A GENERAL EQUILIBRIUM APPROACH TO ANALYZING FINANCIAL STABILITY IN COLOMBIA

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INTRODUCTION

Central banks have achieved positive results for inflation during the last two decades. At the same time, their concern for financial stability has increased, particularly after the late nineties, when they experienced the high costs that come with financial crisis.[1] Moreover, it now seems clear that, under extreme circumstances, financial stability can pose a constraint to the normal operation of monetary policy (See Vargas et al., (32006)).

For these reasons, central banks now use a set of tools to assess and promote financial stability. According to Bårdsen, Lindquist and Tsomocos (2006), these tools range from calculating indicators to designing structural macroeconomic models. The latter are understood as complex environments that allow for an analysis of interaction between the different agents at hand and the financial system (banks, depositors, regulators, etc.), as well as the effect of changes in the stance of monetary policy.

The Bank of England was a recent pioneer in constructing models of this type, particularly dynamic general equilibrium models with a finite horizon (DGEMFH).[2] The main developments in this respect are summarized in the

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[1] See Borio and Lowe (2002), and García Herrero and Del Río (2003) for an interesting interpretation of why financial stability has emerged as a policy problem at a time when inflation is ceasing to be one.

[2] In models of this type, equilibrium is the result of interaction between rational economic agents who must cope with a restricted optimization problem and a finite horizon for reaching a decision.

work of Tsomocos (2003) and Goodhart, Sunirand and Tsomocos (2004, 2005, 2006a and 2006b). The Financial Stability Department at Banco de la República has applied these developments to a recent analysis of the stability of Colombia's financial system. The initial results of that exercise are summarized herein,[3] particularly the assessment of how the model behaved in replicating the series observed in the Colombian financial system.

There are five sections in this article. The first offers justification for using a model to analyze financial stability. The second presents a simplified version of the model that was employed. It is a DGMFH with several features particular to the Colombian financial system. The third and fourth sections outline how the model was applied. Finally, several thoughts about its application are presented in the form of a conclusion.

1. Advantages of Using a DGMFH

Probably none of the tools central banks now use are sufficiently comprehensive to resolve all the problems inherent in a financial stability analysis. A good analysis clearly depends on the use of various tools, applied in a complementary way. Under those terms, the use of general equilibrium models has found a place, because - in a flexible and simplified environment - they involve the interrelations found among all agents in the system.

The study by Bårdsen, Lindquist and Tsomocos (2006) is a careful examination of how different macroeconomic models behave in a financial stability analysis. The results of that comparison suggest that, although no single model can answer all the questions in an analysis of this sort, some have certain features that make them desirable for assessing financial system stability. Those features, and how they come together when the model is applied, are summarized in Figure 1.

According to the diagram, a model that contains the nine desirable features is insufficient to analyze financial stability. It is necessary to have reached a consensus on the particular definition of "financial stability" beforehand. In other words, as concluded by the aforementioned authors, an analysis is the combined product of a definition and the exercise involved in operation of the model. Hence, the definition of financial stability must be operational and quantifiable, so the quantitative results of the model's application can be translated directly into conjectures about the stability of the financial system.

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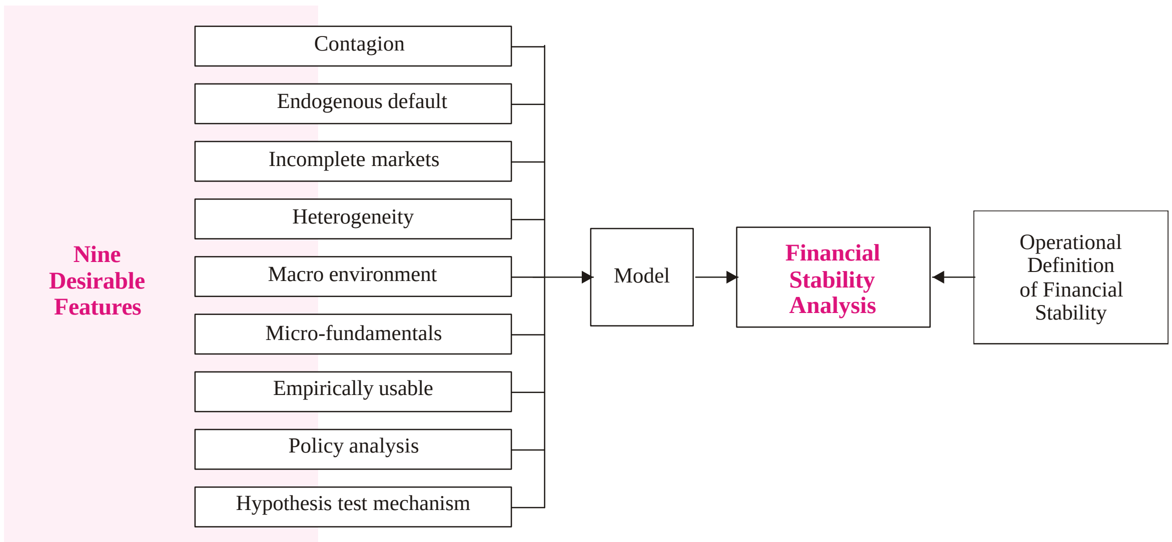
[3] The articles by Saade and Estrada (2006) and Saade, Osorio and Estrada (2006) detail the development of this agenda.

Figure 1

Temporal Structure of the Model



Source: Constructed according to Bårdsen, Lindquist and Tsomocos (2006).

Unlike other macroeconomic models, a DGMFH in its simplest versions (like the one used in this article) contains the nine desirable features shown in Figure 1. It also permits operational use of the following specific definition of financial stability: a situation where profitability for financial institutions is high and there is a reduced risk of default in the markets where these institutions come together (See Bårdsen, Lindquist and Tsomocos (2006).[4]

In short, if this definition is considered general enough to cover the Colombian case,[5] the use of a DGMFH as a complementary tool for analysis can enhance the quality of Banco de la República's monitoring of financial stability, which

[4] The definition of financial stability proposed in this article is intended only for financial stability analysis in connection with the model. Naturally, there are other more general definitions outside the scope of the model. They can be supplemented with the one summarized herein.

[5] For example, it is important to remember that one of the features of the 1998-1999 financial crisis in Colombia was the negative profitability experienced by credit establishments and the reduced rate of portfolio repayment, in both traditional credit markets and the interbank market. According to information published by the Superintendent of Financial Institutions in Colombia, profitability as a percentage of the assets in the financial system at September 1999 was -3.88% (a historic low). The losses accumulated during the crisis were not recovered until mil-2005. In November of that same year, the overdue portfolio as a percentage of the total portfolio reached 16% (a historic high).

explains the Financial Stability Department's recent effort to develop this research agenda.

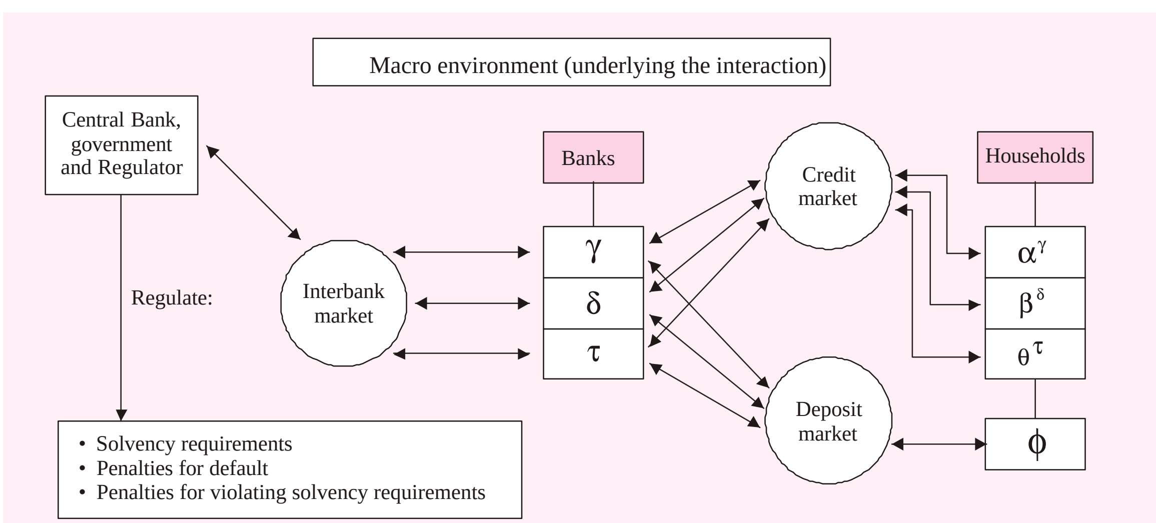
II. Simplified Model: Frame of Reference

Pursuant to the method suggested by Goodhart, Sunirand and Tsomocos (2206a and 2006b), the proposed model allows for coherent interaction between various economic agents in financial markets. Participating in the model are heterogeneous banks: $b \in B = \{g, d, t\}$, private-sector agents who act as bank clients: $h \in H = \{a, b, q, f\}$, a regulator and a central bank. A restricted optimization problem was constructed for each of the banks. Reduced forms of behavior were assumed for the agents in the private sector, due to the impossibility of finding data broken down to the required level and also because this facilitates a computational solution to the model. The temporal horizon is infinite. However, the agents make their optimization decisions by considering finite periods in the future. The agents are rational and base their expectations on two possible "states of nature" (normal, extreme crisis). These can occur in the immediate future, according to a known distribution of probability.

The agents interact in various markets (Figure 2). As in Goodhart, Sunirand and Tsomocos (2006b), the assumption is that, at the start of each period, those

Figure 2

Agents and Interaction



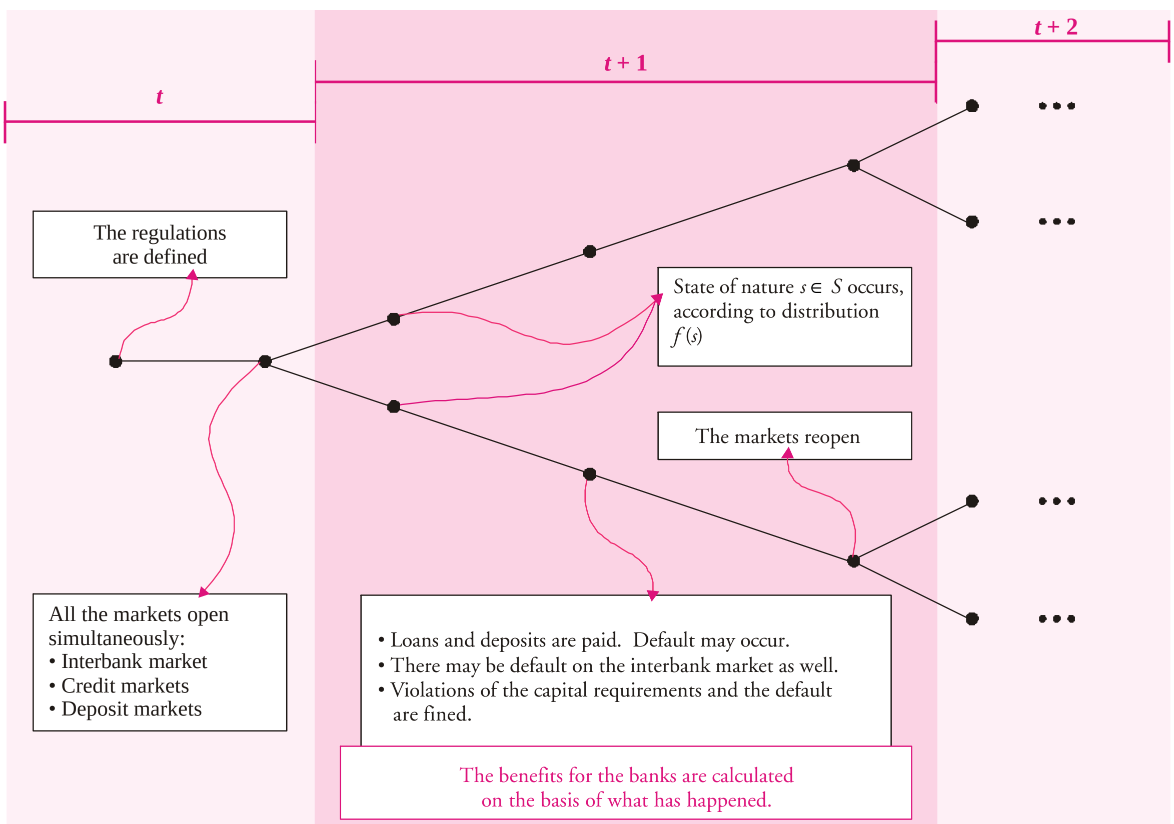
in need of credit have been assessed by the bank, either on the basis of their credit history or according to information constraints (assumption of limited participation). In other words, there is a credit market for each bank to which the client and the respective bank have recourse. In this simplified world, households a, b y q demand credit from banks g, d, y t, respectively. However, on the deposit side, each bank competes in its respective market to attract the aggregate pool of depositors (called f). They diversity its portfolio, depending on the profitability offered.

Finally, there is an interbank market where the banks contract credit among themselves. Participating in this market is a central bank-regulator that supplies or reduces liquidity through open market operations (OMO). The central bank-regulator also establishes certain measures for financial regulation.

The temporal structure of the model is outlined in figure 3. At the end of period t, the credit, deposit and interbank markets open simultaneously. Each bank

FIGURE 3

TEMPORAL STRUCTURE OF THE MODEL



Source: Constructed according to Goodhart, Sunirand and Tsomocos (2006b).

decides how much credit to offer and the volume of deposits to demand on the respective markets, while forming a rational expectation of possible future states of "nature". For their part, households decide on their demand for credit and the deposits to offer, and the central bank conducts OMO on the interbank market.

One of the "possible states of nature" ($s \in S$) occurs at the start of period $t + 1$. Deposits and loans are paid according to the state of nature. There also might be a certain degree of endogenous default by households and banks. The latter would be subject to penalties for failing to meet their contract obligations; these would be proportional to the extent of default, plus penalties for failure to comply with the minimum requirements for solvency. Both the penalties for default and the solvency requirements and the penalties for violating them have been regulated before the markets open in period t. At the end of period $t + 1$, the benefits for the banks are calculated and the financial markets reopen.

The following is a brief explanation of how each agent is modeled, their decision variables, and the particular way they were specified for the Colombian case.

A. The Banking Sector

As mentioned earlier, three heterogeneous banks: $b \in B = \{g, d, t\}$, were modeled. For the Colombian case, each of these banks is associated with a group of entities; namely, g = banks specializing in mortgage loans (BECH), d = domestic banks and t = foreign banks. This classification tries to capture the differences in behavior t among these banks, as observed in the Colombian financial system.[6] With respect to simulation of the model, the three banks differ not only in their initial capital endowment, but also in their preferences as to risk.

Bank $b \in B$ decides the following variables in period $t \in T$: the supply of credit to household h^b ($\overline{m}^b_t$), the deposits demanded of household f ($m^b_{d,t}$), loans on the interbank market (d^b_t), debt on the interbank market (m^b_t),, and the repayment rates (1- default) in $t + 1$, depending on the state that occurs ($v^b_{t+1,s}$ $s \in S$). The decision responds to the solution of an optimization problem with the following characteristics :

$$\underset{\overline{m}^b_t, m^b_{d,t}, d^b_t, m^b_t, v^b_{t+1,s}\, s\in S}{Max\ U^b}, = E^b_t\, [f^b_s(p^b_{t+1,s}) - \{\text{penalidades}^b_{t+1,s}\}],$$

subject to (1) balance sheet restriction and (2) $p^b_{t+1,s} \geq 0$.

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[6] See Avella and Osorio (2005) and Orozco (2005) for an analysis of the differences in how domestic and foreign banks act.

[7] The explicit form the utility function takes is found in Saade and Estrada (2006). Essentially, it is the same as in Goodhart, Sunirand and Tsomocos (2006b), with modifications in the constraints of the problem.

Function $f_s^b(p^b_{t+1,s})$ is quadratic in "benefits" $p^b_{t+1,s}$. these being the sum of income expected from interest in $t + 1$ and the profitability expected from the portfolio of negotiable investments, minus the outlays for interest expected in $t + 1$, considering the repayments rates (1-default) for both the bank and those expected for the households. Penalties function $^b_{t+1,s}$ divides penalties into groups proportional to the amount of default in $t + 1$ by the bank in state $s \in S$, in addition to penalties for failing to meet the requirements on minimum solvency. This optimization problem is not linear in the control variables of the bank.

B. The Private Sector

As mentioned earlier, the agents in the private sector are modeled via reduced forms.

1. *Demand for credit on the part of households $h \in \{a, b, q\}$*

In period t, the demand for credit on the part of household h^b depends negatively on the lending rate offered by bank b, and positively on the level of GDP anticipated for period $t + 1$. In other words, agent h^b rationally anticipates the product level in the immediate future. This, in turn, determines his expected income for $t + 1$. And, given the foregoing, agent hb adjusts the demand for credit in t to smooth his consumption:

$dda\_crédito_t^{h^b} = h\,(E_t\,(GDP_{t+1}),\, r_t^b)$, con $h_1 \geq 0$ y $h_2 \leq 0$.[8]

2. *Supply of deposits from household f*

All the banks compete in the deposit market to attract the resources of depositor pool f. This is contrary to what happens in the credit market, where participation is limited. Pool f tries to diversify its portfolio. The supply of deposits from f to bank b in period t is a positive function of the deposit rate offered by b and depends negatively on the deposit rate offered by the other banks ($b' \neq b$). Nonetheless, household f knows the banks can default on their obligations. Consequently, its deposit supply responds to the "expected profitability" ($r^b_{d,t} \times E_t[v^b_{t+1,s}]$) of its savings in b and the profit its savings would earn with the other banks. Finally, the deposit supply is a positive function of the GDP expected for $t + 1$.

$Of\_depósitos_t^{\,b} = g\,(E_t(GDP_{t+1}),\, r^b_{d,t} \times E_t\,[v^b_{t+1,s}],\, \sum_{b' \neq b} r^{b'}_{d,t}\, E_t\,[v^b_{t+1,s}])$, with $g_1 \geq 0$, $g_2 \geq 0$ and $g_3 \leq 0$.

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8 The following notation is used: $f_k = ¶ f / ¶ x_k$,

3. Repayment rates of households $h \in \{a, b, q\}$

As in Goodhart, Sunirand and Tsomocos (2006b), it is assumed the rates of repayment in $t + 1$ by household h^b to bank b for each of the states ($v^{h^b}_{t+1,s}$, $s \in S$) is a positive function of future GDP. Moreover, repayment in t +1 responds t the banking system's total supply of credit in t. This ratio is negative: an increase in t with respect to the loans offered is associated with a moderate deterioration in the quality of the portfolio, possibly due to fewer filters in the process whereby the banks select debtors[9]

$$v^{h^b}_{t+1,s} = v_s\,(GDP_{t+1,s}, \sum_{b \neq B} \overline{m}^b_t),\ s \in S, \text{ where } v_1 \geq 0 \text{ and } v_2 \leq 0$$

4. GDP

The last of the reduced forms incorporates the GDP path into the model. It is assumed that GDP in $t + 1$ for state s is a positive function of the aggregate supply of credit in t:

$$GDP_{t+1,s} = p_s\,(\sum_{b \neq B} \overline{m}^b_t) \text{ with } p_1 \geq 0.$$

C. Central Bank and Regulator

For the effects of the model, the decisions of the central bank and regulator are exogenous.[10] The regulator determines the minimum solvency requirements ($k^b_{t+1,s}$, $s \in S, b \in B$), in addition to the penalties banks would incur if minimum solvency is not met (l^b_{ks}, $s \in S$, $b \in B$). It also imposes penalties or fines for default on the banks' repayment obligations (l^b_s, $s \in S$, $b \in B$). Finally, the regulator determines the weighted risk of the various assets used to calculate the solvency ratio.

For its part, the central bank conducts OMO on the interbank market, effectively setting the interest rate for trading on that market (r).

D. Equilibrium

There are seven active markets featured in the model: three credit markets, three deposit markets and the interbank market. In each of them, the interest rate is determined by the supply and demand on the market. The model includes

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9 For Goodhart, Sunirand and Tsomocos (2006b), this ratio is positive insofar as a credit rationing can exist.

10 The working agenda for the future attempts to include, in an endogenous way, the decisions taken by economic authorities.

a condition for each possible future state, specifically one that ensures banks structure their expectations correctly with respect to the rate of repayment they receive in $t + 1$ on their interbank loans.

III. CALIBRATION

Two econometric strategies were required to calculate the value of the relevant parameters.

A. Estimate of Long-term Relationships (Cointegration Vectors)

The parameters for the reduced forms of GDP and household credit demand were obtained by estimating cointegration vectors (relationships) between the variables found therein.[11] For the reduced form of credit demand, limitations in available information make it necessary to estimate a set of parameters that is common to the clients of each of the three groups of banks. In this case, the variables included in the system are: consumption, money supply, the unsecured consumer portfolio, inflation, unemployment, GDP and the spread on the consumer portfolio. The strategy proposed by Chrystal and Mizen (2001) is used in this respect.[12] The estimated cointegration ratio is:

$$L_t = 4{,}89 \ln (GDP_{t+1}) - 0{,}723\,(SC_t) + 2{,}18\, p_t + 0{,}19\,(\Delta u_t)$$

where L is the unsecured portfolio, SC is the spread on the consumer portfolio, p is inflation and u is unemployment. The estimators associated with GDP and SC are the values of the parameters of the reduced forms of credit demand used in the simulation.

As to the reduced form of GDP, the system included information on GDP and the entire loan portfolio. Besides normalization, the cointegration vector estimated in this case includes a deterministic tendency component:

$$\ln(GDP_{t+1}) = 0{,}0053t + 0{,}1589 \ln(L_t)$$

where L is the entire loan portfolio. Both the tendency estimator and GDP elasticity to the loan portfolio were used in the simulation as the parameters of the reduced form of output.

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[11] See Hendry and Juselius (2000) for details on estimating restricted cointegration vectors.

[12] See Estrada, Osorio and Saade (2006) for details on the estimate.

B. Panel Data Models

When the reduced forms include components of the general balance sheet or income statement for the three groups of banks, the strategy was to estimate panel data models in which each bank is regarded as a separate individual within the panel. Specifically, the reduced forms of the deposit supply and household repayment were estimated in this way.

In the case of the deposit supply, the dependent variable pertains to the sum of each individual entity's checking accounts and savings deposits. Moreover, the dependent variables are the real GDP (one period ahead), the entity's implicit deposit rate, and the average implicit rate of deposit for the other two groups of banks. The estimate, pertaining to a random effects model in the intercept, yielded the following result.

$$\ln(\text{deposits}_{it}) = C + 1.832 \ln(GDP_{t+1}) + 0.143 \text{ deposit rate}_i - 1.243 \text{ deposit rate } {-i}$$

where *i* refers to a particular bank (-*i* refers to the group of banks other than the one to which *i* belongs).[13]

Finally, the estimate of the reduced form of household repayment included, as a dependent variable, the difference $\left(1 - \frac{\text{overdue portfolio}}{\text{total portfolio}}\right)$ for each individual institution; and, as independent variables, the total portfolio for the three groups of banks and GDP (ahead one period). The results were:

$$\ln\left(1 - \frac{\text{overdue portfolio}_i}{\text{total portfolio}_t}\right) = C + 0.1446 \ln(GDP_{t+1}) - 0.1085 \ln(\text{portfolio}_t)$$

These estimators, and those presented in the foregoing expression, were used as the parameters for each of the reduced forms.[14]

IV. THE RESULTS

Graphs 1 through 4 show some of the series simulated with the tendency model, using the fourth quarter of 1999 as the initial period. The simulations are quarterly. For the purpose of comparison, the simulated series are accompanied by their actual counterparts, with real data.[15]

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13 As noted earlier, the deposit supply is consistent with "expected profitability", which is comprised of the bank's interest and repayment rates. With respect to the estimate for the panel data model, the deposit rate is calculated as the flow of the bank's outlays on total deposits. For this reason, it implicitly includes the repayment rate.

14 The *C* intercepts of each of the two expressions were obtained endogenously to improve the empirical adjustment in the initial period of the simulation.

15 The Superintendent of Financial Institutions in Colombia is the source of each actual series presented in the graphs, with the exception of quarterly GDP, which comes from the National Bureau of Statistics (DANE).

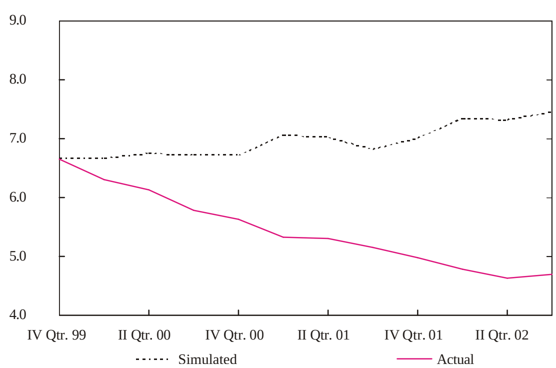
In terms of the credit portfolio (Graph 1), what stands out is the model's capacity to adjust to real data in the short term (approximately one year) for each of the three groups of banks. In the long term, the model's adjustment is far better for the domestic and foreign banks (panels B and C, respectively), than for the BECH (A). This is because common parameters were used for the reduced form of the demand portfolio. The calibration does not detect the differential in BECH behavior. Given the initial conditions, the model also replicates the relative differences in the size of the banks' portfolios (Panel D). It is important to point out that the results are moderately optimistic about the performance of the portfolio, due to a slight overestimation of GDP during the entire simulation horizon (Graph 4).

Graph 1

Loan Portfolio

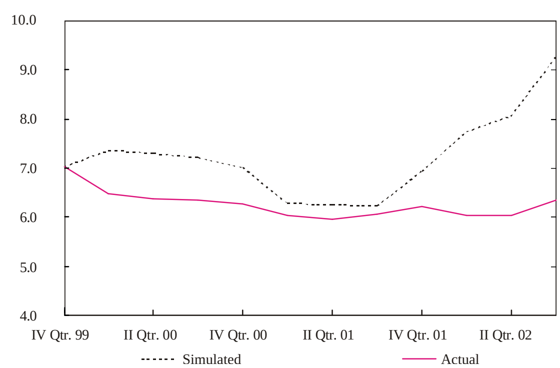
A. Portfolio: BECH

(Trillions of 1994 pesos)



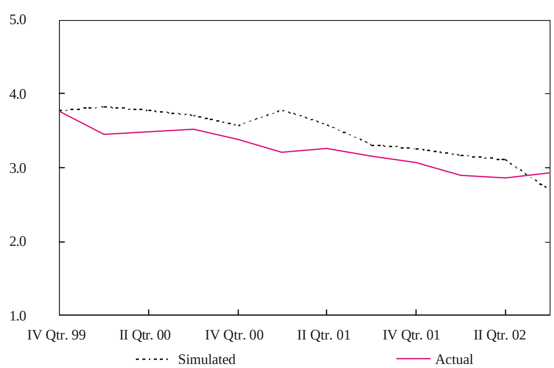
B. Portfolio: Domestic Banks

(Trillions of 1994 pesos)



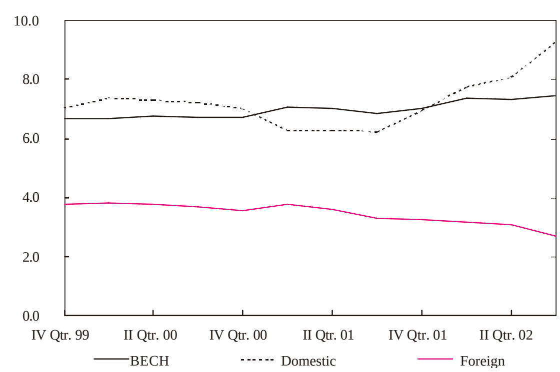
C. Portfolio: Foreign Banks

(Trillions of 1994 pesos)



D. Portfolio Simulation

(Trillions of 1994 pesos)



Source: Colombian Superintendent of Financial Institutions (actual series) and the authors' calculations (simulated series).

As to the pattern of deposits (Graph 2), the adjustment is much better - in both the short and long term -although the optimism (originating with the GDP path) continues to some extent. This outcome confirms the merits of the calibration strategy that was used. In this case, the assumed pool of depositors turns out to be quite adequate, since - in the real world - there appears to be no limited participation when its comes to choosing a bank to open a savings account.

Repayment of the banks' credit portfolio (Graph 3) suggests optimism only in the case of foreign banks and the BECH (panels A and C).[16]

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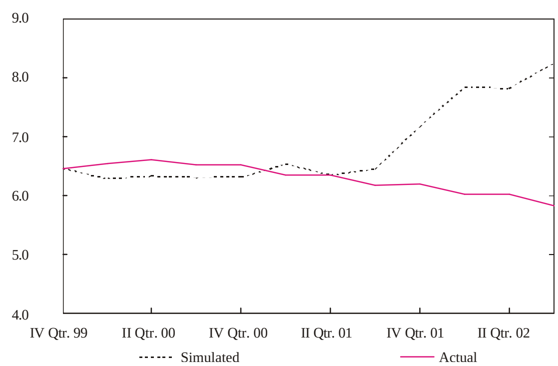
[16] In the simulated BECH repayment series, one sees a jump to the end of the simulation horizon. Rather than a normal outcome, this appears to be an abnormal product of the optimization algorithm used in the simulation.

GRAPH 2

DEPOSITS

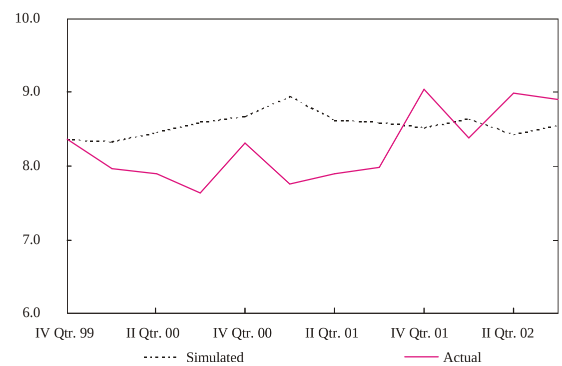
A. DEPOSITS: BECH

(Trillions of 1994 pesos)



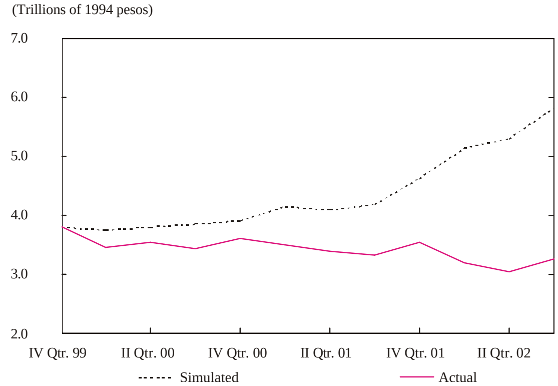
B. DEPOSITS : DOMESTIC BANKS

(Trillions of 1994 pesos)



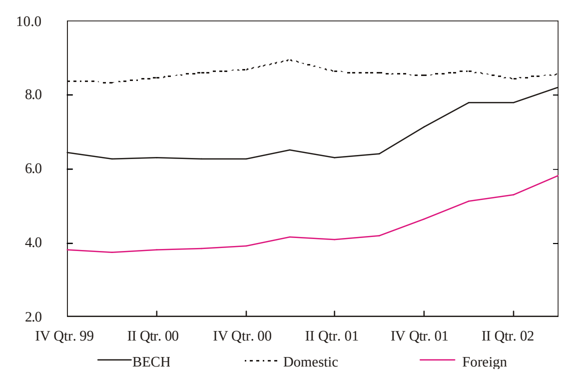
C. DEPOSITS: FOREIGN BANKS

(Trillions of 1994 pesos)



D. DEPOSIT SIMULATIONS

(Trillions of 1994 pesos)

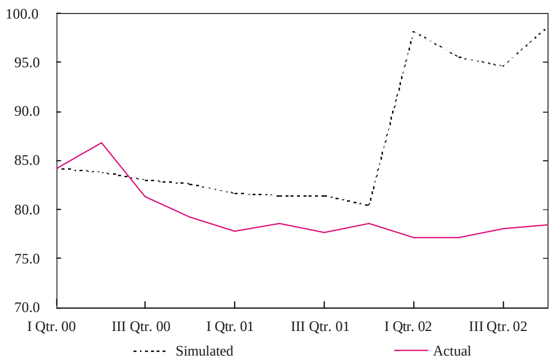


Source: Colombian Superintendent of Financial Institutions (actual series) and the authors' calculations (simulated series).

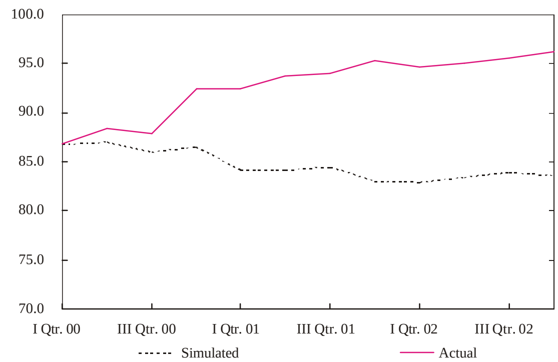
Graph 3

Credit Demanders' Repayment to Banks (Percentage)

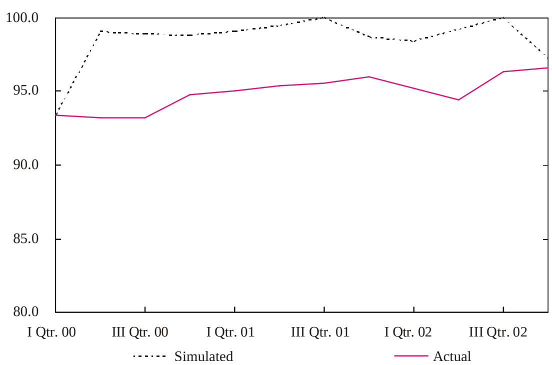
A. Repayment by BECH Clients



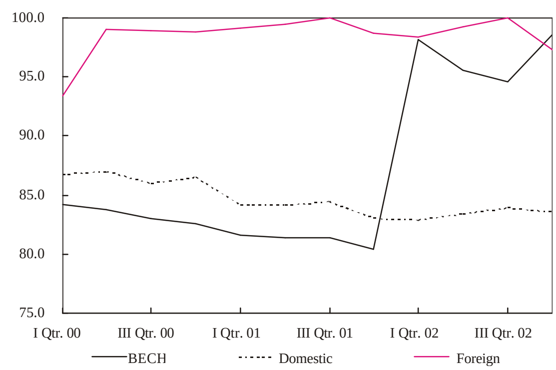
B. Repayment by Domestic Bank Clients



C. Repayment by Foreign Bank Clients



D. Loan Repayment Simulations

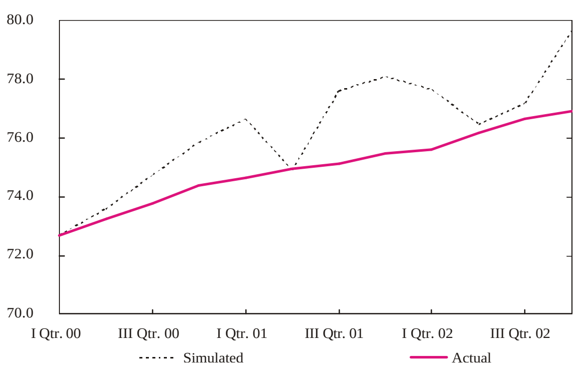


Source: Colombian Superintendent of Financial Institutions (actual series) and the authors' calculations (simulated series).

Graph 4

Gross Domestic Product

(Trillions of 1994 pesos)



Source: DANE (actual series) and the authors' calculations (simulated series).

Panel D shows an interesting outcome: the simulations replicate the stylized event in Colombia in the sense that foreign banks have a better-quality portfolio.[17]

Finally, overestimation of the GDP path (Graph 4) may be the result of calibration problems, which means new strategies aimed in this direction will have to be explored further.

17 The stylized event that foreign banks "attract" better-quality clients is known as cherry picking. See Crystal, Dages and Goldberg (2001).

V. CONCLUSIONS

The chief objective of this article is to summarize the principal results of a research agenda undertaken by the Financial Stability Department at Banco de la República, which consists essentially of applying a DGMFH to analyze the stability of Colombia's financial system. The main results of the simulation of this model (calibrated in advance for the Colombian case) highlight its merits, particularly in the short term, as a useful analytical tool complementary to the ones now being applied.

It is important to emphasize, as noted in the introduction to this article, that the model cannot, on its own, resolve all the problems inherent in a financial stability analysis. In other words, the model is not designed specifically for a certain set of objectives. For example, it is not designed to forecast the future course of GDP. The special comparative advantage of the model is that it permits a careful analysis of those agents in the financial system with the most resources; that is, the financial institutions, as well as the main characteristics of how they interact with the other agents in the economy.

As to the future, there are two complementary tasks for this agenda. First, the structure of the model can be used to simulate the effect of certain exogenous variables, particularly those associated with the regulatory environment and economic policy (e.g. the monetary authority's intervention rate or the minimum solvency ratio).[18] Secondly, it is important to explore ways to adjust the model better and, hence, its capacity for analysis. This includes adding elements of a small, open economy subject to different types of shocks originating in the rest of the world, which would be a good approximation to the environment wherein the Colombian economy operates. Also, some of the problems noted in this article (e.g. the model's optimism) are related to the calibration strategies, where there is plenty of room to improve the estimates in this respect.

[18] Simulating the model based on exogenous paths for GDP is another possibility worth exploring. An advantage associated with this strategy is the possibility of removing an "error source" from the model when adjusting other endogenous variables that are more relevant to a financial stability analysis.

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