Evidence for a Financial Accelerator in a Small Open Economy, and Implications For Monetary Policy

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Evidência de mecanismo de acelerador financeiro em uma economia pequena e aberta, e implicações de política monetária

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Mediante técnicas de estimação Bayesiana, estimamos para a economia colombiana um modelo dinâmico estocástico de equilíbrio geral para uma economia pequena e aberta que se enfrenta a imperfeições no mercado de crédito. Mostramos que a combinação de efeitos de folha de balanço e a escolha do regime de política de taxa de câmbio provavelmente cumpre um importante papel na magnificação e propagação de choques iniciais à economia. Como uma aplicação, mostramos que o nosso modelo explica a crise colombiana de 1998-1999, quando o incremento nos Spreads da dívida teve um impacto importante no crédito doméstico, provocando uma recessão severa.

Classificação JEL: C11, C15, E32, E44, E52.

Palavras chave: modelos DSGE, acelerador financeiro, estimação bayesiana, regime de taxa de câmbio.

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Using Bayesian estimation techniques, we estimate a small open economy dynamic stochastic general equilibrium model with credit-market imperfections for the Colombian economy. We show that the combination of balance sheet effects and the choice of monetary policy regime are likely to play an important role in the magnification and propagation of initial shocks to the Colombian economy. As an application we show that our model explains the 1998-1999 crisis in Colombia, when a sharp rise in spreads on a relatively small proportion of international debt were passed strongly onto domestic lending rates, provoking a severe recession.

I.   INTRODUCTION

The Colombian economy, like many emerging market countries, has been characterized by important business cycles. But the recession at the end of the 1990s was particularly long and severe; output fell 4.2% in 1999 and then took approximately four years to recover to its average growth rate. One of the explanations that has been put forward for the severity of the recession was the poor state of the financial balance sheets of households and firms when the crisis struck; see Chang and Velasco (1998). Colombian debt had increased fourfold between 1993 and 1998 following a financial and commercial liberalization. Property and equity prices increased during the spending spiral. But when these asset prices reversed in 1998, the financial positions of households and firms were suddenly exposed.

Another possible reason why the crisis was so severe is that the Colombian monetary authority tried to pursue a fixed exchange rate regime during the financial distress, raising interest rates when output was falling. The role of a fixed exchange rate regime in amplifying emerging market crises has been suggested by Gertler, Gilchrist and Natalucci (2007) using a calibrated model.

But up until now, much of the analysis of this type of emerging market crises has been more in the form of presenting hypotheses. We need to model, estimate and test for these effects if we want to guide monetary policy in preventing the repetition of crises such as the 1998-1999 Colombian episode.

Fixed investment was especially affected during the crisis, the investment to GDP ratio took six years to recover. The modeling of investment is crucial in gauging

the relative importance of these factors. Many macroeconomic models explaining investment assume perfect capital markets, and therefore, that the Modigliani-Miller theorem holds: financing decisions have no impact on real economic activity, and investment is determined by expected future business profitability and the cost of capital. However, many empirical studies suggest that financial factors such as balance sheet conditions also influence investment expenditures to some extent (Hall,2001). Balance sheet models emphasize how companies will often prefer to use internal funds rather than external borrowing to finance investment because external borrowing is more costly than internal finance. External borrowing incorporates an external finance premium because external lenders cannot perfectly observe and/or control the risk involved in supplying funds to borrowers, a costly state verification problem, and therefore require compensation for expected losses. According to this view, credit market imperfections can amplify initial shocks to that economy. Changes in credit market conditions such as asset prices and debt burdens are not simply passive reflections of the real activity but explain the amplitude and duration of the business cycle.

It is especially important to model credit market imperfections in an open economy context if we are to understand the late 1998-1999 crisis in Colombia. This is not so much because firms built up a large foreign currency debt; only 35% of all corporate debt was foreign currency denominated before the crisis hit. Certainly, the trigger was a sharp increase in international spreads following the 1997 Asian crisis. But it could have been the defense of a fixed exchange rate in the presence of these frictions that explains why these rises in the cost of a relatively small proportion of total debt was passed on so strongly on domestic market rates.

In this paper we develop and estimate a model for a small open economy that takes into account both financial market imperfections and also the exchange rate regime in order to quantify the importance of these factors in the amplification and propagation of shocks in the Colombian economy during the period 1980-2005. The model is based on Bernanke, Gertler and Gilchrist (1999) (BGG hereafter), Dib and Christensen (2008) and Gertler *et al.* (2007). A micro-financial contracting problem between borrowers (firms) and lenders (households) is set into a macroeconomic Dynamic New Keynesian framework (DNK) with sticky prices. The model distinguishes households and entrepreneurs in order to explicitly motivate lending and borrowing. In addition, there are retailers who set the final price of output goods, capital producers who transform output goods into capital goods, a foreign sector that mainly accounts for the effects of exchange rate in the economy, and a government which

conducts monetary policy. The stochastic dynamics is driven by 10 orthogonal structural shocks: technology shocks, demand shocks (to preferences, investment and money demand shocks), foreign shocks (to transfers, foreign prices, country borrowing premium, foreign interest rate, and foreign demand), and monetary policy shocks. The model incorporates credit-market imperfections through the assumption that external funds and internal funds are not perfect substitutes; the external finance premium depends inversely on the value of entrepreneurs own net worth. As noted by Fukunaga (2002), procyclical movements in entrepreneur's net worth caused by unanticipated shocks then lead to countercyclical movements in the external finance premium, and thus make investment volatile. This mechanism is called the "financial accelerator". Dib and Christensen (2008), on the other hand, introduce money in the utility function of households and estimate the model using investment data. This is important in this context, since we are interested in the interaction of the price of capital, financing cost, and investment.

The objectives of the paper are twofold. First, we estimate whether financial frictions helped to propagate and amplify initial shocks in Colombia in a significant way. The Bayesian estimation methodology provides a natural framework for testing the relevance of frictions by comparing the marginal likelihood of different models. In our case we use it to compare a model with financial frictions with a model without them by estimating the elasticity of external finance premium to the leverage ratio. Another advantage of a Bayesian approach to estimate dynamic stochastic general equilibrium models is that it allows a complete characterization of uncertainty in estimating structural parameters by simulating posterior distributions. Our finding is that credit market imperfections play an important role in amplifying the business cycle in Colombia.

Secondly, using the estimated parameter values we compare the response of some macroeconomic variables to an increase in the country borrowing premium of the magnitude that was observed during 1998-1999 in order to assess the importance of the exchange rate regime to explain the exacerbation of the financial distress of the economy. The simulations show that the fixed exchange rate regime is likely to have been important in explaining the severity of the crisis in the Colombian economy.

The rest of the paper is organized as follows. Section II describes some stylized facts of the Colombian economy during the period 1980-2006 and presents evidence on a set of key macroeconomic variables. Section III describes the model. Section IV

reports on our implementation of Bayesian inference methods. Section V presents the results on estimates. Our conclusions are in Section VI.

II. SOME STYLIZED FACTS OF THE COLOMBIAN BUSINESS CYCLE

The depth and duration of Colombian recession of the late 1990s was not predicted by most economic analysts. In the search for explanations, the great weakness in financial conditions of households and firms was often identified as a likely exacerbating factor. This is particularly true in the case of the behavior of investment as we will illustrate below.

Graph 1 describes the behavior of some macroeconomic variables during the period 1980-2006. There have been two severe recessions, the first in 1982 and the second in 1999. These business cycle ware accompanied by similar cycles in asset prices[1] which help to determine the financial conditions of households and firms.

Interestingly, the performance of investment is somehow different in the years prior to the two recessions. During the economic recession at the end of the 1990s, private investment fell unusually sharply in relation to previous recessions and to its standard explanatory factors (user cost and firms profits). In the years before 1982, investment did not grow as much as it did during the 1990s, and also did not fall as much during the downturn. The economy was faced with a high level of debt in the years before the 1999 recession. Credit was much higher during the 1990s than during the 1980s, leaving the Colombian economy in a vulnerable position before the second recession. The behavior of asset prices was not favorable either, since 1996 they started to decline and that weakness persisted until 2003. This was true for both property and equity prices. These asset prices reductions lowered the collateral available to back households and corporate borrowing.

Real consumption spending tracked GDP boom and bust during the 1990s; it rose near 4% during 1997 and fell close to 4% during the 1998-1999 crisis. Net exports were high during the following period of low real exchange rate like during the financial crisis of the 1990s.

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1 Asset prices correspond to a weighted average of equity prices and real estate prices.

Graph 1
The Colombian Business Cycle

Investment
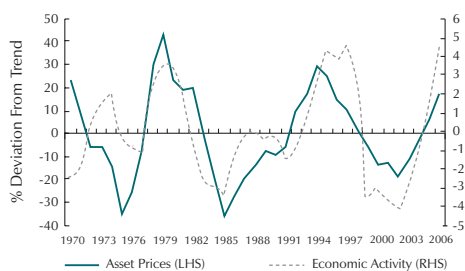
Source: Banco de la República and DANE.

Source: DANE.

Real Consumption

Net Exports
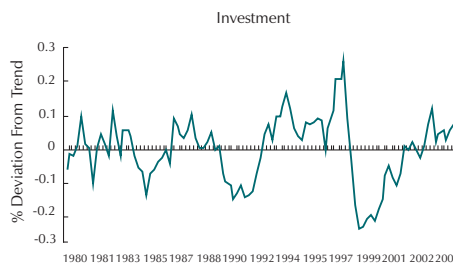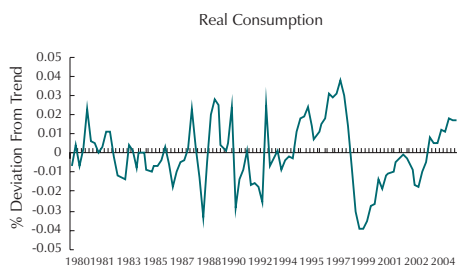
Source: DANE.

Source: DANE.

Debt to GDP Ratio
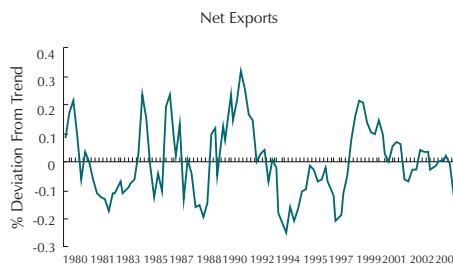
Interest Rate
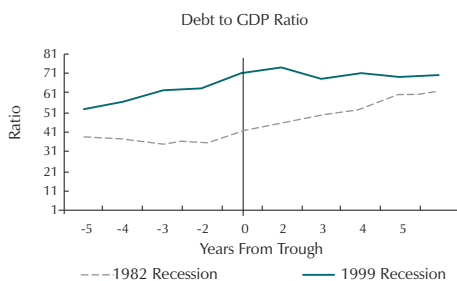
Source: Banco de la Republica.
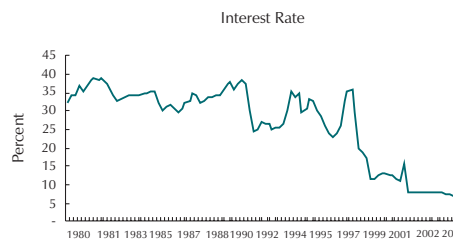
Source: Banco de la República.

III.   THE MODEL

The model we estimate is based on BGG, Dib and Christensen (2008), and Gert-ler *et al.* (2007). A micro-financial contracting problem between firms and lenders is set into an open economy macroeconomic dynamic New Keynesian framework with sticky prices. In the first stage we describe the financial accelerator mechanism developed by BGG.

A.   FINANCIAL ACCELERATOR MECHANISM

The financial accelerator mechanism explains how credit-market imperfections help to propagate and magnify initial shocks to the economy. First, we model the capital-purchasing decisions of entrepreneurs. At this level, there are also external capital producing firms. Entrepreneurs purchase capital from capital producers. In order to finance their investment, they have access to external funds in addition to their own wealth. Capital producers, on the other hand, purchase consumption goods and transform it into capital to sell to entrepreneurs.

1.   Entrepreneurs

Entrepreneurs purchase capital in each period, k_t, and use it in combination with hired labor, h_t, to produce the output goods, y_t, following a constant-returns-to-scale technology:

$$y_t \leq k_t^\alpha (A_t h_t)^{1-\alpha}, \alpha \in (0,1) \tag{1}$$

where A_t is an exogenous technology shock that is assumed to follow the autoregressive process:

$$\log A_t = (1 - \rho_A)\log(A) + \rho_A \log(A_{t-1}) + \varepsilon_{A_t} \tag{2}$$

where $\rho_A \in (0,1)$, $A > 0$, and ε_{A_t} is normally distributed with mean zero and standard deviation σ_A

The entrepreneurs choose k_t and h_t to maximize profits subject to the production technology. The first-order conditions are:

$$r_{kt} = \alpha \xi_t^h \frac{y_t}{k_t} \tag{3}$$

$$w_t = (1-\alpha)\xi_t^h \frac{y_t}{h_t} \tag{4}$$

where ξ_t^h is real marginal cost; w_t is the real wage; and r_{kt} is the real rental rate on capital, all in terms of domestic goods.

We now consider the capital acquisition decision. The entrepreneur finances the acquisition of capital partly with his or her own net worth available at the end of period t, n_t, and partly by issuing nominal bonds, B_{t+1}. Then capital financing is divided between net worth and debt as follows:

$$q_t k_{t+1} = n_{t+1} + \left(\frac{B_{t+1}}{P_t} \right) \tag{5}$$

where q_t is the relative price of a unit of capital which varies depending on the capital production technology[2]. The entrepreneur's demand for capital is determined by comparing the expected marginal return to holding capital with its expected marginal financial cost. The expected gross return to holding a unit of capital from t to $t + 1$, $E_t f_{t+1}$ is defined as:

$$E_t f_{t+1} = E_t \left[\frac{r_{kt+1} x_h + (1 - \delta) q_{t+1}}{q_t} \right] \tag{6}$$

The parameter δ represents the capital depreciation rate. The first term in the numerator, r_{kt+1}, is the marginal productivity of capital. The second term is the capital gain enjoyed by entrepreneurs and x_h is the price of domestic goods relative to the household consumption index, $x_t^h = p_t^h / p_t$.

The financial cost condition for purchasing capital is the main feature of this model. BGG assume that there exist credit market imperfections that make external finance more expensive than internal funds. Additional costs (the premium) over riskless interest rate, R_{t+1}, are imposed on borrowers if they demand external funds. According to BGG, lenders must pay a fixed "auditing cost" if they wish to observe borrower's realized returns. This auditing cost is interpretable as the cost of bankruptcy or default. Since competitive lenders must receive an expected return to lending equal to the opportunity cost of their funds, the borrowers' expected rate of return, $E_t f_{t+1}$, must exceed the riskless interest rate. The default risk depends on the degree to which the entrepreneurs depend on external funds, debt, and this leads to a relationship between two important ratios: The ratio of $E_t f_{t+1}$ to R_{t+1} and the ratio of net worth to assets, as follows:

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2 q_t is in units of the household consumption index.

$$E_t f_{t+1} = E_t \left[R_{t+1} S \left(\frac{n_{t+1}}{q_t k_{t+1}} \right) \right] \qquad \text{with} \qquad S(1) = 1 \qquad S'(\cdot) < 0 \qquad (7)$$

where n_t is entrepreneur's own wealth. When the ratio of internal funds is low the default risk is high and in this case the cost of borrowing rises.

The log-linearized equation for the external finance premium is:

$$f_{t+1} - R_{t+1} = -\psi n_{t+1} + \psi k_{t+1} + \psi q_t \qquad (8)$$

where ψ represents the elasticity of the external finance premium with respect to a change in the leverage position of entrepreneurs, $-\frac{S'(\cdot)}{S(\cdot)} \left(\frac{n_t}{q_t k_t} \right)$. The agency cost and the external finance premium vary with borrowers' financial health. Higher monitoring costs imply a higher elasticity of the premium on external funds to a change in the balance sheet position. Therefore the higher the monitoring costs the greater will be the volatility owing to financial market imperfections.

Finally, we need to describe the evolution of net worth of entrepreneurs. Entrepreneurs borrow $q_{t-1} k_t - n_t$ at an expected interest rate $E_t f_t = R_t S \left(\frac{n_t}{q_{t-1} k_t} \right)$ and receive the ex-post return f_t. Net worth evolves according to:

$$n_{t+1} = f_t q_{t-1} k_t - R_t S \left(\frac{n_t}{q_{t-1} k_t} \right) (q_{t-1} k_t - n_t) \qquad (9)$$

The introduction of net worth as an additional state variable allows us to explain the propagation and magnifications of monetary shocks (and other shocks) to real activity. Shocks to net worth relative to total finance requirements generate endogenous changes in agency costs and in the financial external premium charged above risk-free rates. Furthermore, net worth may be highly sensitive to unexpected shifts in the asset prices, especially if firms are leveraged. This is a kind of multiplier effect. An unanticipated rise in asset prices increases net worth more than proportionately (decreasing external premium) which stimulates investment and, in turn, increases assets prices even further (as we will show below).

2. Capital Producers

The price of capital is determined by a *q*-theory of investment. Capital producers purchase consumption goods as a material input, i_t, and combine it with rented capital, k_t, to produce new capital. Following Dib and Christensen (2008), we assume that capital producers are subject to quadratic capital adjustment costs. Their optimization problem, in real terms, consists of choosing the quantity of investment to maximize profits, so that:

$$\max_{i_t} \left[q_t x_t i_t - i_t x_h - \frac{\chi}{2}\left(\frac{i_t}{k_t} - \delta\right)^2 k_t \right] \tag{10}$$

The disturbance, x_t is, as in Greenwood, Hercowitz and Huffman (1988), a shock to the marginal efficiency of investment. The first-order condition is:

$$q_t x_t - x_h - \frac{\chi}{2}\left(\frac{i_t}{k_t} - \delta\right) = 0 \tag{11}$$

The inclusion of adjustment costs makes the price of capital volatile; therefore asset price volatility contributes to volatility in entrepreneurial net worth.

The aggregate capital stock evolves according to:

$$k_{t+1} = x_t i_t + (1-\delta)k_t \tag{12}$$

where the marginal efficiency of investment, x_t, evolves according to:

$$\log(x_t) = \rho_x \log(x_{t-1}) + \varepsilon_{x_t} \tag{13}$$

where $\rho_x \in (0,1)$ is a first order autoregressive coefficient, and ε_{x_t} is a random Gaussian variable distributed with mean zero and standard deviation σ_x.

B. THE COMPLETE MODEL

We now present a dynamic New Keynesian framework that completes the economic model, adding households, retailers and foreign sector. Retailers buy output from entrepreneurs and slightly differentiate it at no resource cost. The differentiation of

output gives the retailers some market power. Households and firms then purchase CES aggregates of these retail domestic goods. Retailers are introduced to motivate sticky prices and we follow Calvo (1983) in introducing price inertia.

1. Households

Let c_t be a composite of tradable consumption goods. Then the following CES index defines households preferences over home consumption, c_t^h, and foreign consumption, c_t^f:

$$c_t = [(v)^{\frac{1}{\rho}}(c_t^h)^{\frac{\rho-1}{\rho}} + (1-v)^{\frac{1}{\rho}}(c_t^f)^{\frac{\rho-1}{\rho}}]^{\frac{\rho}{\rho-1}} \tag{14}$$

The corresponding consumer price index, p_t, is given by:

$$p_t = [(v)(p_t^h)^{1-\rho} + (1-v)(p_t^f)^{1-\rho}]^{\frac{1}{1-\rho}} \tag{15}$$

Our treatment of consumer's preferences is standard. Instantaneous utility depends on consumption, real balances and leisure. The utility function is as follows:

$$U(c_t, M_t / p_t, h_t) = \frac{\gamma e_t}{\gamma-1}\log\left\{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma}\left(\frac{M_t}{p_t}\right)^{\frac{\gamma-1}{\gamma}}\right\} + \eta\log(1-h_t) \tag{16}$$

where c_t represents consumption, M_t/p_t real money balances, $(1-h_t)$ leisure. The parameters γ and η are positive structural parameters that denote the constant elasticity of substitution between consumption and real balances, and the weight on leisure in the utility function, respectively.

The shock e_t is a taste or preferences shock for consumption while b_t is a money-demand shock. These shocks follow the processes:

$$\log(e_t) = \rho_e \log(e_{t-1}) + \varepsilon_{e_t} \tag{17}$$

and

$$\log(b_t) = (1-\rho_b)\log(b) + \rho_b \log(b_{t-1}) + \varepsilon_{b_t} \tag{18}$$

with $\rho_e \in (0,1)$ and $\rho_b \in (0,1)$.

The representative household is assumed to maximize the expected discounted sum of its utility flows:

$$E_t\left(\sum_{k=0}^{\infty}\beta^k U\left(c_t, M_t/p_t, h_t\right)\right) \tag{19}$$

subject to budget constraint:

$$c_t \leq \frac{W_t h_t}{p_t} + \frac{T_t}{p_t} + \frac{\Omega_t}{p_t} - \frac{M_t - M_{t-1}}{p_t} - \frac{B_{t+1} - R_{t-1}B_t}{p_t} - \frac{s_t B^*_{t+1} - s_t \varphi_{t-1} R^*_{t-1} B^*_t}{p_t} + \frac{s_t T^*_t}{p_t} \tag{20}$$

where s_t denotes the nominal exchange rate; B_t and B^*_t represents the households' nominal bonds denominated in domestic and foreign currency, respectively; R_t and R^*_t the domestic and foreign gross nominal interest rate, respectively and W_t the nominal wage. The household receive a lump-sum transfer, T_t, from the monetary authority, transfers from abroad, T_{t^*} as well as dividend payments, Ω_t, from retailers. In addition, φ_t represents a gross borrowing premium that domestic residents must pay to obtain funds from abroad. As in Gertler *et al.* (2007), the country borrowing premium, φ_t, depends on total net foreign indebtedness and a random shock[3]. It is introduced for technical reasons. Without it net foreign indebtedness may be non-stationary. In particular,

$$\varphi_t = \left(\frac{B^*_t}{\overline{B}^*}\right)^{\varsigma}\exp\varepsilon_{\varphi_t} \tag{21}$$

where $\overline{B}^*$ is steady-state net foreign indebtedness.

Solving the household's problem yields the first-order conditions for the consumption allocation, money demand, labor supply, and the consumption/saving decision:

$$\frac{c^h_t}{c^f_t} = \frac{v}{1-v}\left(\frac{p^h_t}{p^f_t}\right)^{-\rho} \tag{22}$$

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3 Households are the owners of firms in this model and Colombian firms during the nineties had high access to foreign credit.

$$\frac{e_t c_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma} m_t^{\frac{\gamma-1}{\gamma}}} = \lambda_t \tag{23}$$

$$\frac{e_t b_t^{\frac{1}{\gamma}} m_t^{-\frac{1}{\gamma}}}{c_t^{\frac{\gamma-1}{\gamma}} + b_t^{1/\gamma} m_t^{\frac{\gamma-1}{\gamma}}} = \lambda_t - \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \tag{24}$$

$$\frac{\eta}{1 - h_t} = \lambda_t w_t x_t^h \tag{25}$$

$$\frac{\lambda_t}{R_t} = \beta E_t \left(\frac{\lambda_{t+1}}{\pi_{t+1}} \right) \tag{26}$$

where λ_t is the Lagrangian multiplier associated with the budget constraint and $m_t = M_t / p_t$, $w_t = W_t / p_t^h$, $\pi_{t+1} = p_{t+1} / p_t$ are real money balances, real wages, and the gross inflation rate respectively.

In addition, the optimality condition governing the choice of foreign bonds in conjunction with (26) yields the following uncovered interest parity condition (UIPC):

$$E_t \left\{ \frac{\lambda_{t+1}}{\pi_{t+1}} \left[R_t - \varphi_t R_t^* \frac{s_{t+1}}{s_t} \right] \right\} = 0 \tag{27}$$

2.   Foreign Behavior

Following Gertler *et al.* (2007), we distinguish between the wholesale (import) price of foreign goods and the retail price in the domestic market by allowing for imperfect competition and pricing-to-market in the local economy. At the wholesale level, the law of one price holds:

$$p_{w,t}^f = s_t p_t^{f*} \tag{28}$$

where $p_{w,t}^f$ represents the wholesale price of foreign goods in domestic currency, and p_t^{f*} the foreign currency price of such goods. Both foreign nominal interest rate, R_t^* and the nominal price of the foreign good, p_t^{f*} are taken as exogenous. In addition, we assume that foreign demand for home tradable good, c_t^{h*}, is given by:

$$c_t^{h*} = \left[\left(\frac{p_t^{h*}}{p_t^h}\right)^{-t} y_t^*\right]^\varpi \left(c_{t-1}^{h*}\right)^{1-\varpi} \quad 0 \le \varpi \le 1, \tag{29}$$

where y_t^* is real foreign output, which is taken as exogenous[4]. Inertia in foreign demand is represented by the term $\left(c_{t-1}^{h*}\right)^{1-\varpi}$.

3. Retailers

We assume that entrepreneurs sell all their output to retailers. Retailers then sell differentiated output goods to households, capital producers, and the government sector. Given that their output is differentiated, retailers have the monopolistic power to set prices of these final output goods. Following Calvo (1983), we assume that only a fraction $(1 - \phi)$ of sellers are allowed to change their prices. In particular, if the firm cannot set an optimal price, then it evolves according to the non-optimal rule $p_{t+1}^h(j) = p_t^h(j)\left(1 + \pi_t^h\right)^{\gamma_{p^h}}\left(1 + \pi\right)^{1-\gamma_{p^h}}$ where $\gamma_{p^h} \in [0,1]$ is the price indexation degree to past inflation and π is the CPI average inflation[5], and $\pi_t^h = \frac{p_t^h}{p_{t-1}^h}$. This rule implies that if the firm is not allowed to reset prices during l periods, then $p_{t+l}^h(j) = p_t^h(j)\prod_{i=1}^l \left(1 + \pi_{t-1+i}^h\right)^{\gamma_{p^h}}\left(1 + \pi\right)^{l\left(1-\gamma_{p^h}\right)}$.

The problem of the firm j is to pick $p_t^h(j)$ to maximize the discounted sum of expected profits when the firm adjusts prices once:

$$\max_{p_{jt}} E_t \sum_{l=0}^\infty (\beta\phi)^l \frac{\lambda_{t+l}\Omega_{t+l}(j)}{p_{t+l}^h}$$

subject to the demand function for variety j[6]

$$y_t^h(j) = \left(\frac{p_t^h(j)}{p_t^h}\right)^{-\theta} y_t^h \tag{30}$$

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4 The exogenous variables T_t^*, p_t^{i*}, R_t^*, and y_t^* are also assumed to be AR(1) processes.

5 Non-optimizing firms adjust the price with a composite inflation: they assign a weight of γ_{p^h} to past-period inflation rate, and a weight of $1-\gamma_{p^h}$ to the average (steady state) inflation rate. If $\gamma_{p^h} = 1$ there is full price indexation. If $\gamma_{p^h} = 0$ there is no indexation at all.

6 In the monopolistic competition framework of Dixit and Stiglitz (1977) this demand function is derived as the composite of individual final output (retail) goods and the corresponding price index as follows $y_{t+l}^h = \left(\int_0^1 y_{t+l}^h(j)^{\frac{\theta-1}{\theta}}dj\right)^{\frac{\theta}{\theta-1}}$ $p_{t+l}^h = \left(\int_0^1 p_{t+l}^h(j)^{1-\theta}dj\right)^{\frac{1}{1-\theta}}$ where $y_{t+l}^h(j)$ and $p_{t+l}^h(j)$ are the demand and price faced by each individual retailer j, respectively.

where

$$\Omega_{t+l}(j) = \left[p_t^h(j) \prod_{i=1}^{l} \left(1 + \pi_{t-1+i}^h\right)^{\gamma_{p^h}} \left(1 + \pi\right)^{l\left(1-\gamma_{p^h}\right)} - \xi_{t+l}^h \right] y_{t+l}^h(j)$$

The optimal price, $\tilde{p}_t^h$, is characterized by:

$$\frac{\tilde{p}_t^h}{p_t^h} = \frac{\theta}{\theta-1} \frac{E_t \sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} \xi_{t+l}^h \prod_{i=1}^{l} \left\{ \left(1+\pi_{t+i}^h\right)^{\theta} \left(1+\pi_{t-1+i}^h\right)^{-\theta\gamma_{p^h}} \right\} \left(1+\pi\right)^{-\theta l\left(1-\gamma_{p^h}\right)} y_{t+l}^h}{E_t \sum_{l=0}^{\infty} (\beta\phi)^l \lambda_{t+l} \prod_{i=1}^{l} \left\{ \left(1+\pi_{t+i}^h\right)^{\theta-1} \left(1+\pi_{t-1+i}^h\right)^{(1-\theta)\gamma_{p^h}} \right\} \left(1+\pi\right)^{(1-\theta)l\left(1-\gamma_{p^h}\right)} y_{t+l}^h}$$

Because the probability of adjusting prices is independent across firms, a fraction $1 - \phi$ of all the firms adjust each period.

Then $p_t^h = \left[(1-\phi)\left(\tilde{p}_t^h\right)^{1-\theta} + \phi \left[p_{t-1}^h \left(1+\pi_{t-1}^h\right)^{\gamma_{p^h}} \left(1+\pi\right)^{1-\gamma_{p^h}} \right]^{1-\theta} \right]^{\frac{1}{1-\theta}}$.

After some algebra we arrive at the hybrid Phillips curve

$$\hat{\pi}_t^h = \frac{\beta}{1+\beta\gamma_{p^h}} \hat{\pi}_{t+1}^h + \frac{\gamma_{p^h}}{1+\beta\gamma_{p^h}} \hat{\pi}_{t-1}^h + \frac{(1-\beta\phi)(1-\phi)}{\phi(1+\beta\gamma_{p^h})} \hat{\xi}_t^h \tag{31}$$

where variables with hats are log deviations from steady-state values.

Owing to imperfect competition, foreign goods sold in the local economy are subject to an analogous mark-up over the wholesale price. According with equation (28) retailers of foreign goods face the marginal cost $p_{w,t}^f$ and set prices according to a Calvo-style price setting equation. The inflation rate for foreign goods then satisfies

$$\hat{\pi}_t^f = \frac{\beta}{1+\beta\gamma_{p^f}} \hat{\pi}_{t+1}^f + \frac{\gamma_{p^f}}{1+\beta\gamma_{p^f}} \hat{\pi}_{t-1}^f + \frac{(1-\beta\phi^f)(1-\phi^f)}{\phi(1+\beta\gamma_{p^f})} \hat{\xi}_t^f \tag{32}$$

where $\pi_t^f = \frac{p_t^f}{p_{t-1}^f}$, the corresponding real marginal cost is $\xi_t^f = \frac{s_t p_t^{f*}}{p_t^f}$ and $(1-\phi^f)$ denotes the probability that a retailer of foreign goods resets its price in any given period. We assume that retailers of domestic and foreign goods face the same degree of price rigidity, so that $\phi^f = \phi$.

Finally, CPI inflation may be expressed as:

$$\hat{\pi}_t = (\hat{\pi}_t^h)^\nu (\hat{\pi}_t^f)^{1-\nu}$$

(33)

4.   Monetary Policy Rule

To close the model we assume, following Ireland (2003), that the central bank conducts monetary policy by adjusting a linear combination of the short-term nominal interest rate, R_t^n, and the money growth rate, $\mu_t = M_t / M_{t-1}$, in response to deviations of output, y_t, and inflation, π_t, from their steady-state values. Thus reaction function of the monetary authority is:

$$\frac{R_t^n}{R^n} = \left(\frac{\pi_t}{\pi}\right)^{\rho_\pi} \left(\frac{y_t}{y}\right)^{\rho_y} \left(\frac{\mu_t}{\mu}\right)^{\rho_\mu} \exp\left(\varepsilon_{R_t^n}\right)$$

(34)

where ε_{R_t} is the monetary policy shock.

IV.   BAYESIAN ESTIMATION

In order to test for of a financial accelerator mechanism in Colombia, we estimate and compare two versions of the model. The first model is estimated assuming that a financial accelerator mechanism (FA model) exists. The second is a constrained version of the model without financial rigidities, $\psi = 0$, that collapses to a standard DNK model. In addition, for Colombia, only about 35% of debt during the sample period was in units of foreign currency. For this reason, in our baseline exercises we have assumed that entrepreneur's debt was in domestic currency units[7].

The log-linearized version of the model forms a linear rational expectation system. The solution takes the form of a state-space model, driven by the 10 exogenous shocks e_t, b_t, x_t, A_t, ε_{Rt}, R_t^*, p_t^{f*}, y_t^*, T_t^* and φ_t. The structural parameters can be estimated by

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7 If debt is denominated in foreign currency, the entrepreneurial net wealth and the external finance premium equations are modified as follows:

$$n_{t+1} = f_t q_{t-1} k_t - \left[R_t S(\cdot)\varphi_{t-1} R_{t-1}^* \frac{S_t}{S_{t-1}} \frac{p_{t-1}}{p_t}\right] \frac{S_{t-1} B_t^*}{p_{t-1}} \text{ and } E_t f_{t+1} = S(\cdot) E_t \left[\varphi_t R_t^* \frac{S_{t+1}}{S_t} \frac{p_t}{p_{t+1}}\right].$$

a Bayesian procedure using data on five variables: consumption, investment, money real balances, the short-term nominal interest rate, and inflation.

A.   METHODOLOGY

We apply Bayesian techniques for several reasons. Firstly, from a practical point of view, the use of prior distributions over the structural parameters makes the highly non-linear optimization algorithm more stable. This is particularly valuable when only relatively small samples of data are available, as is the case with Colombian time series. Secondly, the Bayesian approach has the advantage of facilitating comparison of models that are non-nested and taking explicit account of all uncertainty surrounding parameter estimates. Thirdly, the Bayesian approach allows us to formalize prior information coming from previous studies, and, in this way, creates a link with the previous calibration-based literature. Finally, the potential under-identification problems, which could emerge in DSGE models, can be reduced by the use of informative priors using a Bayesian strategy, as in Canova (2007).

This empirical approach involves obtaining the posterior distribution of the model's parameters based on its log-linear state-space representation. The posterior distribution is obtained by the combination of the likelihood function for the observed data (obtained from a Kalman filter) with the selected prior distributions for each of the parameters of the model. If conjugacy is obtained by this combination, then the posterior can then be analytically optimized with respect to the model parameters directly, otherwise, computational tools, like Monte-Carlo Markov-Chain (MCMC) sampling, should be used.

Formally, defining Θ as the parameter space, we wish to estimate the model parameters, denoted by $\theta \in \Theta$. Given a prior p(θ), the posterior density of the model parameters, θ, is given by:

$$p\left(\theta \mid Y^T\right) = \frac{L\left(\theta \mid Y^T\right) p\left(\theta\right)}{\int L\left(\theta \mid Y^T\right) p\left(\theta\right) d\theta} \tag{35}$$

where $L\left(\theta \mid Y^T\right)$ is the likelihood conditional on observed data, Y^T. The likelihood function is computed under the assumption of Gaussian distributed disturbances by

combining the state-space representation implied by the solution of the linear ratio-
nal expectations model and the Kalman filter.

The posterior distribution is typically characterized by measures of central location,
such as the mode or the mean, and measures of dispersion, such as the standard
deviation, or as the highest posterior density (HPD).

Having applied this procedure to both models, the DSGE models are compared in
their ability to fit the data. Suppose we have two competing models, A and B, whose
prior distribution are $p(A)$ and $p(B)$, respectively. Model comparisons are based on
the ratio of the posterior model densities, known as the Posterior Odds ratio:

$$\frac{p(A \mid Y^T)}{p(B \mid Y^T)} = \frac{p(A)p(Y^T \mid A)}{p(B)p(Y^T \mid B)} \tag{36}$$

where $p(Y^T \mid A)$ and $(Y^T \mid B)$ are the marginal densities of the data conditional on the
model A or B, respectively. When competing models are assigned equal prior probabi-
lities, so that $p(A) = p(B)$, posterior odds are equivalent to the ratio of the marginal like-
lihoods. In this paper, we estimate these marginal densities using the Laplace approxi-
mation[8]. As the value of the Posterior Odds ratio is higher than 1, the data information
alters the prior odds in favor of A, or against A when it is lower than 1.

B.   DATA

We estimate the models using quarterly data on consumption, inflation, interest
rates, real money balances, and investment for the period 1980:1-2005:4. All of
these variables are measured as deviations from trend obtained using a Hodrick-
Prescott filter with a smoothing parameter of 1600. Data on both consumption and
investment are used, rather than data on output alone; as this helps to identify the
capital adjustment cost and capital share parameters. Consumption is measured
by real personal consumption expenditures, while investment is measured by real
gross private investment. We calculate real money balances by dividing the M1

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8 The laplace approximation is the logarithm of the posterior density. Second-order
approximations are used to obtain posterior moments, instead of modal or first-order approximations,
see Carlin and Louis (1998).

money stock by the GDP deflator and inflation is measured as changes in the GDP deflator. Finally, the short-term nominal interest rate is measured by the 90-day deposit rate. Consumption, investment, and real money balances are all expressed in per-capita terms.

C. CALIBRATION AND PRIORS

Before estimating the models it is necessary to calibrate several parameters in the model that remain unidentified even with data on six variables. Some are set to match key steady-state ratios. The parameter, η, that measures the weight of leisure in the representative household's utility function, cannot be estimated without data on employment, Ireland (2003). The calibrating value $\eta = 1.315$ implies that in steady-state households spend about one third of their time working. The parameter, θ, determining the steady-state markup of price over marginal cost, cannot be estimated without data on wages; the calibrating of $\theta = 6$ implies a steady-state markup of 20 percent, a common value used in the literature. The constant associated with money demand, b, is set to 0.052 to ensure that the steady-state ratio of real balances to consumption is close to its historical value. We set the steady-state leverage ratio equal to 0.26, according to its empirical counterpart over our estimation sample. The discount factor, β, is set equal to 0.99 to match the steady state real interest rate - approximately four percent - and the depreciation rate, δ, is set at 0.025. The parameter ρ that measures consumption intra-temporal elasticity of substitution is set equal to 1. To match the average ratio of consumption to GDP in Colombia over the period 1980-2005 - nearly 0.65 - we set the share of domestic in goods in the consumption composite, ν, equal to 0.76. With regard to the parameters of the export demand, the elasticity of exports' demand τ was calibrated in 0.75 and the share parameter ϖ equal to 0.25. This implies a relatively high degree of inertia in export demand in line with the response of the Colombian exports during the period 1980-2005. The elasticity of country risk premium with respect to net foreign debt, ς, is set equal to 0.00003, which as pointed out by Gelrtler *et al.* (2007) should be small enough so that the friction in the world capital market does not alter the high-frequency model dynamics but nonetheless makes net foreign indebtedness revert to trend. According to their historical value, we set the steady-state external finance premium at 1% and the steady-state leverage ratio equal to 0.8. Finally, the price indexation degree parameters, γ_{p^h} and γ_{p^f} are set equal to 0.5 (the results are not heavily dependent on these parameters).

We estimate the remaining 27 parameters in the model. Table 1 summarizes our assumptions regarding the prior distributions. Those structural parameters that are only bounded from below are modeled using a gamma distribution. In particular, for the elasticity of money demand with respect to interest rate, γ, we assume a gamma distribution with mean 0.14. The adjustment cost parameter, χ, also follows a gamma distribution with mean 0.5 with standard deviation of 1. Therefore this coefficient can vary in a 90% confidence interval between 0.089 and 3.841. This is a wide range that intends to account for the uncertainty that we have about this parameter. The prior for the elasticity of the external finance premium with respect to firm leverage, ψ, follows a gamma distribution with mean 0.1 and standard deviation of 0.5.

Table 1
Prior Distribution for the Parameters of the Models

Name	Range	Density	Mean/Mode	Std/Df	90 %	Interval
ψ	$[0, \infty)$	Gamma	0.100	0.500	0.023	0.221
γ	$[0, \infty)$	Gamma	0.140	1.000	0.066	0.236
χ	$[0, \infty)$	Gamma	0.500	1.000	0.335	0.665
ϕ	$[0, 1]$	Beta	0.500	0.100	0.335	0.665
ρ_π	R	Gaussian	1.400	0.500	0.804	1.996
ρ_y	R	Gaussian	0.600	0.100	0.424	0.776
ρ_μ	R	Gaussian	0.600	0.300	0.447	0.753
α	$[0, 1)$	Beta	0.500	0.100	0.335	0.665
ρ_a	$[0, 1]$	Beta	0.500	0.200	0.172	0.828
ρ_b	$[0, 1]$	Beta	0.500	0.120	0.302	0.698
ρ_e	$[0, 1]$	Beta	0.500	0.120	0.302	0.698
ρ_x	$[0, 1]$	Beta	0.500	0.120	0.302	0.698
ρ_y^*	$[0, 1]$	Beta	0.500	0.250	0.097	0.903
$\rho_{p^f}^*$	$[0, 1]$	Beta	0.500	0.250	0.097	0.903
ρ_T^*	$[0, 1]$	Beta	0.500	0.250	0.097	0.903
σ_A	$[0, \infty)$	Inv. Gamma	0.003	2.000	0.001	0.017
σ_e	$[0, \infty)$	Inv. Gamma	0.018	2.000	0.001	0.017
σ_b	$[0, \infty)$	Inv. Gamma	0.030	2.000	0.002	0.028
σ_x	$[0, \infty)$	Inv. Gamma	0.033	2.000	0.013	0.169
σ_{eR}	$[0, \infty)$	Inv. Gamma	0.027	2.000	0.003	0.042
$\sigma_{p^f}^*$	$[0, \infty)$	Inv. Gamma	0.067	2.000	0.001	0.017
σ_φ	$[0, \infty)$	Inv. Gamma	0.003	2.000	0.001	0.017
σ_y^*	$[0, \infty)$	Inv. Gamma	0.089	2.000	0.001	0.017
σ_T^*	$[0, \infty)$	Inv. Gamma	0.003	2.000	0.001	0.017

The mode and the degrees of freedom for the inverse gamma are presented.

Source: author's calculations.

The probability that prices remain unchanged for the next period, ϕ, follows a beta distribution with a mean of 0.5, a common value in the literature. The capital share, α, also follows a beta distribution with mean 0.5.

The prior distribution for the parameters in the interest rate rule are modeled as normal distributions in order to allow for a more general policy rule as in Ireland (2003). The prior mean for the inflation feedback coefficient in the policy rule, ρ_π, is set to 1.4 based on previous work by Bernal (2002). For the other two parameters in the policy rule, ρ_y and ρ_μ, the prior mean was set to 0.6, with standard deviation of 0.1 and 0.3, respectively. The autoregressive parameters of the stochastic shocks should lie in the (0,1) interval range, and therefore are modeled using beta distributions. Finally, the prior distribution for the standard deviations of the structural shocks follows an inverse gamma.

V.   ESTIMATION RESULTS

The posterior means and the 5 and 95 percentiles of the posterior distribution of the parameters are calculated from the output of the Metropolis algorithm and summarized in Table 2[9]. The plots of the prior and posterior densities are presented in Graph 2 which gives an indication of how informative the observed data are about the structural parameters. Overall, it appears that the data are quite informative on the behavioral parameters, as indicated by the lower variance of the posterior distribution relative to the prior distribution. Two exceptions are the output response in the interest-rate rule and the capital's share in the production function.

The central question of interest for the empirical analysis is whether the financial accelerator mechanism helps in fitting the data. First, we present the parameter estimates and the Posterior Odds test to compare the models with (FA) and without (NoFA) the financial accelerator mechanism. Next, we present some impulse response implied by the models in order to illustrate the different model dynamics implied by the financial accelerator.

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9 The results are based on a total of 100,000 draws and four independent chains. The Brooks and Gelman (1998) convergence criteria are achieved.

Graph 2
Priors and Posteriors Densities
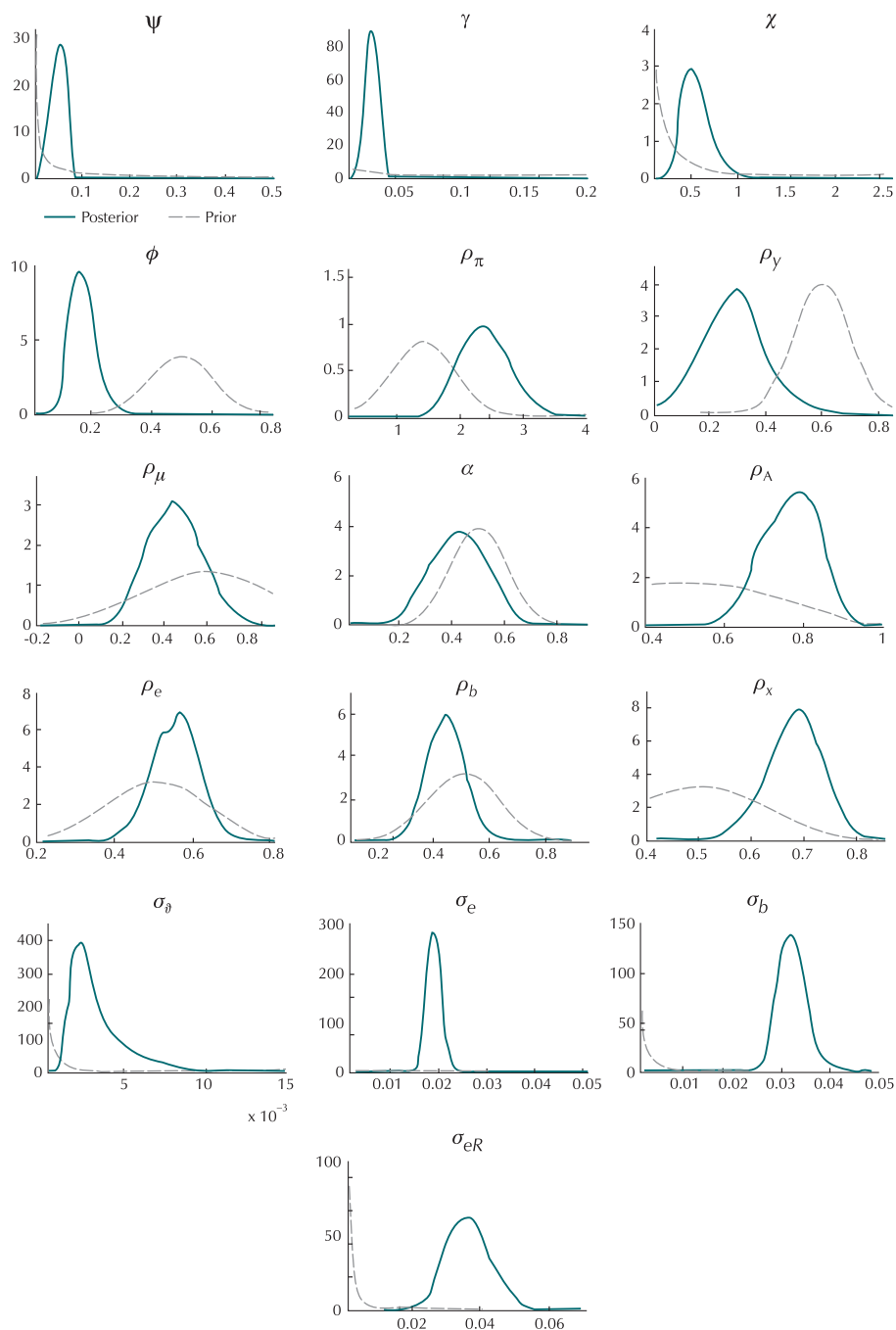
Source: author's calculations.

Table 2
Posterior Distribution for the Structural Parameters

Parameter	Mean	FA Model		NoFA Model		
		5 %	95%	Mean	5 %	95 %
ψ	0.050	0.027	0.073			
γ	0.028	0.021	0.036	0.020	0.011	0.034
χ	0.565	0.328	0.767	0.234	0.172	0.281
ϕ	0.169	0.104	0.235	0.194	0.111	0.271
ρ_π	2.408	1.738	3.060	1.159	0.905	1.213
ρ_y	0.292	0.093	0.462	-0.051	-0.079	-0.028
ρ_μ	0.448	0.242	0.655	0.075	0.002	0.174
α	0.438	0.258	0.580	0.654	0.533	0.768
ρ_a	0.763	0.655	0.877	0.838	0.767	0.889
ρ_b	0.432	0.318	0.551	0.455	0.327	0.564
ρ_e	0.546	0.459	0.648	0.610	0.510	0.726
ρ_x	0.677	0.596	0.766	0.693	0.597	0.803
ρ_y^*	0.485	0.112	0.892	0.488	0.086	0.857
$\rho_{p^f}^*$	0.572	0.123	0.923	0.510	0.141	0.928
ρ_T^*	0.497	0.088	0.895	0.510	0.087	0.891
σ_A	0.026	0.016	0.036	0.052	0.031	0.072
σ_e	0.019	0.017	0.021	0.014	0.012	0.016
σ_b	0.032	0.027	0.037	0.030	0.027	0.035
σ_x	0.046	0.023	0.067	0.013	0.010	0.015
σ_{eR}	0.037	0.026	0.047	0.018	0.015	0.020
$\sigma_{p^f}^*$	0.009	0.001	0.006	0.005	0.002	0.009
σ_φ^*	0.004	0.001	0.006	0.004	0.001	0.007
σ_y^*	0.005	0.002	0.010	0.004	0.002	0.009
σ_T^*	0.004	0.001	0.007	0.004	0.002	0.007
Laplace Approx.		1302.3			1298.8	
Posterior Odds (FA/NoFA)			34.090			

Source: author's calculations.

A.   ESTIMATES AND TESTS

The main result is that the posterior mean of the elasticity of the external finance premium with respect to leverage, ψ, is statistically higher than zero and equal to

0.050, see Table 2. This estimate turns out to be similar to the value calibrated by Bernanke and Gertler (2000).

Other estimates are plausible, for both models the posterior mean of the constant elasticity of substitution between consumption and real balances, γ, is about 0.02 which is similar to the value estimated for the US by Ireland (2003). On the other hand, conditional on the FA model the posterior mean of the capital adjustment cost parameter, χ, is 0.56 while under the NoFA model the posterior mean estimate is 0.23. These estimates are similar to the 0.25 value used by BGG. Capital adjustment costs have an important interaction with the financial accelerator mechanism. If capital adjustment costs are high, the price of capital will respond to shocks to a greater extent. The price of capital has a direct effect on the net worth of firms and the cost of external financing, as in Dib and Christensen (2008). The higher capital adjustment cost in the FA model suggests that the FA mechanism may be helping to generate investment volatility.

The estimates of the Calvo probability of not resetting optimally prices are 0.17 in the FA model and 0.19 in the NoFA model. This implies an expected price duration of about 1.2 quarters, a result that is in line with Julio and Zárate (2007), for the PPI. For both models the posterior mean of the capital share parameter, α, is above 0.4, somewhat higher than the value that is often used in calibration exercises.

In both models the estimates for the policy rule coefficients, ρ_π, ρ_y, and ρ_μ, indicate that the central bank of Colombia has responded more strongly to inflation devia-tions than to output or to money-growth fluctuations.

Finally, we use the Bayesian Posterior Odds ratio (equation 38) to compare the models in their ability to fit the data. The prior probabilities for each model are assumed equal to 1/2. Therefore, the odds ratio test is the ratio of the marginal density of the data. The approximation of the log data densities of each model is presented in the last row of Table 2. The posterior odds of FA model versus NoFA model is roughly 1 to 34 and thus strongly favors the FA model[10].

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10 The posterior odds ratio is obtained as the exponential of the difference of the Laplace approximations.

B.   VARIANCE DECOMPOSITIONS

Table 3 shows the forecast-error decomposition of the de-trended output, consumption, investment, money growth, inflation, and the nominal interest rate attributed to each of the 10 shocks (foreign shocks are aggregated). In the NoFA model, productivity shocks account for a high percentage of the variance of all of the variables except inflation and investment. In the FA model, both foreign shocks and monetary policy shocks account for a large part of output fluctuations, together they account for more than 50 percent of the forecast error variance of output. This means that monetary policy shocks and foreign shocks have played an important role in driving business cycles in Colombia. The FA model increases the role of these shocks because it introduces a direct transmission mechanism from monetary policy that is missing in the NoFA model.

The variance decomposition also shows that in the FA model the preference shocks and the foreign shocks are the main driver of consumption while in the NoFA model the main driver force are the productivity shocks. It is quite clear that in both models monetary policy shocks are the most important drivers of inflation.

Table 3
Forecast Error Variance Decompositions (At the Mode of the Posterior Distribution)

Variable	Preference Shock e_t	Money Demand Shock b_t	
With Financial Accelerator			
Output	6.1	1.3	
Consumption	20.1	0.1	
Investment	4.1	1.5	
Money	2.2	15.0	
Inflation	1.3	4.8	
Nominal interest rate	7.8	7.4	
Without Financial Accelerator			
Output	3.0	0.1	
Consumption	35.1	0.1	
Investment	2.8	0.0	
Money	0.5	16.4	
Inflation	0.1	5.2	
Nominal interest rate	17.2	13.0	

Source: author's calculations.

C.   IMPULSE RESPONSES

1.   With and Without Financial Accelerator

Previously we have established that the parameter capturing the financial accelerator mechanism had a positive posterior mean. How important could that be? We now examine the responses of the whole model to the effects of an expansionary monetary policy shock. Graph 3 shows the impulse responses with and without the financial accelerator. In each figure the dashed line designates the "baseline" impulse response which is from a model with the same steady state as the complete model with imperfect credit markets, but in which the additional dynamics associated with the financial accelerator have been "turned off". The solid line corresponds to the model that includes the financial accelerator mechanism. In response to a monetary policy shock of a 100 basis points, the addition of credit-market frictions does not substantially affect the behavior of the nominal interest rate. But the financial accelerator mechanism implies a significant amplification and propagation of the monetary policy shock on investment and output. In particular, the response of real output is twice as strong with the financial accelerator included than without it and

Investment Efficiency Shock x_t	Productivity Shock A_t	Monetary Policy Shock eR_t	Foreign Shocks
With Financial Accelerator			
15.1	0.6	26.3	50.7
2.9	0.2	2.9	71.6
54.1	0.1	32.7	7.5
13.6	0.8	28.3	40.1
6.1	0.8	43.0	44.1
9.5	0.3	19.1	55.9
Without Financial Accelerator			
26.8	69.6	0.4	0.1
22.3	40.8	0.7	1.1
72.8	24.2	0.2	0.0
21.8	59.5	1.5	0.4
6.7	28.8	59.1	0.1
14.2	53.7	1.7	0.2

the response of investment is increased fivefold. Moreover, the persistence of the shock is longer in the FA case.

Graph 3
Responses to a Monetary Policy Shock: With and Without Financial Accelerator
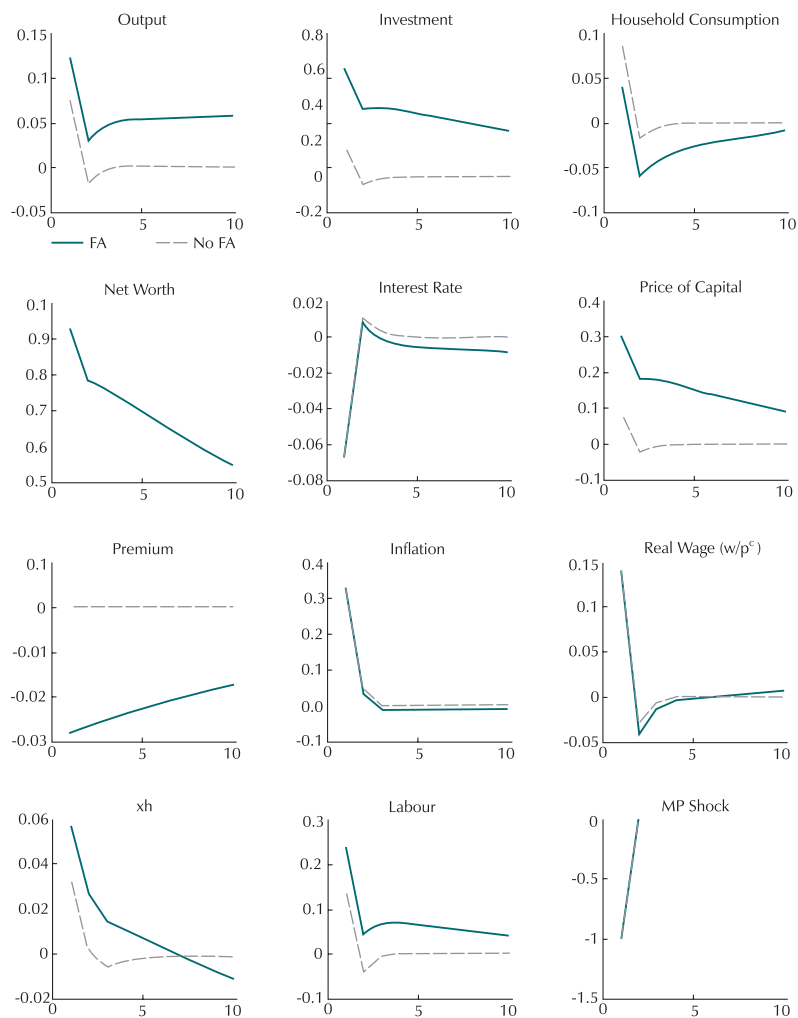
Source: author's calculations.

The mechanism is as in BGG: The unanticipated decline in the policy rate stimulates the demand for capital, which in turn increases investment and the price of capital. The increase in asset prices increases net worth, forcing down the finance premium, which further stimulates investment.

2.   Exchange Rate Regimes

Here we consider the model's response to a country's risk premium shock under two scenarios: (a) a pure fixed exchange rate regime and (b) a floating exchange rate regime, where the monetary authority follows a Taylor rule like the one presented in equation (34). The motivation is to test whether the position of having to defend an exchange rate peg make severe financial distress more likely, Gertler *et al.* (2007). Then we evaluate whether the model is able to replicate a financial crisis like the one which occurred in Colombia in 1998-1999.

We consider a 600 basis point increase in the country's borrowing premium, φ, similar to the increase observed in the EMBI Latin America in Colombia during the financial crisis. We assume a first-order autoregressive process with a 0.5 coefficient. The results are presented in Graph 2.

Before 1998, Colombia was in a managed float with a band 7% wide. When the crisis first struck, the monetary authority tried to keep the exchange rate fixed, with the domestic nominal interest rate rising sharply following the rise in the country's borrowing premium. Interest rates also rose in real terms which, in turn, induced a contraction in output. The financial accelerator mechanism exacerbated the fall in output - the increase in the interest rates caused a contraction in asset prices which induced a fall in net worth and an increase in leverage ratios that increased the external finance premium. Investment and output fell even further. The monetary authority abandoned the peg as the crisis unfolded.

Overall, the model captures the key outcomes of the Colombian experience. The decrease in output was 4.2%, while the model predicts a fall of 3.7%. Consumption dropped about 5.5% compared with nearly 4.0% in our estimates. In the Colombian data, the drop in real investment was 34% and the predicted is 20%. The data and the model imply a large reduction in imports which drove the expansion in net exports.

As Graph 4 illustrates, the crisis might have been less severe under a credible flexible exchange rate regime. Because the nominal interest rate is no longer tied to the foreign interest rate but follows the Taylor rule, the increase in the country risk premium produces a depreciation of domestic currency which acts as a shock absorber. The depreciation of currency produces an increase in exports and CPI inflation. The nominal interest rate increases to fight inflation but its increase is lower than in the case of a fixed exchange rate regime. The fall in investment and output is moderate.

Graph 4
Responses to a Country Risk Premium Shock
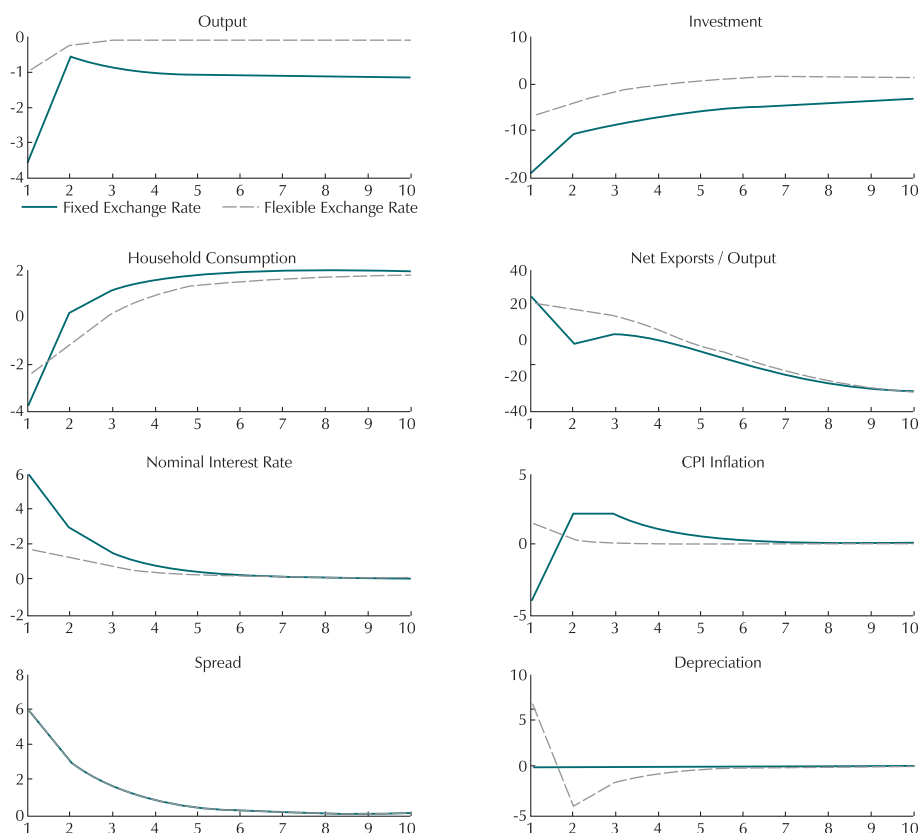
Source: author's calculations.

VI.   FINAL REMARKS

This paper estimates a small open economy dynamic general equilibrium model with credit-market imperfections for the Colombian economy. We find empirical evidence, in the form of an estimated probability distribution, that a financial accelerator mechanism was a crucial part of the explanations for the strong swings of investment and output observed during the period 1998-1999. The results also show that the response of the macroeconomic variables in the estimated model give an increase in the country foreign borrowing premium as the one observed between

1998 and 1999, and a monetary authority that tried to defend a fixed exchange rate, are very much in line with the behavior observed in the data.

We used a Bayesian procedure to compare two versions of the model: one with and one without the financial accelerator. The estimated value of the key parameter in the accelerator mechanism, the elasticity of the external finance premium with respect to firm leverage, is statistically significant. A Posterior Odds test finds an improvement in the model's fit with the data when the financial accelerator is present. According to the variance decompositions, a monetary policy shock is able to explain about 18% of the business cycle in Colombia.

This paper does not claim that financial accelerator effects were the single determinant of investment in the 1998-1999 recession, but rather that financial frictions helped to magnify the effect of other shocks such as monetary policy. For this reason we are able to explain the findings of other researchers. We show that a model without financial frictions could incorrectly identify a great role for productivity shocks in explaining movements in output. But in a model with financial frictions the variance decomposition attributes a greater proportion of output to monetary policy.

Of course, the estimated model remains stylized and should be further developed. In particular, some other nominal and real rigidities might be included in order capture more of the sources of the business cycle in Colombia.

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