Financial Inefficiency and Real Business Cycle in Colombia

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Abstract

In a dynamic, stochastic, general equilibrium model, we explore the optimal response of the inhabitants of a closed economy to an inefficient *ad hoc* financial system that in its intermediation duty looses a fraction of aggregate savings which otherwise would become aggregate investment. The incidence over the cycle of shocks to average financial inefficiency and technology is analyzed, as well as the steady state welfare gain of a reduction in average financial inefficiency. The descriptive power of the model is assessed with Colombian data between 1970 and 1992. The results in the paper suggest that the model's predictions are largely consistent with aggregate behavior of the Colombian economy, making it possible to explore several issues of financial liberalization and deepening.

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1. Introduction

Since the beginning of the 1970's, an important bulk of literature has developed to reexamine the relationship between the financial sector activity and economic

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growth, which has been strongly motivated by the important empirical evidence offered by developing countries. In those countries both inefficiency and repression in the financial sector suggested an obstacle for economic growth. However, the relevance of these factors in the explanation of the business cycle of developing nations remains an unexplored issue. With this in mind, the present paper intends to analyze some aspects of the incidence of financial inefficiency in the context of a Real Business Cycle (RBC) model, with an empirical application particular to the Colombian case. An artificial closed economy is built, subject to stochastic shocks in a dynamic, general equilibrium context, which includes an *ad hoc* inefficient financial sector[1].

The rest of the paper develops as follows. In the second part a revision of the theoretical framework that formalizes the measurement of financial inefficiency is presented. In the third part the Colombian evidence concerning financial inefficiency is reviewed, together with a brief summary of papers previously developed in the same direction. In the fourth part, the model, its solution and calibration are presented. In the fifth part the cyclical properties of the artificial economy are described and compared with those of the main real Colombian data between 1970 and 1992. In the sixth part the welfare gain of a reduction in the average inefficiency of the financial system is analyzed. In the last section, conclusions are drawn and possible future extensions of the model are stated.

2. Measurement of Financial Inefficiency

There are two economic perspectives for the measurement of financial inefficiency at a micro level. The first of these associates the problem to the existence of scale and scope economies in banking firms. The second and most innovative is the X-efficiency approach. We now distinguish both concepts and briefly review the benefits and difficulties of each measurement.

The pioneering literature in the measurement of inefficiency by scale economies is based on the assumption that the average cost curve for banks is relatively flat, U-shaped, where medium sized firms are more efficient in scale terms than those which are either small or large. The inefficiency is a product of the nonexploitation of profits (in cost reduction) which makes such scale economies possible. Anyhow this method presents various inconveniences (many of these are econometric, as it

[1]There are no domestic or international papers that tackle this matter, in the light of Real Business Cycles (RBC) models. Furthermore, RBC models calibrated for Colombia are scarce, being important Suescún (1997), and Hamman and Riascos (1988).

is shown in Berger, Hunter and Timme, 1993), where the most relevant is the fact that it is assumed that firms find themselves on their efficient cost frontier and any deviation from it is random, which is obviously contradicts the inefficiency issue. The most important papers that examine the existence of this type of inefficiency in Colombia are Bernal and Herrera (1983), Suescún (1987), Villegas and Acosta (1989) and Ferrufino (1991).

The literature that deals with the measurement of X-inefficiency, seeks for the inefficiency that arises from the impossibility of firms to control costs. This means that the X-efficiency describes all the technical and distributive efficiencies, different to those of scale and scope. There exists consensus upon the fact that financial inefficiency is primarily characterized by X-inefficiency and not scale or scope inefficiency. Berger, Hunter and Timme (1993) show that X-inefficiency can represent a 20% or more of banking costs, while scale and scope inefficiency represent only a 3% or 4% of such costs[2]. Anyhow, this methodology presents problems in the sense that there exist various empirical approximations for its measurement, and these occasionally differ in their results. The only paper for Colombia that uses this result is that of Misas and Suescún (1996) and their conclusion indicates that the inefficiency in the Colombian financial sector may well be close to "eat" 1% of the GDP. This result will be used in the calibration of the model later on.

3. Evidence of Financial Inefficiency in Colombia

The literature on financial inefficiency has rapidly grown ever since the seminal contributions of McKinnon (1973) and Shaw (1973). Based upon these papers, this branch of economic theory has subdivided, as Fry (1982) indicates, in contributions addressed towards relating inefficiency and financial repression with monetary, fiscal and precautionary topics (coincident with the potential uses of the bank reserve, which is considered by many as an important part of the inefficiency of the financial system).

In the Colombian case, it is possible to mention some papers which have attempted to develop further analysis in this matter. Zuleta (1995) presents an open economy model in which elements that may bring to life a financial crisis are explored in the face of financial deepening, which easily result in a deterioration of loans because of the relaxation of lending criteria by banks, and in particular

[2] Misas and Suescún (1996), point this difference in Colombia to be 3% to 4% of scope and scale inefficiency, and 25% to 35% X-inefficiency, of total banking costs.

because of the increasing trade deficit which rises the demand for money. Gomez (1997) builds a partial equilibrium model based in Chari, Jones and Manuelli (1996), with banks but without money, in which the incidence on the spread of a reduction of the reserve requirements and an increase in efficiency of the financial system, are examined. The model is calibrated for Colombia. Vargas (1997) presents a two period model in which financial intermediation, subject to costs or distortions which generate a gap between loans and deposit interest rates, is introduced in an *ad hoc* manner. With this model, the fiscal and monetary situations related to the financial deepening in Colombia, are studied.

Additionally, the paper by Carvajal and Zuleta (1996), must be mentioned, as it constitutes the inspiration to the type of exogenous inefficiency which is employed in this model, following in spirit Pagano (1993)[3]. This paper presents a Ramsey-Cass and Koopmans type model, proposed by Pagano, in order to find evidence on the incidence of financial intensification in the Colombian case, under the presence of inefficient elements in the system.

In the following model, which is calibrated with Colombian data, a scheme of financial inefficiency is introduced, without specifying its origin, since the objective pursued is the analysis of the incidence of such inefficiency upon the business cycle, leaving aside the reasons of its existence.

4. The Model

Suppose an economy which is subject to two stochastic shocks[4], both of which are independent and identically distributed. These shocks affect technology and average financial inefficiency, the former explained later on.

The artificial economy is inhabited by a continuum of identical households which live infinitely[5]. The representative household is of measure Nt and the number of members per household grows at a rate of $\eta_N - 1$. Labor is elastically

[3]Pagano (1993) proposes an endogenous growth technology of the AK type, in which the financial system's better information lets it act as an investment-proyects-risk-valuator, in a way which establishes an ordering of those potentially successful. The risk-spreading task of financial intermediation stimulates risky but more profitable projects, fostering long run growth. In Pagano's words, a developed financial system overrides the asymmetry problems that generate credit rationing, as stated by Stiglitz and Weiss (1981).

[4]Shocks are revealed to agents in each period. However, future shocks are unknown.

[5]Blanchard (1985) proposes another approximation to small economy modeling, in which agents live finitely, facing a positive death probability in each period of time, that follows a *Poisson* process.

supplied in the intensive margin, i.e., it is divisible, contrary to Hansen (1985)[6]. Preferences are defined upon stochastic streams of the consumption good and per capita leisure i.e., $\{c_t\}_{t=0}^{\infty}$, $\{l_t\}_{t=0}^{\infty}$. The problem solved by the representative household, then corresponds to the maximization of the expected lifetime utility, given by:

$$W = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(c_t, l_t) \right\} \tag{4.1}$$

where $\beta \in (0,1)$ reflects time preference. E_0 is the mathematical expectations operator, conditional on information available at time zero. Expectations are based on the known probability distribution of the stochastic processes which affect the economy. The utility function adopts the familiar constant elasticity of substitution (C.E.S)[7] format:

$$U(c_t, l_t) = \frac{\left(c_t^{1-\alpha} l_t^{\alpha}\right)^{1-\sigma}}{1-\sigma} \tag{4.2}$$

where the intertemporal elasticity of substitution is given by $\frac{1}{\sigma}$ and α represents the relative weight of leisure within the utility function. The budget and time constraints are:

$$N_t c_t + I_t \leq Y_t \tag{4.3}$$

$$1 = l_t + n_t$$

where I corresponds to investment, Y is income (both at an aggregate level) and n are hours worked. Without loss of generality, it is assumed that households own and manage the productive sector taking the necessary investment and employment decisions. The unique sector, combines capital and effective labor units in

[6] The distinction consists in that in the present context, agents may work part of each unit of time, while in the indivisible labor approach they work the complete unit of time, and face a positive probability of being unemployed. That is, the explanation of the variation in total hours worked in the former relies on the number of workers entering the labor force, while in the latter, arises because of the variation in hours worked itself.

[7] This type of functions fulfil Inada (1964) conditions that assure interior solutions, as well as the standard neoclassical conditions.

its constant returns production[8] function[9]:

$$Y_t = e^{z_t} F_t(K_t, n_t N_t H_t) \tag{4.4}$$

where z_t is a shock to technology, which follows a Markov process, i.e.,

$$z_{t+1} = \rho z_t + \varepsilon_{t+1}$$

and ε is $i.i.d \sim N(0, \omega_\varepsilon)$. The capital transition function is characterized as:

$$K_{t+1} = (1-\delta)K_t + (1-g_{It})I_t \tag{4.5}$$

[8]We also used adjustment costs in the model, as is now standard in RBC literature. Those costs are introduced to reduce the excessive volatility of investment in response to shocks, at cycle frequencies. However, the economy arrives to the steady state with or without those adjustment costs. For reasons that we show later in the paper, adjustment costs turned out to be unnecessary in the calibration of our model. In particular, we modified the artificial economy to incorporate the adjustment costs in the production function, as follows:

$$Y_t = e^{z_t} F_t(K_t, n_t N_t H_t) - CA_t$$

where

$$CA_t = \frac{\varphi}{2}\left[\frac{\left(\frac{K_{t+1}}{\eta_N \eta_H} - K_t\right)^2}{N_t H_t}\right]$$

CA_t are adjustment costs of capital, φ is the adjustment parameter and the CA function is supposed convex. As we illustrate in section 3.3.1 ahead, the model has to be transformed to its stationary representation, which implies that $ca_t = \frac{CA_t}{N_t H_t}$, so that CA becomes:

$$ca_t = \frac{\varphi}{2}\left(k_{t+1} - k_t\right)^2$$

In the expression above, it is verified that adjustment costs vanish in steady state, when k doesn't change. Taking this into account, equation 3.8 can be rewritten as (noting that time subscripts are eliminated, and variables in $t+1$ are denoted with primes ($'$)):

$$\tilde{c} = e^z k^\theta n^{1-\theta} - \frac{\varphi}{2}\left(k' - k\right)^2 - i \ .$$

For a justification of adjustment costs as explained by intersectorial labor movements, see the three sector model in Suescún (1997).

[9]Constant returns to scale permit a natural aggregation, in a way that K and HL become complementary in an Edgeworth sense (see King, Plosser y Rebelo, 1987, pg. 2). This type of function fulfil Inada (1964) conditions that assure interior solutions, as well as the standard neoclassical conditions.

here, K corresponds to capital, $\delta \in (0,1)$ is the depreciation rate and investment is considered to be irreversible, i.e., $I_t \geq 0$. As it was previously mentioned, and following Pagano (1993) and Carvajal and Zuleta (1996), in the intermediation process turning savings into investment, the financial system appropriates a fraction g_I of aggregate savings in each period, which accounts for the intermediation margin, commissions, insurance etc. and we suppose here these resources are "dumped in the garbage". The type of inefficiency we are suggesting is X-inefficiency, as it deals with a bad costs control. Then, the parameter g_I corresponds to the shock upon the level of inefficiency[10] in the financial system and follows a Markov process, just as technology does, but independent from the former, so that $g_{It+1} = (1-\gamma)\bar{g}_I + \gamma g_{It} + \zeta_{t+1}$, where $\bar{g}_I$ is the average level of the process and ζ_{t+1} is *i.i.d.* $\sim N(0, \omega_\zeta)$.

As we said, households combine capital and labor efficiency units in production. A Cobb-Douglas form is then supposed for the production function, in the following way:

$$F(K_t, L_t) = K_t^\theta (n_t N_t H_t)^{1-\theta} \tag{4.6}$$

The parameter $\theta \in (0,1)$ represents, as usual, the fraction of the product devoted to capital remuneration. Following Suescún (1997), H corresponds to the human capital incorporated in each worker, which grows at an exogenous rate grater than 1, i.e., $\eta_H = H_{t+1}/H_t > 1$, and is not depreciated.

4.1. Central Planner Equilibrium[11]

The problem solved by the central planner is the maximization of (3.1) given (3.2), subject to (3.3) - (3.6) and the stochastic shocks that affect the economy. The preferences and technology are consistent with the steady state growth, according to the conditions imposed in King, Plosser and Rebelo (1998). The model shall additionally be transformed in a stationary representation, normalizing the variables according to their growth sources. Note that the economy grows in population and labor efficiency[12]. The transformed variables are represented in lower case letters (and consumption presents a squiggle):

[10] We introduce the shock in capital's transition equation, for it is indeed a disturbance to accumulation.

[11] Note that in the present context, given the *exogeneity* of financial inefficiency the central planner's problem results in an allocation identical to that of the decentralized economy, which is pareto optimal.

[12] However, in the utility function leisure is a stationary variable, so it doesn't have to be transformed.

$\tilde{c}_t = \frac{c_t}{N_t H_t}$; $k_t = \frac{K_t}{N_t H_t}$; $i = \frac{I_t}{N_t H_t}$, *etc.*

The discount factor is transformed[13] as $\tilde{\beta} = \beta(\eta_H^{1-\alpha})^{1-\sigma}$ and requires that $\tilde{\beta} < 1$ so that the return function is finite. As a consequence the non-stochastic transformed model, converges to a feasible steady state.

As it is to be expected in this type of models, the present does not have an exact analytical solution, therefore a numerical solution is required. The theory suggests several algorithms. The one used in this case is a version of the Optimal Linear Regulator Algorithm (see Technical Appendix for details on the theoretical foundation of the algorithm).

The relevant information for the planner in her problem is a triplet of state variables which can be separated between endogenous and exogenous. The exogenous states are $\phi = (g_I, z)$, i.e., the exogenous shocks. The endogenous state is k. The planners decision or control vector is then $\Lambda = (\tilde{c}, i, l)$, taking the exogenous shocks' motion laws as given. From now on, the time subscripts will be suppressed and a $(')$ shall designate the values of variables in $t+1$. The dynamic structure if the problem satisfies the following *Bellman* equation:

$$v(k, z, g_I) = \max_{\Lambda} \left\{ u(\tilde{c}, l) + \tilde{\beta} E\left[(k', z', g_I') \mid \phi \right] \right\} \tag{4.7}$$

subject to:

$$\tilde{c} = e^z k^\theta n^{1-\theta} - i \tag{4.8}$$

$$k'(\eta_N \eta_H) = (1-\delta)k + (1-g_I)i \tag{4.9}$$

$$1 = l + n \tag{4.10}$$

$$z' = \rho z + \varepsilon' \tag{4.11}$$

$$g_I' = (1-\gamma)\bar{g}_I + \gamma g_I + \zeta' \tag{4.12}$$

4.2. Calibration and Model Solution

In order to obtain a solution to the sequential problem of the agent, a quadratic (second order) approximation must be applied to the functional problem exposed previously, making the computational calculus of linear decision rules possible.

[13] Using the assumption that $N_0 = H_0 = 1$.

Therefore a second order Taylor expansion around the steady state is made, after substituting the non-linear constraints of the sequential problem in the *Bellman* equation, or simply linearizing those that are non-linear and excluding them from the return function. The latter procedure is the one we employ in the present paper[14]. Once done this procedure, the Riccatti equation is built, and directly iterated until the fixed point of the system is found, which determines the value function, even though it is not necessary to make a functional distinction of it, fulfilling in each step of the process the linearized non-linear constraints and the motion laws of exogenous shocks (see Technical Appendix).

In this section we also identify the parameter values that are consistent with the model economy hitting certain quantitative targets observed in the Colombian economy, so that the artificial economy replicates the stylized facts or empirical regularities observed in the real series. In particular, the growth values of population (η_N) and human capital (η_H) per household, $\tilde{\beta}, \sigma, \alpha$ in the preferences, θ in technology, the depreciation rate δ, and those associated to the shocks (including their mean values, in the case of inefficiency of the financial sector $\bar{g}_I$, and the variance of the disturbances ε and ζ on the shocks) are to be determined.

As Suescún (1997) indicates, the lack of empirical evidence regarding the possible values that the mentioned parameters may take for the Colombian case, makes the most commonly employed calibration method since the work of Kydland and Prescott (1982) difficult to employ. For the parameters that are not known from previous papers, the procedure employed here consists of taking such values from the long term relations in the Colombian economy, i.e., from household's first order conditions evaluated at the deterministic steady state, and imposing some target values. These will know be considered.

The per capita GDP and population growth rates ($\eta_H = 1.0324, \eta_N = 1.0136$) are calculated from the Colombian series between 1970-1992. The per capita GDP is weighted by the employed population. The data source is Departamento Nacional de Planeación (DNP). For the same data series, values of capital-product ratio ($\frac{k}{y} = 1.8909$), consumption-product ratio ($\frac{c}{y} = 0.8171$) and the investment-product ratio ($\frac{i}{y} = 0.1914$) which correspond to averages, are calculated. Investment is defined as total gross capital formation plus consumption of durable goods, taken from the NIPA.

[14]The first order expansion of the law of motion of capital, around the deterministic steady state results:

$$k_{t+1}(\eta_N \eta_H) = \bar{g}_I i + (1-\delta)k_t + (1-g_I)i_t - i g_{It}$$

The real interest rate r is fixed in 10% as it is suggested by Harberger (1973)[15]. In the same way, the intertemporal elasticity of substitution $\frac{1}{\sigma}$ is taken from Ogaki, Ostry and Reinhart (1996), which corresponds to 0.588.

Having found target values for η_N, η_H, r, k/y, $\tilde{c}/y$, i/y, and σ, we proceed to find values for the remaining parameters of the model from the long term relations of the economy, i.e., from the first order conditions evaluated at the deterministic steady state. The reason for this is based upon the fact that under such conditions, the obtained parameters shall be *deep*, what makes the model invariant to the changes in policy stances, and therefore represents the ideal laboratory for the analysis of different policies. In this way, the parameter α of preferences, which corresponds to the relative importance of leisure and consumption within the utility function, is obtained following Cooley and Prescott (1995) from the optimality conditions of the representative household. From the first order condition for labor it is easily found that:

$$(1-\theta)\frac{y}{\tilde{c}} = \frac{\alpha}{1-\alpha}\frac{n}{1-n} \tag{4.13}$$

from which a value of $\alpha = 0.6269$ is obtained, supposing $n = 0.34$, i.e., the representative household works one third of the day. Furthermore, the Euler equation in steady state, for the household's problem characterized in the Bellman equation, implies:

$$\frac{(\eta_N \eta_H)}{\tilde{\beta}} - 1 = \theta\frac{y}{k}(1-g_I) - \delta \tag{4.14}$$

For a capital share in product of $\theta = 0.3$, and a value for $\delta = 0.0578$, the average financial system inefficiency $\bar{g}$ (redefining g as $\bar{g}$ which appears in 3.12 as the process' mean value) is obtained from the previous equation, taking into account that the real interest rate is equal to $\frac{(\eta_N \eta_H)}{\tilde{\beta}} - 1 = r$,

$$\bar{g}_I = 1 - \left(\frac{r-\delta}{\theta}\frac{k}{y}\right) \tag{4.15}$$

from which a value of $\bar{g} = 0.0053$ is found. This value was calibrated so as to be about 20% higher than the 1% of the GDP suggested by Suescún and Misas

[15]There are other estimates for the real interest rate in Colombia, being the most recent that in Pombo (1999). He finds that for the 1970-1995 period, such rate is 13,4%, which accounting for depreciation results in a rate near 10%, that we adopt in the paper.

(1996)[16].

As for the exogenous shocks, it is considered for simplicity that the cross effects between them are negligible, so that it is not necessary to build an autorregressive vector (VAR) for these. Employing the parametrized technology (i.e., with $\theta = 0.3$), the process for the productivity shock is calculated from the estimation of a first order autoregressive process for (the log of) Solow residual series for the period in question, just as it is indicated in expression 3.11. An important persistence in the shock is found ($\rho = 0.9674$, with a standard error of 0.0145).

The persistence γ, of the shock to average inefficiency $\bar{g}$, as expressed in 3.12, is found following Carvajal y Zuleta (1996), by using the series of managerial and labor expenses as a fraction of aggregate savings, for the overall Colombian financial institutions, between 1970 and 1992. From these, a persistence parameter of $\gamma = 0.7301$ (standard error of 0.1511) is obtained for the first order autoregressive process for the mean value. The variances of the disturbances to both shocks are pinned down by forcing the economy to mimic the volatility of investment and income, keeping the relative size between them[17]. The parameters of the model are summarized in table No.1.

5. Cyclical Properties of the Artificial Economy

The ability of the model economy to mimic key qualitative and some quantitative aspects of aggregate and sectorial cyclical behavior of the Colombian economy is remarkable, taking into account that the second moments of the simulated series are close and of equal signs to those of the real series (Tables No. 2 and 3). In particular, it is important to highlight the similarity between the covariance of income and investment, and income and consumption, with those observed in Colombia. As in the present context leisure is not introduced in the utility function in the Hansen (1995) manner, the model fails to capture its relation

[16] We decided to take this value from Misas y Suescún (1996) as we mentioned in part two above, because it is the only calculation for Colombia that uses the notion of X-inefficiency, which appears to be the most relevant type of financial inefficiency, domestically and abroad. The additional 20% we used derives from the fact that the X-inefficiency takes the best intermediarie of the group in study as perfectly efficient, the rest being qualified as inefficient relative to former. However, the most efficient intermediarie may well be inefficient, which motivates us to use a slight higher value than Suescún y Misas (1996). This higher value is of 0.0053, which accounts for 1.2% of GDP.

[17] Our proxy of financial inefficiency is 13 times more volatile than Solow residuals. We then keep that relative size in the artificial variances.

with income (not shown in tables), in spite of the high elasticity of substitution of the Colombian economy (1.7007), but perhaps because of the low transitory component of real wages (see Blanchard and Fischer (1989), chap.7).

The rest of the aggregates behave in a satisfactory manner, even though the covariance between the financial inefficiency and the product is lower, a phenomenon that can be well explained by the proxy election. Besides, we couldn't use others because of the non-existence of data or low reliability on the existent series. It is possible that at an aggregate level the covariance is much greater than that suggested by the model and that this could be due to homogeneity problems in the measurement done by the intermediaries.

The standard deviations present an even better behavior. This is due to the fact of the no deed of adjustment costs, which proved to be an obstacle for the good performance of the financial inefficiency variable in the model. Moreover, it can be said that inefficiency enters the model as a capital adjustment cost, and the introduction of an additional form of it results in a loss a accuracy.

In Figure No. 1, the dynamic effect of separate innovations upon the technological and financial inefficiency persistent shocks (i.e., using the estimated persistence parameters within the shocks), equivalent to two positive standard deviations in the first period and zero from then on to the latter, and 1/10 of a standard deviation and zero from then on to the former[18], can be observed. It is important to mention that all of the series are expressed in logarithms and detrended with Hodrick-Prescott filter, with the exception of shocks, which are Hodrick-Prescott filtered in levels.

While the response to the innovation in technology is for consumption, investment and income to grow upon their initial steady state and then returning to their respective steady state after 50 periods, as is standard in RBC literature, it is worth mentioning the effect of the innovation to average financial inefficiency. The economy displays an interesting although expected effect, in terms of the main aggregates. Both income and investment reach higher steady states after the reduction in financial inefficiency, approximately 30 periods after it (income growing and then falling pronouncedly to the new steady state, and investment growing smoothly to the new steady state). Consumption reaches a higher steady state level also, falling since the innovation until the new and higher steady state.

[18]The reason why we chose 1/10 of a (negative) standard deviation as the magnitude of the innovation to average financial inefficiency, relies on the fact that it assures that the former continues to be positive, i.e., in spite of the diminished average financial inefficiency, there is still a positive fraction of aggregate savings that is lost.

6. Financial Inefficiency and Welfare

We now turn to quantify the steady state welfare gain of a reduction in average financial inefficiency. From the first order conditions it is observed that the average financial inefficiency is a function of the capital share in the product, the real interest rate, the depreciation rate and the capital-product ratio. Suppose that this mean value is reduced in a percentage $\vartheta > 0$. From equation (3.5), capital increases in each period exactly in the same proportion, increasing the representative household's utility because of higher consumption, without ambiguity. Even in (4.2) it is observed that the steady state real interest rate (given by $\theta\frac{y}{k}(1-\bar{g}_I)-\delta$, increases as well). Savings are greater during the transition and in steady state. Obviously, the economy experiences a greater growth because of greater capital accumulation.

Equally, from the first order conditions for capital and labor, it is possible to find that consumption is equal to:

$$\tilde{c} = (1-\theta)\left[\frac{(\eta_N \eta_H) - \tilde{\beta}(1-\delta)}{n^{1-\theta}(1-\bar{g}_I)}\right]^{\frac{\theta}{\theta-1}} n^{1-\theta}\frac{1-\alpha}{\alpha}\frac{1-n}{n} \tag{6.1}$$

In steady state, it is found that a reduction of 50% ($\vartheta = 0.5$) in the average financial inefficiency, increases consumption in 0.1154%. In order, reductions of 40%, 30%, 20% and 10%, increase steady state consumption in 0.0923%, 0.0692%, 0.0461%, and 0.0230% respectively. These represent evident improvements in welfare, since, for example, the increase in consumption for the case of a 50% reduction in financial inefficiency, accounts for 1/4 of a percentage point of the GDP.

7. Conclusions

A stochastic, artificial, small and closed economy is introduced, inhabited by an perpetual dynasty, in which savings are intermediated by an *ad hoc* financial system. In the process of such intermediation, the system appropriates a fraction that is not transformed into investment but "wasted" in the form of margin, commission, insurance policies etc., becoming X-inefficiency. The economy, which is equivalent in its centralized and decentralized solution due to the exogeneity of the process of financial inefficiency, is calibrated to replicate the Colombian main empirical regularities for the period 1970-1992.

It is found that the ability of the model economy to mimic Colombian real series is remarkable, in terms of their second moments. The similarity in covariance between income and investment, and income and consumption is highlighted, although covariance between income and financial inefficiency falls a short. Additionally, covariance between hours worked and income (not shown in tables) is strongly underestimated, and this may be explained, in spite of the high Colombian intertemporal elasticity of substitution, by the low transitory component in aggregate wages.

In addition, estimates of steady state increases in welfare, in terms of an increase in steady state consumption, are calculated, based on potential reductions in average financial inefficiency. This gains are significant but difficult to achieve. For example, a 50% reduction in average inefficiency, which by any means is a very ambitious target for reformists of the financial system, increases consumption by about 1/4 of a GDP percentage point. Less aggressive policies in that direction, of say, a reduction in 10% of the financial inefficiency, would reach a gain in steady state consumption of approximately 1/17 of a GDP percentage point.

As a result of the good approximation of the described economy to the Colombian case, this model may be employed as a laboratory to verify various types of financial liberalization.. Natural extensions of the model can be directed to the introduction of money and the opening of the economy to international trade, where currency and foreign bonds are substitutes of physical investment. Equally, the financial inefficiency may be defined in a different manner, employing different X-inefficiency estimations, justified by the described reasons of heterogeneity between the different empirical measurements.

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Table No.1. Calibrated Parameters[19]

$\eta_N\eta_H = 1.0445$	$\tilde{\beta} = 0.9496$	$\sigma = 1.7007$
$i/y = 0.1914$	$k/y = 1.8909$	$r = 0.1$
$\theta = 0.3$	$\bar{g}_I = 0.0053$	$\delta = 0.0578$
$\alpha = 0.6269$	$\gamma = 0.7301$	$\rho = 0.9674$

Table No. 2. Cyclical Properties of the Colombian Economy (1970-1992)[20]

		Correlation with
Aggregates	STD.(%)	GDP
GDP	1.73	1
Consumption	1.70	0.78
Investment	4.34	0.41
Solow Residuals	0.72	0.87
Financial Inefficiency	25.63	-0.55

Table No.3. Cyclical Properties of the Artificial Economy[21].

		Correlation with
Aggregates	STD..(%)[22]	GDP
GDP	1.66 (0.57)	1
Consumption	1.89 (1.42)	0.85 (0.28)
Investment	3.17 (1.15)	0.40 (0.31)
Solow Residuals	1.02 (0.31)	0.87 (0,67)
Financial Inefficiency	5.67 (1.27)	-0.34 (0,39)

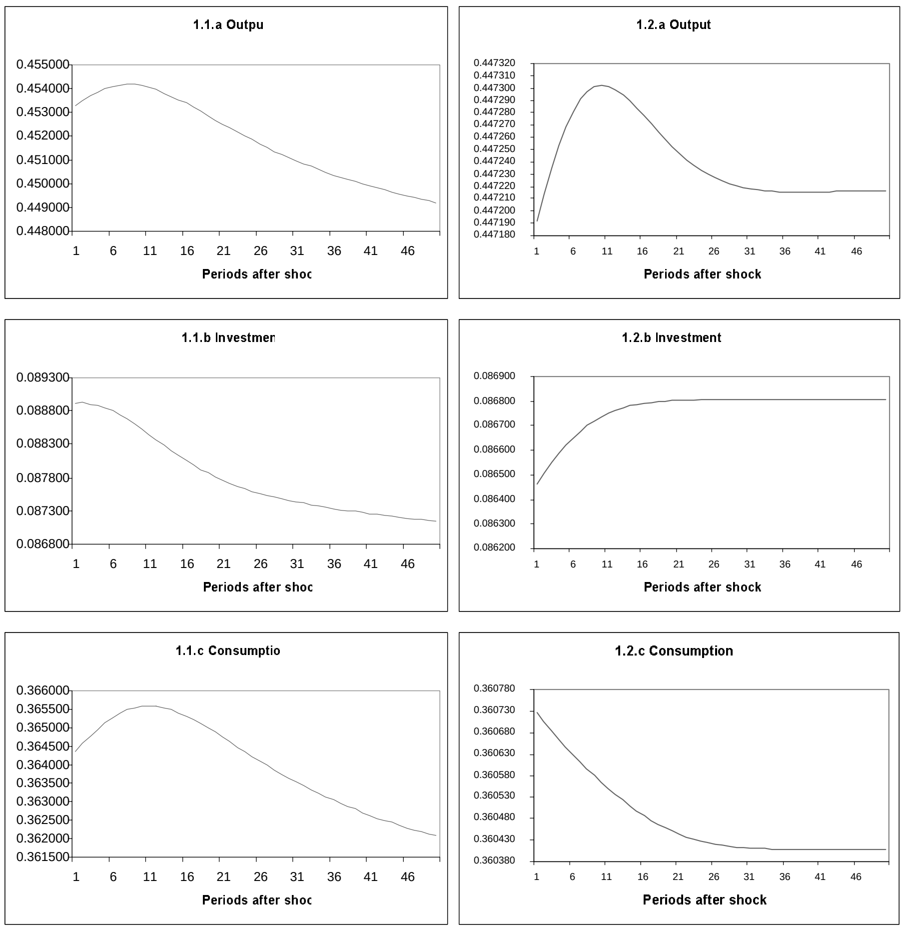
[19] Each period corresponds to one year of the Colombian economy.

[20] Annual data between 1970 and 1992. All series are in per capita terms except Solow residuals, using employed population, and all are expressed in logarithms (except again Solow residuals) and Hodrick-Prescott filtered, with a smoothing parameter of 500.

[21] Reported statistics correspond to averages over 100 replications of the artificial economy, of enough number of periods, so as to generate series equivalent in time to those of the Colombian economy. All series are expressed in logarithms (except Solow residuals) and Hodrick-Prescott filtered, with a smoothing parameter of 500. The computational work is done in MATLAB.

[22] Standard Deviation in parenthesis. Statistics in %.

Figure No. 1. Dynamic effect of an innovation of two (positive) standard deviations to the technology shock (Graphs 1.1), and an innovation of 1/10 of a (negative) standard deviation to average financial inefficiency (Graphs 1.2).



9. Technical Appendix

In this section we illustrate the implementation of a deterministic version of the Optimal Linear Regulator Algorithm. Let X_t be a vector of state variables. Tis vector is partitioned in the form: $X_t = \begin{bmatrix} 1 \\ X_t^- \end{bmatrix}$, where X_t^- is the vector of state variables[23]. Let V_t a vector of control or decision variables. The problem to be solved consists in finding an infinite sequence of control variables $\{V_t\}_{t=0}^{\infty}$ in order to

$$\max \quad \sum_{t=0}^{\infty} \beta^t r\left(1, X_t^-, V_t\right)$$

subject to:

$$X_{t+1}^- = g\left(X_t^-, V_t\right)$$

where $r(\cdot)$ is the return function, generally non-quadratic, and $g(\cdot)$ is a vector of laws of motion of the state variables. The aforementioned problem may be transformed in a "linear-quadratic" one, with simple solution:

$$\max \quad \sum_{t=0}^{\infty} \beta^t r\left(X_t, U_t\right)$$

where,

$$r(X_t, U_t) = X_t^T \bar{R} X_t + U_t^T \bar{Q} U_t$$

subject to:

$$X_{t+1} = \bar{A}_x X_t + \bar{A}_u U_t$$

T is the transpose operator, U_t and X_t are the vectors of decision and state variables of the "linear-quadratic" problem, $\overline{R}$ is a symmetric negative semidefinite matrix, $\overline{Q}$ is a symmetric negative semidefinite matrix and both result of the second order Taylor series expansion of the return function r, in the neighborhood of the steady state. Finally, $\bar{A}_x$and $\bar{A}_u$ are the transition matrices, or simply the constraints for the sequential problem, and are linear in nature (or have been linearized, near the steady state also).

This sequential problem has an equivalent functional representation. Let the value function be quadratic, i.e., $V(X_t) = X_t^T P X_t$, where P is a symmetric negative semidefinite matrix, the Bellman equation can be written as:

[23] The constant is essential, given that in the Taylor Series Expansion cross terms independent of state as well as control variables appear.

$$X_t^T P X_t = \max_{U_t} \left\{ X_t^T \bar{R} X_t + U_t^T \bar{Q} U_t + \beta X_{t+1}^T P X_{t+1} \right\}$$

subject to:

$$X_{t+1} = \bar{A}_x X_t + \bar{A}_u U_t$$

From the first order conditions, we find:

$$U_t = -\beta \left[\bar{Q} + \beta \bar{A}_u^T P \bar{A}_u \right]^{-1} \left(\bar{A}_u^T P \bar{A}_x \right) X_t$$

or in an equivalent way:

$$U_t = -\bar{F} X_t$$

where $\bar{F}$ is a matrix es una matrix in terms of P, i.e., $\bar{F} = \bar{F}[P]$ and P is unknown. Substituting the optimum value for U_t in the Bellman equation, results:

$$X_t^T P X_t = X_t^T \bar{R} X_t + \left(-\bar{F} X_t \right)^T \bar{Q} \left(-\bar{F} X_t \right) +$$

$$\beta \left\{ \left(\bar{A}_x X_t + \bar{A}_u \left(-\bar{F} X_t \right) \right)^T P \left(\bar{A}_x X_t + \bar{A}_u \left(-\bar{F} X_t \right) \right) \right\}$$

where after some algebra it can be found that:

$$P = \bar{R} + \bar{F}^T \bar{Q} \bar{F} + \beta \left(\bar{A}_x^T - \bar{F}^T \bar{A}_u^T \right) P \left(\bar{A}_x - \bar{A}_u \bar{F} \right)$$

Given that $\bar{F}$ is a function of P, the latter can be replaced in the above expression:

$$P = \bar{R} + \bar{F}[P]^T \bar{Q} \bar{F}[P] + \beta \left(\bar{A}_x^T - \bar{F}[P]^T \bar{A}_u^T \right) P \left(\bar{A}_x - \bar{A}_u \bar{F}[P] \right)$$

This last expression corresponds to the Matricial Riccatti Equation. To solve the Riccatti Equation, that is, to find the value for P, there are three different methods: the "doubling algorithm", Vaughan's algorithm and the direct iteration algorithm. In the paper we use the direct iteration method. Under special circumstances, this equation has a unique solution: A negative semidefinite matrix that is obtained as the limit when $j \to \infty$ iterating in the Riccatti difference equation:

$$P_{j+1} = \bar{R} + \bar{F}[P_j]^T \bar{Q} \bar{F}[P_j] + \beta \left(\bar{A}_x^T - \bar{F}[P_j]^T \bar{A}_u^T \right) P_j \left(\bar{A}_x - \bar{A}_u \bar{F}[P_j] \right)$$

Once obtained P, $\bar{F}$ can be found, as well as the linear optimal decision rules.