increase in non-performing loans, due to the loose and inefficient credit monitoring and evaluation policies of banks following a credit boom.[6]

$$\ln(\nu_{t+1,s}^{h^b}) = g_{h^b,s,1} + g_{h^b,s,2}\ln(\text{GDP}_{t+1,s}) + g_{h^b,s,3}\ln(\overline{m}_t^\gamma + \overline{m}_t^\delta + \overline{m}_t^\tau), \tag{8}$$

where $\nu_{t+1,s}^{h^b}$ is the repayment rate of household h^b at $t+1$ to the bank b if state s occurs.

3.2.3 Supply of deposits

Household ϕ diversifies his deposit portfolio. The supply of deposits to bank b at time t depends positively on the deposit rate offered by this bank, and negatively on the rate offered by the remaining banks (b'). Moreover, since in this model banks may default endogenously, the agent ϕ takes this into consideration. Additionally, household ϕ's supply of deposits is a positive function of

[6] In Goodhart et al. (2006b) such relation is positive, because of the possibility of a *Credit Crunch*. In this case, a lower supply of credit is reinforced by rising defaults.

the expected GDP for $t+1$.

$$\begin{aligned}\ln(d^{\phi}_{b,t}) = {} & z_{b,1} + z_{b,2}\ln[p(\mathrm{GDP}_{t+1,i}) + (1-p)(\mathrm{GDP}_{t+1,ii})] \\ & + z_{b,3}(r^{b}_{d,t}[pv^{b}_{t+1,i} + (1-p)pv^{b}_{t+1,ii}]) \\ & + z_{b,4}\sum_{b'\neq b}(r^{b'}_{d,t}[pv^{b'}_{t+1,i} + (1-p)pv^{b'}_{t+1,ii}])\end{aligned} \tag{9}$$

where $d^{\phi}_{b,t}$ is the amount of deposits household ϕ offers to bank b at time t.

3.3 The Central Bank and the regulator

At the beginning in time t, the Regulator sets the capital adequacy requirements for each bank ($\overline{k}^{b}_{t+1,s}, b \in B, s \in S$), defines the penalties for failing to meet such requirements ($\lambda^{b}_{k,s}, b \in B, s \in S$), and regulates the penalties banks will incur if they default ($\lambda^{b}_{s}, b \in B, s \in S$). It also sets the risk weight on trading book, loans and interbank loans ($\overline{\omega}\,\widetilde{\omega}\,\omega$); these are used to calculate the capital adequacy ratio.

The Central Bank participates in the interbank market conducting open market operations (OMOs), and so also determining the level of the policy rate (ρ_t).

3.4 Future GDP

The GDP for each possible state at $t+1$ is assumed to be a positive function of the aggregate credit supply of this economy at time t:

$$\ln(\mathrm{GDP}_{t+1,s}) = u_{s,1} + u_{s,2}\mathrm{trend} + u_{s,3}\ln(\overline{m}^{\gamma}_{t} + \overline{m}^{\delta}_{t} + \overline{m}^{\tau}_{t}), \quad s \in S \tag{10}$$

3.5 Market clearing condition

This model has three credit markets, three deposit markets, and an interbank market. For each one there is a market clearing condition which determines the corresponding interest rate: [7]

– Bank b's credit market clears

$$1 + r^{b}_{t} = \frac{\mu^{h^{b}}_{t}}{\overline{m}^{b}_{t}}. \tag{11}$$

[7] $r^{b}_{t}, r^{b}_{d,t}$, and ρ_t are ex-ante nominal interest rates.

– Bank b's deposit market clears

$$1 + r^b_{d,t} = \frac{\mu^b_{d,t}}{d^{\phi}_{b,t}}. \tag{12}$$

– Interbank market clears

$$1 + \rho_t = \frac{\overline{B}_t + \sum_{b \in B} \mu^b_t}{M_t + \sum_{b \in B} d^b_t}, \tag{13}$$

where $\overline{B}_t$ = government bonds, and M_t = money issued by the Central Bank.

3.6 Equilibrium

See Goodhart et al. (2006b) for more details. The monetary equilibrium with commercial banks and default (MECBD) at time t has a set of endogenous variables such that:

– All banks maximize their expected future payoff: $E_t[\Pi^b[\pi^b_{t+1,s}]]$.
– All markets clear.
– Banks form correctly their expectations about the repayment rate they receive from their interbank lending:

$$\widetilde{R}_s = \frac{\sum_{b \in B} \nu^b_{t+1,s} \mu^b_t}{\sum_{b \in B} \mu^b_t}, \quad s \in S. \tag{14}$$

– The reduced form equations for GDP, deposit supply, credit demands, and household repayment rates are satisfied.

4 Calibration

This section assess whether the model of the previous section can be used to represent, and adequately catch, the structure and operation of the Colombian financial system.

To reduce the spectrum of Colombian banks to three heterogeneous institutions (banks γ, δ and τ in the model), the Colombian financial system was divided into three groups: mortgage banks (BECH), domestic banks (DB) and foreign banks (FB). Each bank in the model was associated, rather than with a particular institution, with a particular group.[8] BECH were aggregated into

[8] In November 2005, mortgage banks accounted for 17.6% of total financial system assets, while foreign and domestic banks accounted for 70.3%. Leasing institutions, small financial corporations and cooperatives accounted for the remaining 12% of assets.

bank γ, while DB and FB were aggregated into banks δ and τ respectively. Household borrowers $\{\alpha, \beta, \theta\}$ are, therefore, the borrowers of BECH, DB and FB respectively at any point of time. This will be important when computing the relevant parameters of the private sector's reduced forms. Finally, the private agent ϕ corresponds to the aggregate pool of depositors of BECH, DB and FB.

To obtain a numerical solution for the system of equations extracted from the model (see Appendix 1), it is necessary to calculate the values of the relevant parameters or exogenous variables of the model. Insofar as the simulations use realistic values of these variables and parameters, their output should be more reliable.

Four strategies were used to obtain those values. The selection of a particular strategy in computing a particular parameter depended on the amount of available information and on the need to improve the empirical fit of the model. The four strategies were as follows:

– *Endogenization of the particular parameter in the first period of the simulation* Following Goodhart et al. (2006b), the endogenous variables of the model are not necessarily the endogenous variables of the system of equations. It is possible to make use of this fact to impose exogenously (from real data) the value of some endogenous variables of the model in the initial period of the simulation (t_0), such as loans and interbank debt. In terms of the system of equations, this releases some *degrees of freedom* that are used to calculate endogenously the values of some parameters in order to improve the empirical fit of the model. From the second period of the simulation, the estimated parameters are used as exogenous values, while the exogenous variables of the first period are again endogenous. This strategy was used for estimating the intercepts of some private sector reduced forms and risk aversion coefficients.
– *Policy variables* Observed and imposed directly from real data. This is the case of the policy rate, the regulatory capital adequacy ratio, and the risk weights.
– *Econometric calibration* The parameters of the private-sector reduced forms (with the exception of intercepts) were calculated by means of econometric techniques.
– *Arbitrary imposition* This is the case of those variables for which there is no available and/or reliable information, such as the penalties on the violation of CAR and default, the probability of the occurrence of any state of nature and the return on the portfolio of Other Assets.

In order to save space, the results under the first and the second strategies (that are different for each of the simulations conducted in the following section) will not be reported.[9] So, only the results under the third and the fourth strategies will be presented here. These results are summarized in Table 1.[10]

[9] These results are available via e-mail from the authors if requested.

[10] For a full description of the techniques and results of the econometric estimations, see Appendix 2.

Table 1 I: Calibrated using econometric strategies. II: Arbitrarily selected

I	$a_{h^b,3}$	4.8932	$z_{b,3}$	0.1432
	$a_{h^b,4}$	−0.7236	$z_{b,4}$	−1.2437
	$g_{h^b,s,2}$	0.1446	$u_{s,2}$	0
	$g_{h^b,s,3}$	−0.1085	$u_{s,3}$	0.159
	$z_{b,2}$	1.8324		
II	$\lambda^b_{k,s}$	0.1	p	0.95
	$\lambda^b_{s=i}$	0.9	r_A	0.13
	$\lambda^b_{s=ii}$	1.1		

Following the strategy by Chrystal and Mizen (2005), the income elasticity as well as the interest rate elasticity of loan demand is common to all the three household borrowers($\{\alpha, \beta, \theta\}$). The former was found to be equal to 4.89, and the latter, to −0.72.

The elasticity of the repayment rate with respect to the GDP and to the amount of credit of the previous period is also common to the three households. The former was found to be equal to 0.14, and the latter to −0.10.

The elasticities of the supply of deposits of agent ϕ with respect to the GDP, the own interest rate and the interest rate of the other banks were found to be equal to 1.83, 0.14 and −1.24, respectively.

Finally, the computation of the reduced form of the GDP yielded an elasticity to the amount of credit equal to 0.15. The trend component was found to be statistically insignificant, and was therefore set equal to zero.

The penalties on the violation of the capital adequacy ratio and on default in the good and the bad state of nature were set arbitrarily equal to 0.1, 0.9 and 1.1, respectively. Finally, the probability of the good state of nature was set equal to 0.95, while the return on other assets to 0.13.

Using these values for the respective parameters, together with the values obtained under the two other strategies, the model of the previous section was simulated under several scenarios. The results of those simulations are now presented in the following two sections.

5 Performance of the model

This section presents the results of the simulations of this model. The simulations were conducted under two initial conditions. The first subsection shows the set of the results of a simulation whose initial period mimics the structure of the Colombian financial system in the first quarter of 1997.[11] The second set of results corresponds to a simulation that uses the last quarter of 1999 as initial period.

[11] As mentioned in the previous section, some endogenous variables are imposed exogenously in the first period of the simulation. In this sense, the simulated values of the first period for some endogenous variables of the model is exactly the same as (*mimics*) the actual values.

The reason for using these periods as starting conditions is to explore the performance of the model in replicating the behavior of the financial system during a crisis and during a recovery. The Colombian economy experienced during these two initial periods the onset of a recession (in the case of 1997-I) and an economic recovery (1999-IV).

For each of the initial conditions, the reported results of the simulations are classified into five groups: loans, deposits, households' repayment rates, interbank repayment rates and GDP. For comparison, all the graphs shown below give not only the results of the simulations but also the observed behavior of the particular series.[12]

5.1 The recession period: 1997-I to 1999-II

The results of the simulations, using the first quarter of 1997 as the initial period, are presented in Figs. 5 and 6. From panel I of Fig. 5, it is clear that the model exhibits a remarkable empirical fit on a 2-year horizon. This is particularly the case for BECH, insofar as the model predicts the downturn in mortgage loans observed during the recession. For DB the model slightly overestimates the behavior of loans. The model also replicates the relative size of the loan portfolio of the different groups of banks.

The simulation of deposits (panel II) shows an even better empirical fit. The model exhibits a slight underestimation, a weaker phenomenon for the case of BECH and FB. The behavior of simulated deposits shows that, in the context of the model, the path of deposits does not completely determine the evolution of loans. Financing via capital is also relevant for the operations of a bank.

In the case of the households' repayment rates, presented in panel I of Fig. 6, the simulation of DB exhibits the best empirical fit. In the case of BECH and DB, the model replicates the fall of the repayment rate during the financial crisis of the late nineties. Moreover, the model is able to mimic one of the clearest stylized facts of the Colombian financial system: FB cherry-pick the loan market insofar as its debtors exhibit the highest repayment rate.[13]

As far as the overestimation of loans produced by the model is concerned, there are two points to consider. The first point is that the calibration strategy employed for calculating the parameters of the reduced form of households' demand for loans is not optimal, particularly in face of the different behavioral patterns exhibited historically by these three groups of banks.[14] The second point is made clear in panel III of Fig. 6: the simulated GDP permanently grows faster than the actual observed data. This is clearly a source of overestimation for the whole model.

[12] The source of the observed series is the National Financial Superintendent's Office, with the exception of GDP, taken from the NIPA of the National Administrative Department of Statistics (DANE).

[13] See Crystal et al. (2001).

[14] For analysis of the comparative behavior of FB and DB in Colombia, see Osorio and Avella (2005).

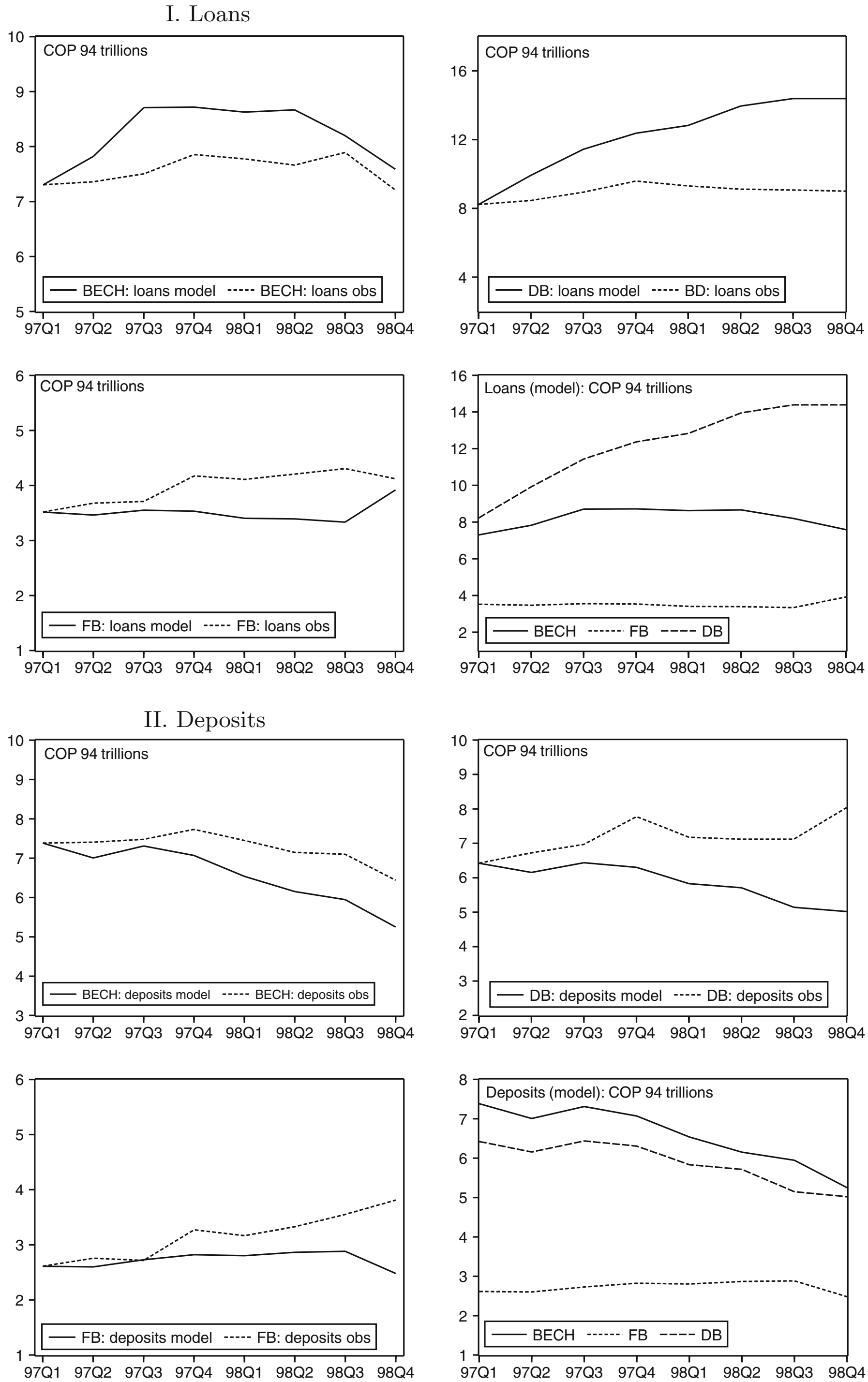

Fig. 5 $t_0 = 1997\,\mathrm{q}1$

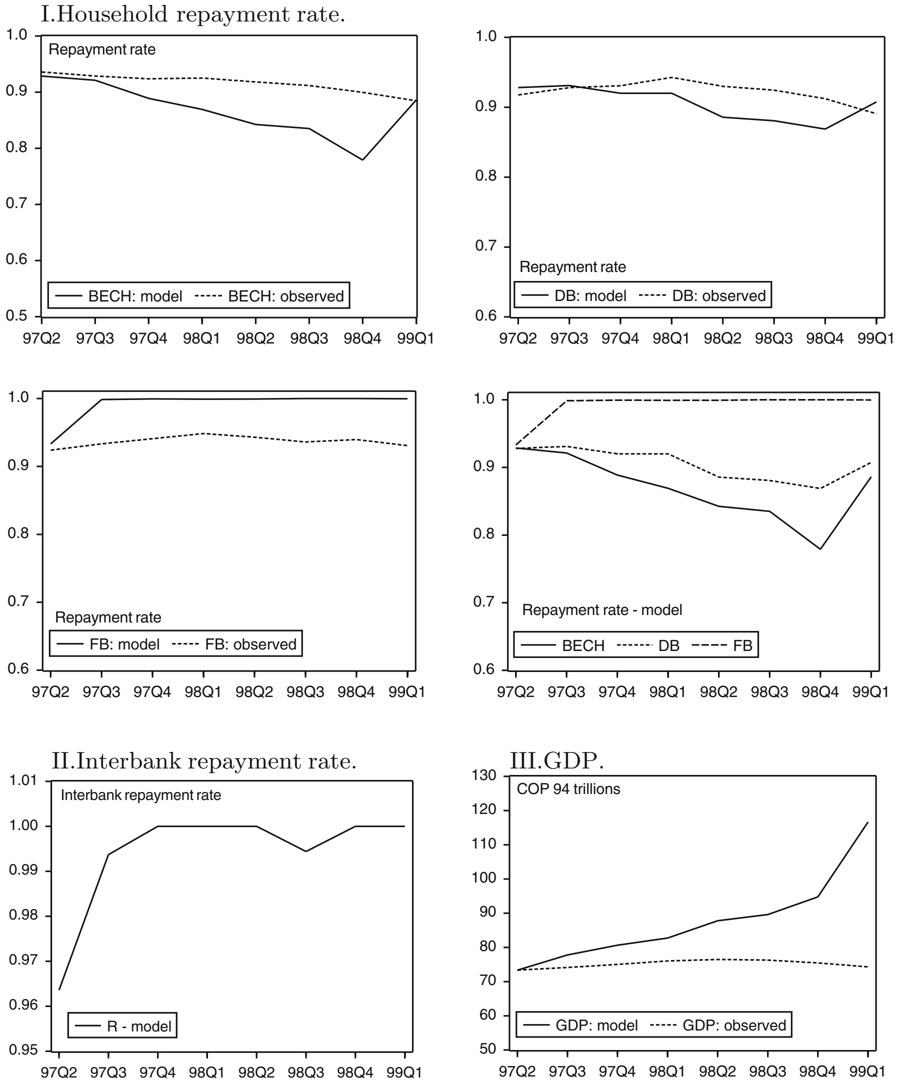

Fig. 6 $t_0 = 1997\,\mathrm{q}1$

5.2 The recovery period: 1999-IV–2002-IV

Figures 7 and 8 present the result of the simulation when the initial period is identified with the end of the Colombian financial crisis and the onset of the economic recovery (which continues today).

From the panel I of Fig. 7, it is clear that overestimation remains as an important issue. In this case, FB exhibit the best empirical fit, while the recovery of loans in the model for DB is faster than actually occurred. Turning to deposits,

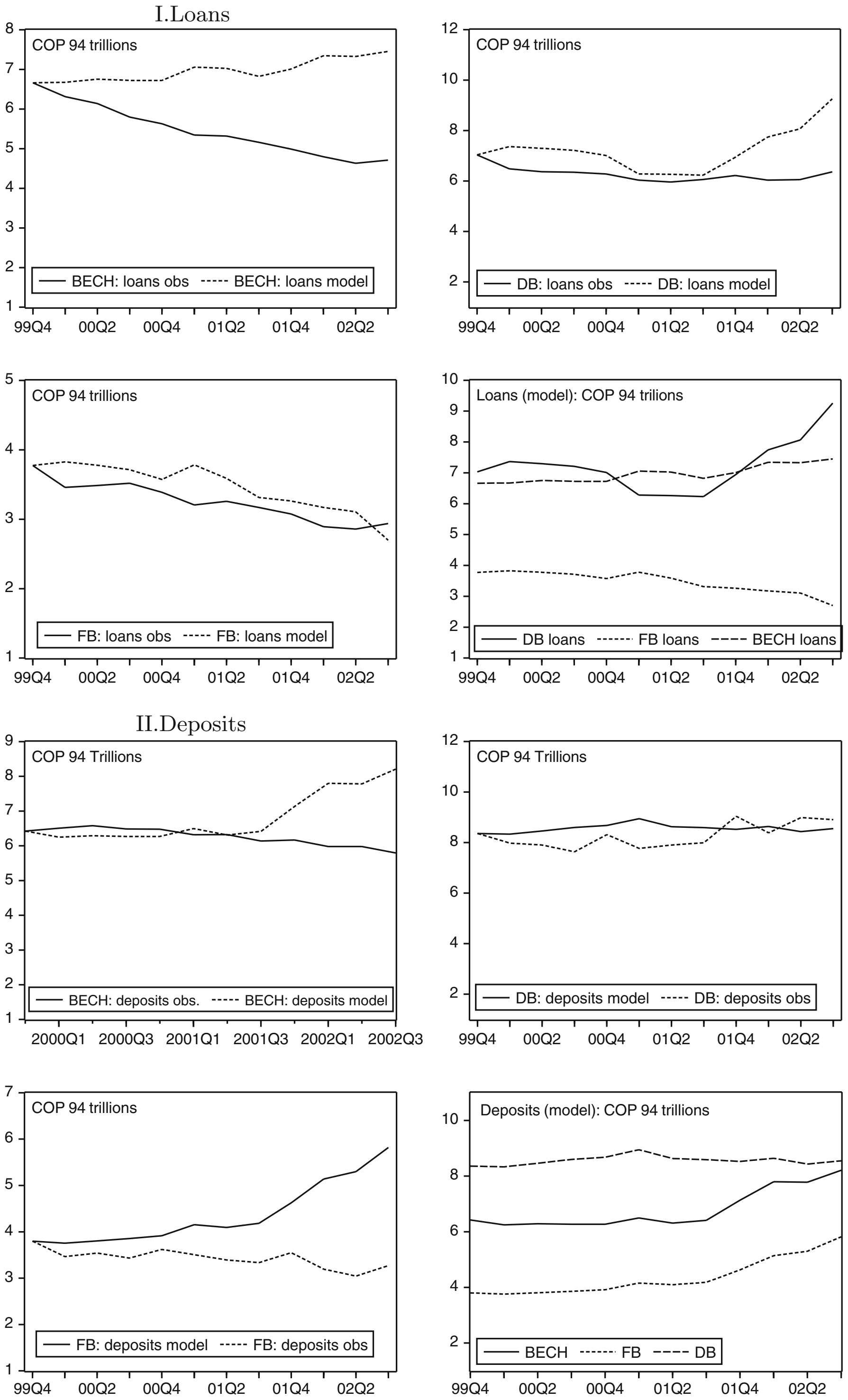

Fig. 7 $t_0 = 1999\,\mathrm{q}4$

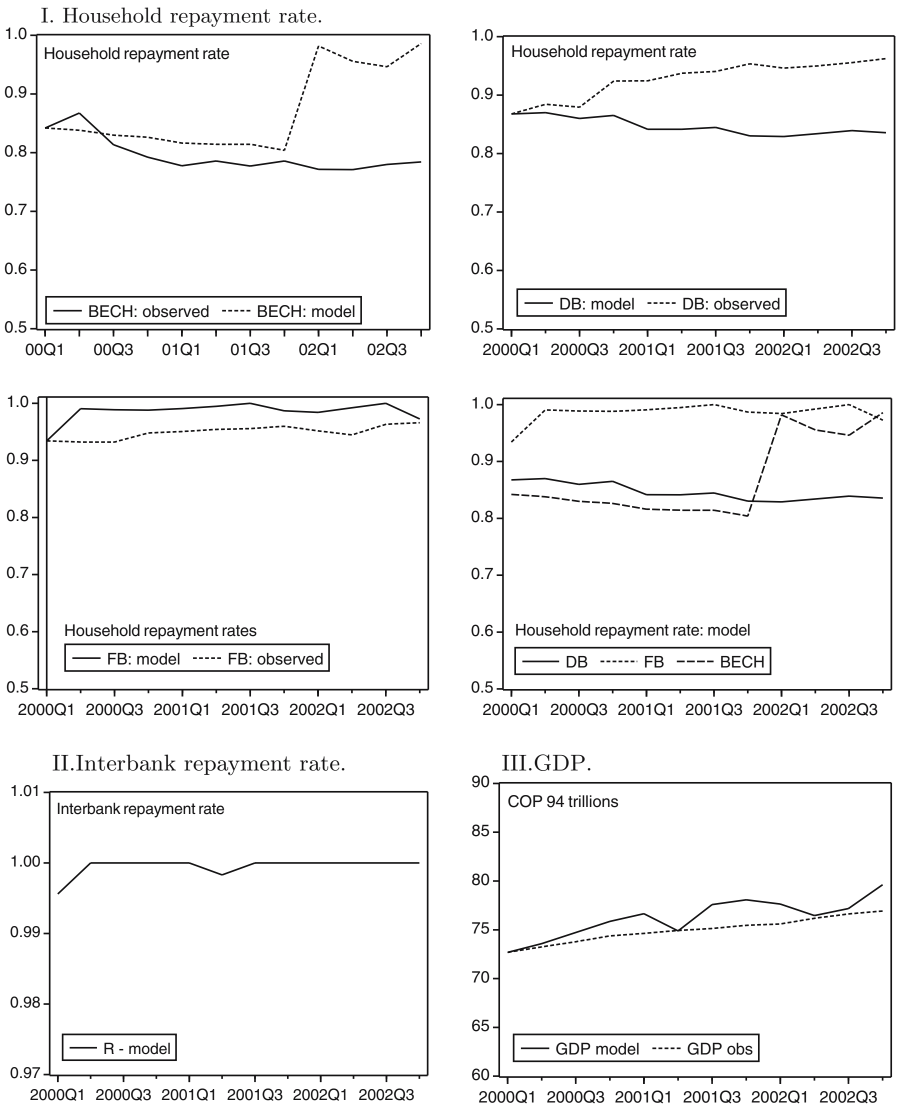

Fig. 8 $t_0 = 1999\,q4$

overestimation is not so important neither for DB nor for the first year of simulations of BECH and DB.

In panel I of Fig. 8 the model still picks up FB's cherry-picking.[15] Overestimation of GDP continues here, but not as markedly as previously.

[15] The almost discrete jump in the repayment of BECH appears to be a problem of the optimization algorithm rather than a behavioural fact of BECH.

6 An exogenous path for GDP?

As already noted, an important source of overestimation for the whole model is the overprediction of the simulations in terms of the growth of GDP. To tackle that problem, this section omits from the model the reduced form of GDP. Instead, GDP is treated as an exogenous rather than an endogenous variable, and its exogenous path is obtained from actual data. In other words, the observed evolution of GDP is plugged into the model in order to get rid of a source of perturbation.

This experiment was conducted using exactly the same initial periods as in the previous section.

6.1 The recession period: 1997-I–1999-II

Panel I of Fig. 9 shows that overestimation of DB loans ends when GDP is treated as exogenous. Instead, there is now a slight underestimation.[16] But, in the case of BECH, sizeable overestimation remains. Overall, the empirical fit seems better under this specification of the model.

This is particularly true for deposits. In panel II it appears that, despite a certain degree of underestimation, the real trends are captured almost perfectly by the model: a decrease in the deposits of BECH and a stabilization (with a small increase at the end of the simulation horizon) of the deposits of FB and DB. A good empirical fit is also obtained for the households' repayment rate, presented in panel I of Fig. 10. The decrease in repayment rates is well captured, as well as the cherry-picking by FB.

6.2 The recovery period: 1999-IV–2002-IV

In the post-recession period, overestimation appears again, especially in the final year. In the case of DB, however, this recedes over time, and the main trends are well captured (see panel I of Fig. 11).

The output of the simulation of deposits (panel II) exhibits a slight underestimation, but the empirical fit is good for the whole horizon. This is also the case of the repayment rate of households (Fig. 12). The mimicking of the cherry-picking behavior is maintained in this simulations.

7 Concluding comments

During the last year, the Financial Stability Department of the Central Bank of Colombia has been working on a research agenda related to the implemen-

[16] This calls for an evaluation of the accuracy of the econometric calibration procedures employed. As the parameters of the demand for loans are common among the three households, the calibration does not capture the different features, behavior and objectives of BECH in comparison with DB and FB. This might explain why the BECH data are persistently missed by the simulations.

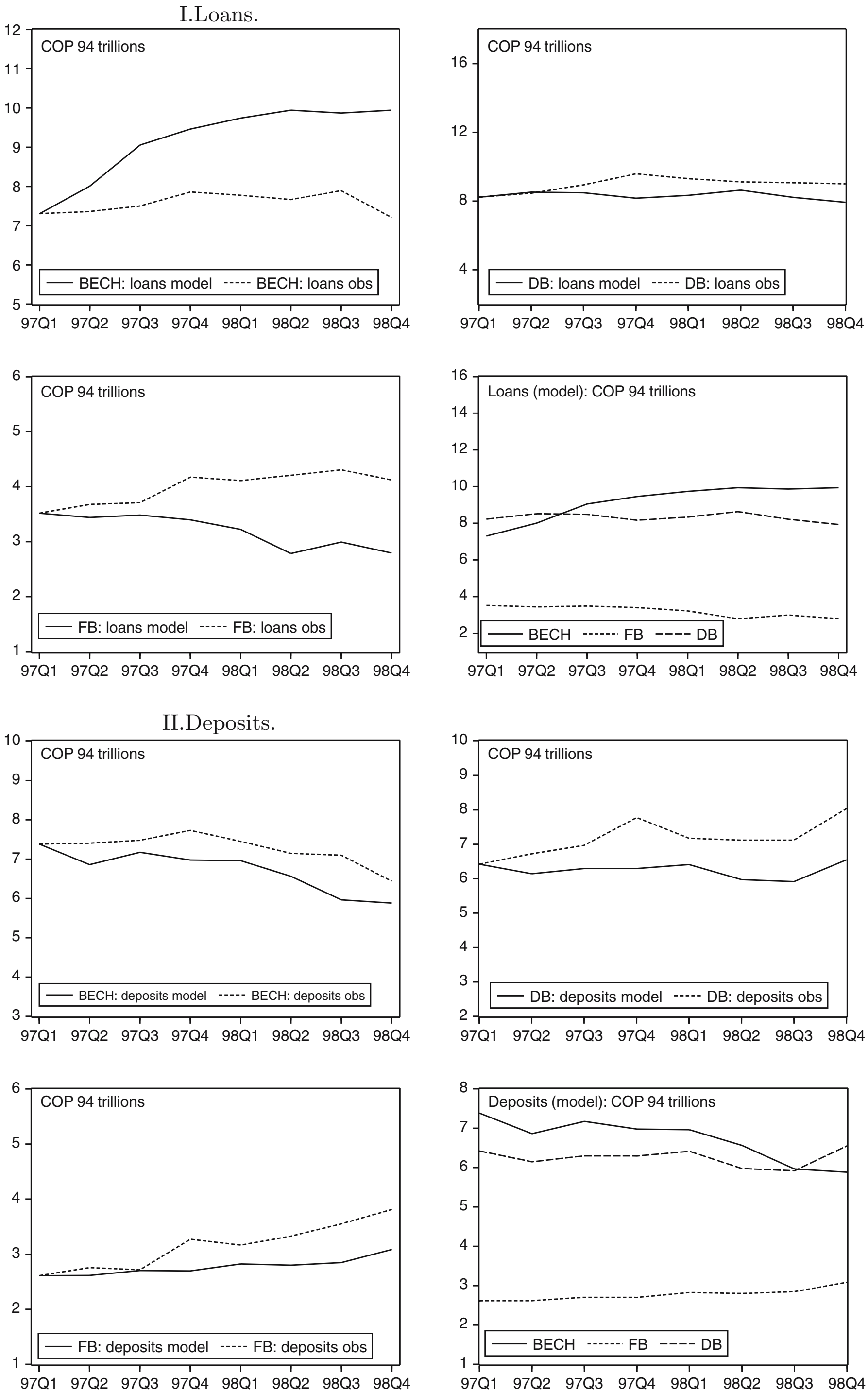

Fig. 9 $t_0 = 1997\,\mathrm{q}1$. GDP exogenous

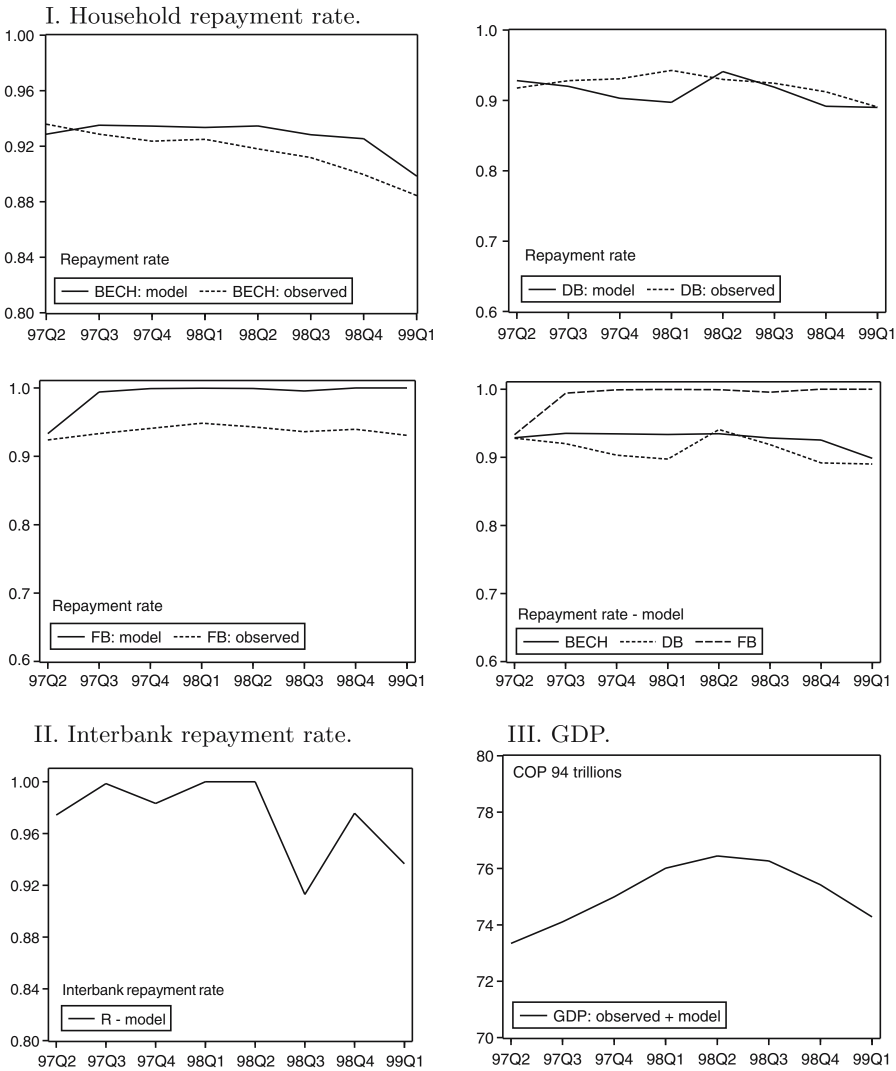

Fig. 10 $t_0 = 1997\,\mathrm{q}1$. GDP exogenous

tation of an FHGEM in the spirit of Goodhart et al. (2006b) to the Colombian financial system, to enhance the available tools for the analysis of financial stability. This paper presents the preliminary results of this work.

The main results of the implementation and simulation of the model are encouraging, insofar as they suggest that the model can serve satisfactorily as a tool for financial stability analysis. The empirical fit of the model is remarkable (especially in the short-run), as well as its capacity to mimic some of the most important stylized facts of the Colombian financial system at different stages of the business cycle.

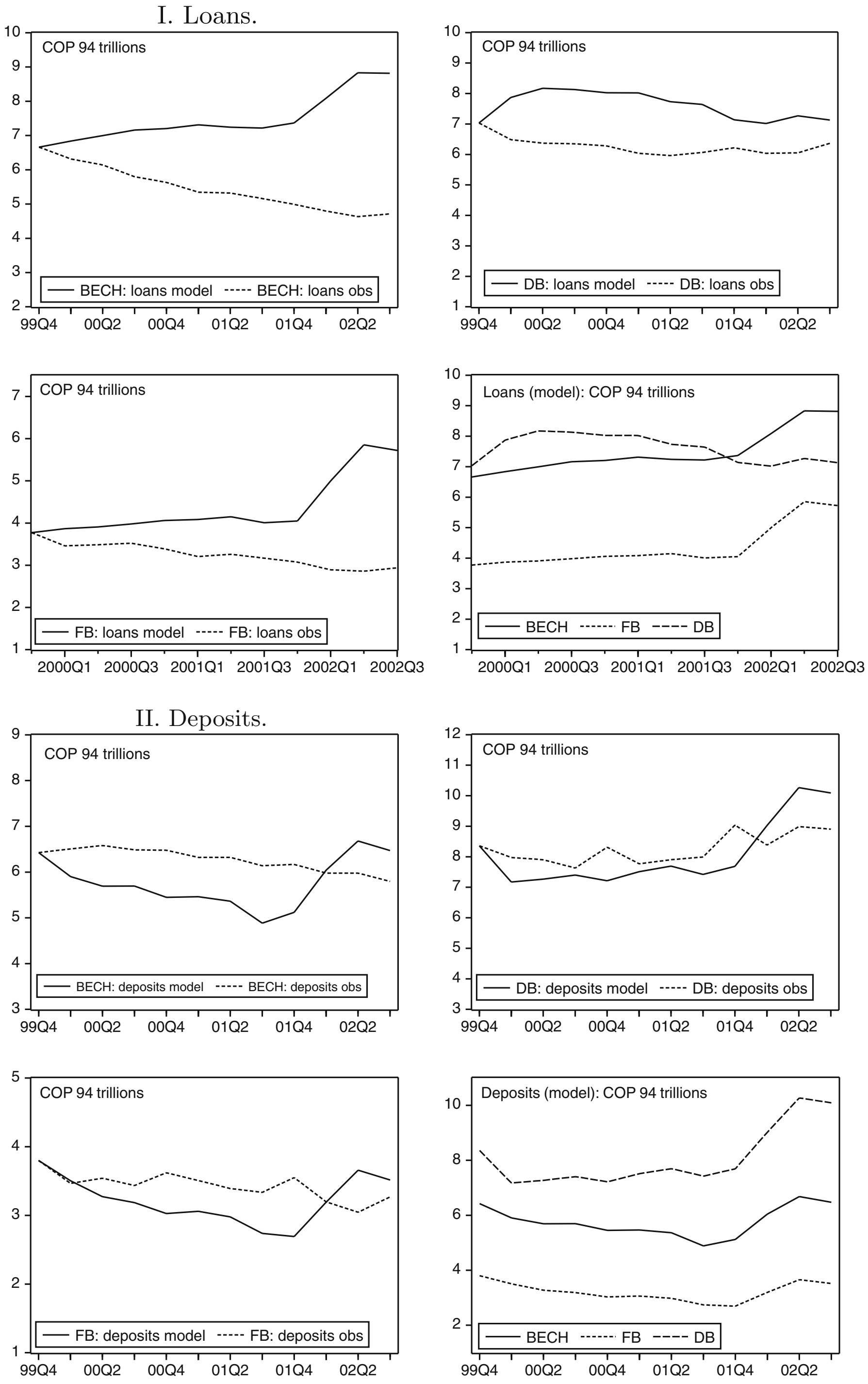

Fig. 11 $t_0 = 1999\,\mathrm{q}4$. GDP exogenous

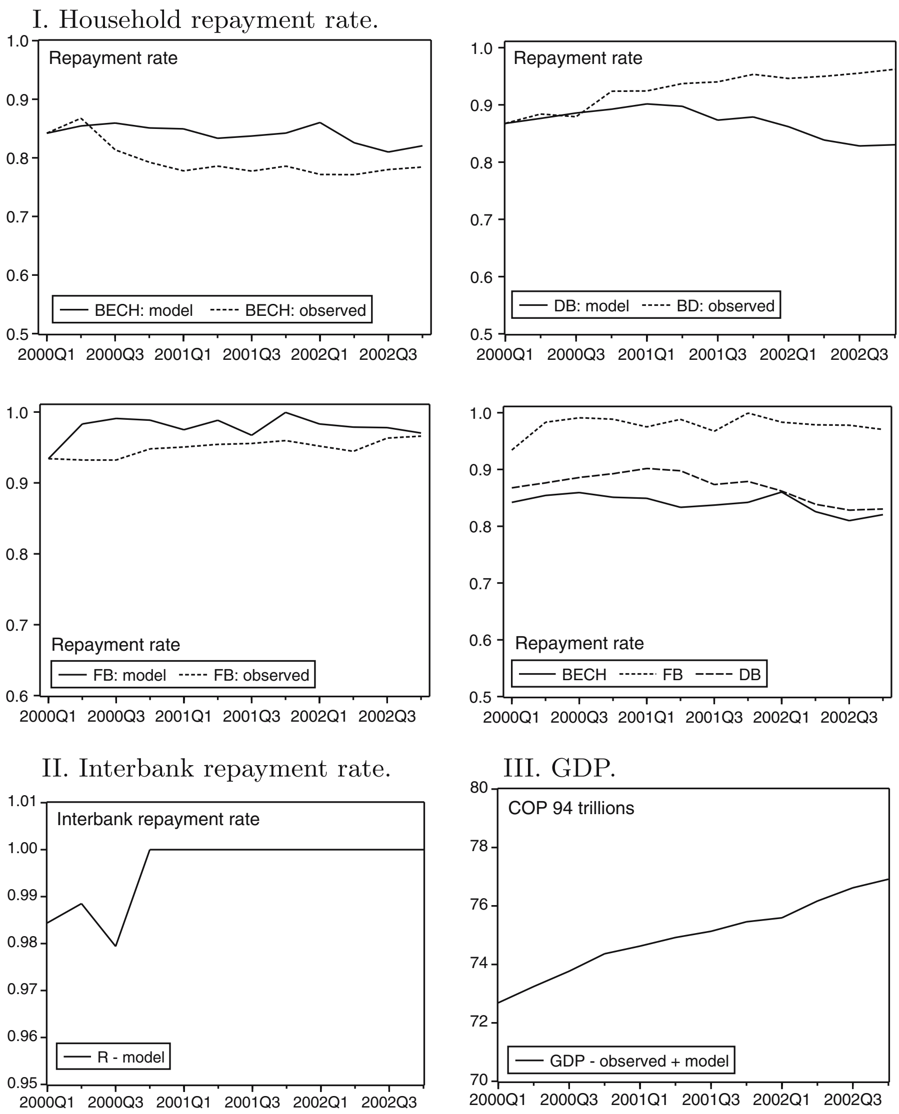

Fig. 12 $t_0 = 1999\,\text{q}4$. GDP exogenous

Nevertheless the model cannot solve all the puzzles that arise in the analysis of financial stability. The model was not designed to reach some important goals (e.g. the model was not designed for GDP forecasting). The comparative advantage of this model is its special focus on the behavior (and the interaction with the rest of the economy) of the most important units of the financial system, i.e. the financial institutions.

Two complementary tasks are open for this research agenda in the future. First, the model should be used to assess the effect that policy variables (such as CAR, policy rate or penalties) have on financial stability. This is a very important *acid test* for the use of the model as a tool for financial stability analysis, and it is likely to be its most important function in the future. The results of such *sensitivity* exercises may also serve to feedback into the features of the model. This interactive process between simulations and evaluations is important for the development of the agenda.

Second, the empirical fit of the model needs to be improved. This might be done using two complementary approaches. The first approach is the improvement (and eventually, rethinking) of the econometric calibration strategies. Despite the suppression of one of the sources of overestimation in the model (endogenous GDP), the problem remained in some cases. This leads us to think that the evaluation of calibration techniques goes next. The second approach is the incorporation of some particular (idiosyncratic) features of the Colombian financial system into the model. Among them, the incorporation of an international environment as a potential source of shocks to the financial system is important, insofar as there is wide agreement that the Colombian economy is a small open economy, and its financial system is much influenced by that.

Acknowledgements The opinions contained herein are those of the authors and do not necessarily represent those of the Banco de la República or of its Board of Directors. Useful comments by participants at the *Workshop on Assessing Financial Vulnerabilities* of the International Monetary Fund and the Banco de la República de Colombia are gratefully acknowledged. The authors also thank the participants of the *LSE-FMG Conference on Financial Stability: Theory and Applications*, held in May 2006.

Appendix 1: Implementation of the model

This model describes the following system of equations to solve:

Optimization conditions for banks: For bank b, with

$$\begin{aligned} x^b &= \left(m_t^b, \mu_t^b, d_t^b, \mu_{d,t}^b, \nu_{t+1,s=i}^b, \nu_{t+1,s=ii}^b\right) \\ \mathrm{Min}_{x^b} \quad & f^b(x^b) = -\mathrm{E}_t[\Pi_{t+1}^b] \end{aligned} \tag{15}$$

such that:

$$\begin{aligned} g_1^b(x^b) &= \overline{m}_t^b + d_t^b + A_t^b - \left(\frac{\mu_t^b}{1+\rho_t} + \frac{\mu_{d,t}^b}{1+r_{d,t}^b} + e_t^b + \text{others}_t^b\right) = 0 \\ g_2^b(x^b) &= (1+\rho_t)\,\nu_{t+1,i}^b\mu_t^b + \left(1+r_{d,t}^b\right)\nu_{t+1,i}^b + \text{others}_t^b + e_t^b \\ &\quad -\left(\nu_{t+1,i}^{h^b}\left(1+r_t^b\right)\overline{m}_t^b + \left(1+r_t^A\right)A_t^b + \widetilde{R}_{t+1,i}d_t^b\,(1+\rho_t)\right) \le 0 \\ g_3^b(x^b) &= (1+\rho_t)\,\nu_{t+1,ii}^b\mu_t^b + \left(1+r_{d,t}^b\right)\nu_{t+1,ii}^b + \text{others}_t^b + e_t^b \\ &\quad -\left(\nu_{t+1,ii}^{h^b}\left(1+r_t^b\right)\overline{m}_t^b + \left(1+r_t^A\right)A_t^b + \widetilde{R}_{t+1,ii}d_t^b\,(1+\rho_t)\right) \le 0 \end{aligned}$$

– 6 equations per bank = 18 equations

$$\nabla f^b(x^b) + \lambda_1^b \nabla g_1^b(x^b) + \lambda_2^b \nabla g_2^b(x^b) + \lambda_3^b \nabla g_3^b(x^b) = 0$$

– 2 equations per bank = 6 equations

$$\lambda_2^b \times g_2^b(x^b) = 0, \quad \lambda_3^b \times g_3^b(x^b) = 0$$

– Additionally 1 restriction must be satisfied strictly for each bank = 3 equations

$$g_1^b(x^b) = 0$$

– $\lambda_2^b \geq 0, \qquad \lambda_3^b \geq 0$

Reduced form equations: Credit demands (three equations), supply of deposits (three equations), household repayment rates (three households × 2 states = 6 equations), and future GDP (two equations).

Market clearing conditions: There are seven active markets in this model: three credit markets, three deposit markets, and the interbank market. Each one has an equation describing the market clearing conditions.

Expectations about the interbank repayment rate: Two equations.

Appendix 2: Results of calibration procedures

Demand for loans from households To obtain the values of the parameters of the reduced-form Eq. (7) for the households' demand for loans, this paper followed closely the work by Chrystal and Mizen (2005), whose results are used in the model by Goodhart et al. (2006b).

The goal of this exercise is to estimate, for the case of Colombia, long-run relationships (cointegration vectors) between the following variables: private consumption, broad money, unsecured lending, credit spread, deposit spread, real GDP, inflation and unemployment.[17]

To estimate cointegration vectors between these variables, it is necessary to perform standard unit-root tests in order to confirm the non-stationarity of the series.[18] To save space, Table 2 present the results of these tests for private con-

[17] Private consumption, real GDP, as well as the unemployment rate, were obtained from the National Accounts Data of the National Administrative Bureau of Statistics (DANE). Broad money was associated with M3 (the broadest monetary aggregate in Colombia) and was obtained from Banco de la República databases. CPI Inflation was obtained from the same source. Unsecured lending was defined as consumer credit (including those credits fall due) plus what is referred to as *other guarantees for consumer credit*. This definition corresponds approximately to unsecured lending for consumption purposes. Data were obtained from the National Financial Superintendent's Office. Deposit spread was calculated as an implicit deposit rate minus an implicit interbank rate. Credit spread was obtained as an implicit loan rate minus the reference rate of the Colombian financial system (DTF). Both spreads were also obtained from the National Financial Superintendent's Office. All variables are expressed in real terms, and in logs in the case of non-percentage variables. Finally, the variables have a quarterly frequency for the period 1996–1–2005–3.

[18] See Hendry and Juselius (2000).

Table 2 Augmented Dickey–Fuller unit root tests

Variable	Exogenous	Test stat.	Critical value (5%)
Unsecured lending	Cons, trend	0.529	−3.523
(log)	Constant	0.202	−2.935
	None	0.952	−1.949
Private consumption	Cons, trend	−0.929	−3.523
(log)	Constant	0.318	−2.935
	None	1.229	−1.949
Broad money	Cons, trend	−2.709	−3.533
(log)	Constant	−3.009	−2.941[a]
	None	0.409	−1.950

[a]Intermediate tests like case 2 used in Hamilton (1995) did not point to the rejection of the null hypothesis of unit root under this case

sumption, M3 and unsecured consumer lending, which are the central variables of the exercise.

Once the nonstationarity of the variables has been confirmed, it is possible to make use of the error-correction representation of a cointegrated system (See Hamilton 1995) to determine the number and magnitudes of the cointegration vectors, by means of the Johansen (1995) procedure. The results of the Johansen cointegration test are reported in Table 3. Before proceeding, it is worth noting some features of the test: first, two lags (for differenced series) were chosen to perform the test. This was suggested by Akaike and Hannan–Quinn Information Criteria in the context of a vector autoregression for the variables in levels. Second, no deterministic component was included inside the cointegration vector. Third, both Trace and Maximum-eigenvalue test statistics have been modified with the small-sample correction proposed by Reinsel and Ahn (1992). Finally, all seven variables were introduced as endogenous.[19] The results shown in Table 3 suggest either two cointegration vectors (Trace test-statistic) or 1 cointegration vector (Max-eigenvalue test-statistic) at a significance level of 5%. If the small-sample correction is not used, both test-statistics suggest the presence of at most five cointegration vectors.
To obtain numerically an economically interpretable cointegration vector, the next step is to impose justifiable (on economic grounds) restrictions on the estimation of the vector. A likelihood-ratio test allows us to discern if the data reject the imposed restrictions.[20] As the objective of this exercise is to obtain long-run elasticities for a reduced form of households' demand for loans, the imposed restrictions are used to obtain a cointegration vector whose structure replicates that of Eq. (7). In particular, the coefficient on unsecured consumer lending was restricted to be equal to 1, while those on money, consumption

[19] Reinsel and Ahn (1992) suggest multiply the test statistics for a factor $\frac{T-pk}{T}$ where T is the number of observations, p is the number of lags used in the cointegration test, and k is the number of variables. With 39 observations, 2 lags and 8 variables, the factor of correction is 0.589.

[20] See Hendry and Juselius (2000).

Table 3 Johansen cointegration tests

Nr. of CV	Trace Stat.	Critical value (5%)
None	187.3341005	156
At most 1	124.829715	124.24
At most 2	87.6315378	94.15
At most 3	56.3092835	68.52
At most 4	34.48013657	47.21
At most 5	16.57791154	29.68
At most 6	7.54321698	15.41
At most 7	1.213669251	3.76
Nr. of CV	Max-eigenv Stat.	Critical value (5%)
None	62.5043855	51.42
At most 1	37.19818898	45.28
At most 2	31.32223663	39.37
At most 3	21.82915282	33.46
At most 4	17.90221914	27.07
At most 5	9.03470045	20.97
At most 6	6.32954714	14.07
At most 7	1.213669251	3.76

and deposit spread were restricted to zero. The latter restriction means that the deposit spread is not long-run-related with loans.[21]
Under the imposed restrictions, the estimated cointegration relationship is as follows:

$$L_t = 4.893ln(GDP_{t+1}) - 0.723(CS_t) + 2.188(\pi_t) + 0.190(\Delta U_t), \qquad (16)$$

where L is unsecured lending, CS is the credit spread, π is inflation and U is unemployment.

The coefficients on ln(GDP) and on Credit Spread are then used, in the simulations, as the elasticities of the reduced-form (7) for every nature-selected agent.

Supply of Deposits by agent ϕ As mentioned in Sect. 3, agent ϕ comprises the pool of depositors of the three banks of the model. In terms of the simulations, therefore, agent ϕ aggregates the whole body of depositors of BECH, foreign and domestic banks. To determine the exogenous parameters of the reduced-form given by Eq. (9), an unbalanced panel data set with 41 banks (BECH, foreign and domestic banks) was constructed. This set includes three variables: real deposits(which will be the dependent variable in the estimations) , real GDP, and implicit deposit rates calculated for each group of banks.[22]

[21] Under a free number of cointegration vectors (up to seven, the number of variables), the LR test-statistic is 8.400166, which does not reject the null hypothesis of valid restrictions at a significance level of 1%.

[22] Real GDP was obtained from the National Accounts Data of the National Administrative Bureau of Statistics (DANE). Deposits include demand as well as saving deposits. Under this definition, no certificate of deposit is included. To obtain real deposits, deposits were deflated using the CPI index provided by Banco de la República. Implicit deposit rates were constructed by dividing the interest payments to demand and saving deposits and the stock of these deposits. This information was provided by the National Financial Superintendent's Office. Time series are quarterly for the span 1995:1–2005:3. Real GDP and Real deposits are transformed using logarithms.

From this data set, using static variable intercepts, panel data models were estimated, whose final structure was determined by Breusch-Pagan and Hausman test-statistics.[23] A general form of the estimated model is as follows:

$$\ln(D_{i,t}) = \alpha_i + \beta_1 \ln(y_{t+1}) + \beta_2(\mathrm{d}r_{i,t}) + \beta_3(\mathrm{d}r'_{i,t}) + u_{i,t}, \tag{17}$$

where D is real deposits, y is real GDP, dr is the bank implicit deposit rate, dr' is the implicit deposit rate of the other two groups of banks,[24] and i and t refer to the specific bank and time, respectively. Finally, $u_{i,t}$ is the error term. Before proceeding to the results of the estimation, comparison of Eqs. (17) and (9) suggest an important feature of the estimation. From Eq. (3.9) it is clear that the elasticity of the deposit supply by agent ϕ is calculated with respect to the expected value of GDP and bank repayment rates, which incorporates a probability distribution for both states of nature. In order to estimate an econometric model, it is possible to believe that GDP as well as repayment rates have undergone both states of nature, and therefore the observed time series (real GDP and implicit deposit rate) can be used to calculate retrospectively the sensitivities with respect to their expected values.

Table 4 shows the best estimated specification, which corresponds to a random-effects model.[25]

Table 4 Random-effects estimation of (17)

Method: GLS		
Number of observations		1,275
Number of individuals (banks)		41
Dependent variable: $\ln(D_{i,t})$		
	Coefficient	Std. error
β_1	1.83243	0.38181
β_2	0.1432	0.27544
β_3	−2.48742	0.48305
R^2	Between	0.1586
	Within	0.1162
	Overall	0.0479
Intercept variance		1.85497
Error variance		0.47139
Interc. variance as percentage of total variance		0.93933

23 See Hsiao (1986) for an explanation of how panel data models are estimated.

24 This means that, for example, if we are analyzing a foreign bank, dr' is a weighted average of the implicit rates of BECH and domestic banks.

25 The χ^2 distributed test-statistic of the Breusch–Pagan test (whose null hypothesis is zero variance of intercept) is 17101.28, with a p value of 0.00001. This suggests that a random-effects model beats an OLS model for this data set. On the other hand, the χ^2 distributed test-statistic of the Hausman test (null hypothesis of random-effects against the alternative of fixed-effects) is 0.001, with a p value of 1.

β_1 and β_2 in the preceding table correspond to the parameters quoted in Table 1 (the exogenous elasticities of agent ϕ's supply of deposits with respect to income and own interest rate). $z_{b,4}$ is set equal, however, to 0.5 times β_3. This is because $z_{b,4}$ enters in the reduced form (9) as the coefficient on the SUM of implicit interest rates, while β_3 enters in the panel estimation as the coefficient on an average implicit rate. If the average employed in the panel estimation approximates to an arithmetic unweighted average of its components, $z_{b,4}$ is approximately equal to 0.5 times β_3.

Household's repayment rate on loans The exogenous parameters of the reduced form (8) were estimated using a panel data set in much as the same way as the preceding subsection. In this case, as in that of the demand for loans, the parameters were set to be common for agents α, β, and θ.[26]
This panel data set involves bank-specific information about the percentage of non-performing loans, credit and real GDP (as independent variables).[27] As the dependent variable is repayment instead of default, the dependent variable is 1-% of non-performing loans.
The model estimated for the reduced form (8) is summarized in the following expression:

$$\ln(1 - \mathrm{NPL}_{i,t+1}) = \alpha_i + \beta_1 \ln(y_{t+1}) + \beta_2(\mathrm{loans}_{i,t}) + u_{i,t} \qquad (18)$$

where NPL corresponds to the ratio of nonperforming loans to total loans, *loans* corresponds to total loans, y is Real GDP, $u_{i,t}$ is the error term, and i and t refer to the specific bank and moment of time, respectively.

The results under the best specification, which corresponds to a random-effects model,[28] are presented in Table 5.

Gross domestic product The estimation of a cointegration relationship between real GDP and total loans allowed us to obtain the credit-elasticity of GDP [$u_{s,3}$ in the reduced form (10)], as well as the coefficient on its trend component ($u_{s,2}$ in the same expression). The latter was obtained by including a trend in the estimated cointegration vector.

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[26] This is justified on two grounds. First, this follows the calibration strategy of Goodhart et al. (2006b). Second, an independent estimation for each group of banks (to allow different sets of parameters for different agents) faces two problems: first, lack of reliable data; and second, even when made, preliminary estimations for some groups of banks produce incorrect signs, unexpected magnitudes and/or significance of the variables.

[27] Real GDP was obtained from the National Accounts Data of the National Administrative Bureau of Statistics (DANE). Information on the percentage of non-performing loans (i.e.: the ratio of non-performing loans to total loans) was obtained from the National Financial Superintendent's Office, and was deflated using the CPI index from the Banco de la República. Information is quarterly for the period 1995:1–2005:3. All variables are expressed in logs.

[28] The Breusch-Pagan test statistic for this specification is 3.355, with a p value of 0.00001, and the Hausman test-statistic is 2.25, with p value of 0.3241. Both results point to the appropriateness of random-effects model.

Table 5 Random-effects estimation of (18)

Method: GLS		
Number of observations		1,281
Number of individuals (banks)		42
Dependent variable: $ln(1 - \mathrm{NPL}_{i,t+1})$		
	Coefficient	Std. error
β_1	0.144628	0.0344375
β_2	−0.108533	0.0178444
R^2	Between	0.1775
	Within	0.0394
	Overall	0.0329
Intercept variance		0.083774
Error variance		0.058528
Interc. variance as percentage of total variance		0.671992

Table 6 Augmented Dickey–Fuller unit root tests

Variable	Exogenous	Test stat.	Critical value(5%)
Real GDP	Cons,trend	−0.58180	−3.526
(log)	Constant	0.67771	−2.9369[a]
Total loans	Cons,trend	−2.798	−3.544[a]

[a]Intermediate Tests like case 4 used in Hamilton (1995) Table B.7 did not point to the rejection of the null hypothesis of unit root under this case

As mentioned before, the estimation of a cointegration vector requires non-stationarity in the included variables.[29] Table 6 presents the augmented-Dickey–Fuller unit root test results for real GDP and total loans.

Although with different deterministic components, the test cannot reject the null hypothesis of unit root for both series. Once confirmed to be non-stationary, it is possible to use the error correction representation of a cointegrated system to test for the presence of cointegration relationships between the variables (Johansen 1995). The Johansen cointegration test has been performed with 1 lag in differenced variables, according to Hannan–Quinn and Akaike information criteria calculated in the context of a vector autoregression for the variables in levels. Once again, the test-statistics of the Johansen cointegration test have been small-sample corrected.[30] Table 7 presents the results of the test.

Both trace and max-eigenvalue test statistics point to the existence of a cointegration vector between real GDP and total loans at a significance level of 5%. This result remains unchanged if the small-sample correction is not implemented.

[29] The sources of real GDP and total loans were mentioned before. Variables are expressed in logs. Finally, loans were deflated using the CPI index of the Banco de la República. The frequency of variables is quarterly for the span 1994:4–2005:3.

[30] With 39 observations, one lag and two variables the factor of correction is 0.948.

Table 7 Johansen cointegration tests

Nr. of CV	Trace stat.	Critical value (5%)
None	29.859	25.32
At most 1	4.296	12.25
Nr. of CV	Max-eigenv stat.	Critical value (5%)
None	24.252	18.96
At most 1	4.296	12.25

To interpret economically the estimated cointegration vector, a normalization on the coefficient associated to GDP is imposed. Under this normalization, the cointegration relationship estimated is given by:

$$\ln(GDP_{t+1}) = 0.0053t + 0.158979 \ln(L_t) \tag{19}$$

where L refers to total loans. $u_{s,3}$ was then set equal to the coefficient on L_t in expression (19). The insignificance of the estimated trend coefficient allowed to set $u_{s,2}$ equal to zero.

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