Optimal Commodity Price Stabilization over the Business Cycle

Rodrigo Suescún*

This paper develops a model to study the design, characterization and dynamic implications of stabilization policies in a dynamic general equilibrium model of the business cycle for an economy tainted by the Dutch disease. The model incorporates a stabilization scheme for the producer price of an export crop in a three-sector RBC model. Stabilization funds have been very popular instruments in developing countries to deal with export price instability. This paper shows that such schemes cannot improve the functioning of the economy, notwithstanding the assumed suboptimality of private outcomes and the possibility of having welfare enhancing policies.

Key words: Business cycles; Dynamic games; Price stabilization; Optimal policies; Small open economy
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* *Correspondence to*: Banco de la República, Carrera 7 # 14-78, piso 4, Bogotá, Colombia. E-mail address: rsuescme@banrep.gov.co

1 Introduction

The volatility of international commodity markets has been a major cause for concern among policy-makers in developing countries and academics. A recent study, sponsored by the World Bank (Little et al., 1993), reviews the experience of 18 developing countries that faced terms of trade shocks over the 1974-1989 period and presents striking arguments suggesting that countries that experienced favorable terms of trade shocks did not perform better than countries that underwent negative shocks. It identifies two problems with positive shocks: the first is bad economic policy induced by government euphoria[1], and the second, is the paradoxical effect, known as Dutch disease. The so-called booming sector and Dutch disease literature argues that export windfalls may expose developing countries to undesirable macroeconomic adjustment. According to the simplest version of the theory[2], a temporary export boom increases domestic income and aggregate demand. Since the nonbooming tradable good can be imported at given world prices, equilibrium requires increases in nontradable output and in its relative price in order to get rid of the excess demand emerging from the wealth effect of the boom. This is the so-called *spending effect*, and explains the basic symptoms of the Dutch disease: real appreciation, i.e., a decline in external competitiveness, and a contraction of the nonbooming tradable sector, i.e., deindustrialization. These effects are reinforced by the so-called *resource movement effect*, which is brought about when the booming sector pulls production factors out from other activities.

Policy-makers concerned with industrialization and export diversification usually deem as harmful Dutch disease responses to transient terms of trade shocks. However, this type of adjustment can be rationalized as an efficient outcome. Government intervention has been justified in the presence of market failures or distortions, exacerbated by export booms, that constrains private decisions (Neary and van Wijnbergen, 1986). A possible rationale for government intervention, very popular in the literature, is provided in van Wijnbergen (1984) and Krugman (1987). They adopt the hypothesis, based on evidence on productivity growth in trade-oriented industries, that accumulated experience in the nonbooming tradable sector is the source of a learning by doing externality that ends up explaining technological progress and economywide growth. In such models Dutch disease responses are truly symptoms of a disease. In such models, to capture the gains from the existence of dynamic economies of scale the best policy is to promote the nonbooming tradable activity with a production subsidy, whether or not there is boom. Furthermore, as shown by van Wijnbergen (1984), during a boom it is usually optimal to increase this subsidy to induce the socially optimal level of production in the sector where the externality takes place.

However, besides these very general and vague policy recommendations, the literature has paid little attention to the design of optimal policies at business

[1] This idea has recently been rationalized by the so-called "voracity effect" in Tornell and Lane's (1998) paper.

[2] See for example, Corden and Neary (1982) and Corden (1984).

cycle frequencies. Should policies fully or partly insulate the nonbooming tradable sector from volatility in world commodity markets? What is the optimal degree of contraction for this sector? Should policies look for a partial or a full reversal of the likely resource allocation and real appreciation of the exchange rate associated with an export boom? How should policies be adjusted along the cycle of world commodity prices? How should policy prescriptions change when the intervention is financed with distortionary taxation?

On the other hand, the type of policy instruments studied in the literature are not usually the ones available to policy-makers in developing countries. Subsidy schemes financed with nondistortionary taxes are rarely seen. What is interesting to note is that almost all developing countries face export price instability by structuring different kinds of domestic price stabilization schemes to try to isolate the economy from those external shocks.[3] Based on Newbery and Stiglitz (1981), it is well understood that the microeconomic benefits of stabilization policies are generally unimportant. However, the assessment of the role of a stabilization scheme in a general equilibrium framework, as a macroeconomic policy instrument, is an open question. Given this policy instrument, what is the optimal policy? Again, the literature is mute on how a price stabilization scheme must be run.

The purpose of this paper is to study the design, characterization, and dynamic implications of optimal policies in a dynamic general equilibrium model of the business cycle for an economy tainted by the Dutch disease. For the sake of the argument, it is assumed that technological progress arises as a by-product of activities in the nonbooming tradable firm. The accumulation of experience is a process external to the firm. The policy instrument is a stabilization fund that acts as a monopsonist with the power of setting the producer's price of the booming good. The domestic price of the booming good is endogenized by setting up an economy with two heterogeneous agents, the representative household and the stabilization fund, which interact through a dynamic Stackelberg game. Also for the sake of the argument, the fund's policies can be welfare enhancing because the fund is able to internalize the effect of its decisions on the sector source of the externality, in particular, and on household behavior,

[3] See Knudsen and Nash (1990) for examples on the wide diversity of purposes of stabilization schemes. According to their taxonomy, the present paper is concerned with "export marketing boards". Our board is a monopsonist that buys the commodity from domestic producers and sells it in the international market.

Simply to mention some examples, marketing boards have existed for commodities like coffee, tea, cocoa, jute, rice and wheat.

In the particular case of coffee, which is the base of the empirical analysis in the paper, some examples of stabilization funds are the following: "Office des Cultures Industrielles" and "Burundi Coffee Company" in Burundi; "Office National de Commercialisation des Produits de Base" in Cameroon; "National Federation of Coffee Growers" in Colombia; "Costa Rican Coffee Institute" in Costa Rica; "Salvadoran Coffee Company" in El Salvador; "Coffee and Tea Development and Marketing Authority" in Ethiopia; "Haitian Institute for the Promotion of Coffee and Export Produce" in Haiti; "Caisse de Stabilisation et de Soutien des Prix de Produits Agricoles" and "Caisse de Stabilisation des Cours" in Ivory Coast; "Kenya Coffee and Marketing Board" in Kenya; "Office des Cultures Industrielles du Rwanda" and "Rwandaise Exportation" in Rwanda; and "Coffee Marketing Board" in Uganda.

in general.

Domestic price stabilization schemes have been criticized on two grounds. The first is the observation regarding the efficiency of the scheme when shocks to the relative price of the commodity exhibit infinite or very high persistence. The absence of forces inducing mean-reversion in the price generating process may end up putting in peril the financial sustainability of the scheme (Grilli and Yang, 1988; Cuddington and Urzúa, 1989). A more practical criticism is the observation that stabilization schemes fail because they are prone to pursue diverse incompatible objectives like taxation, income stabilization, income distribution, etc. (Gilbert, 1993). None of these criticisms apply to this paper. The merits of the policy instrument depend solely on its suitability to improve private outcomes.

This paper is structured as follows. Section 2 provides some preliminary evidence, focused on a sample of coffee producer countries, on the pervasiveness of Dutch disease responses to export price booms. Section 3 lays out a dynamic general equilibrium model in which a representative household and a stabilization fund interact through a dynamic Stackelberg game. Section 4 characterizes the equilibrium for the heterogeneous-agent economy. Section 5 discusses calibration and computation. Section 6 presents the findings and robustness results and Section 7 concludes.

2 Empirical Effects of Temporary Export Booms

This section presents preliminary evidence on the manner in which resources get allocated in response to export windfalls. To illustrate the type of macroeconomic adjustment endured by countries whose foreign exchange revenues heavily depend on a narrow basket of primary commodities, the evidence reported is circumscribed to the experience of a sample of coffee producer countries and windfalls are identified with disturbances to the world price of the commodity. Coffee is one of the major non-oil exports of developing countries.

According to Deaton and Laroque (1992) primary commodity prices, among which the price of coffee is a good example, are remarkably volatile, displaying occasional spikes and seemingly exhibiting mean reversion or stationarity around a deterministic trend. This process is also characterized by a high degree of serial correlation. It is possible to identify that most of the major spikes experienced by coffee prices in the postwar period correspond to those changes registered in 1953, 1956, 1963, 1967, 1969, 1975, 1981 and 1986, all of them associated with frosts and/or droughts generally occurring in southern Brazil[4] and clearly understood as transitory by market participants.

Figure 1 displays impulse response functions to world coffee price innovations based on unrestricted vector autoregressions estimated for each of the following seven countries: Colombia, Costa Rica, El Salvador, Ethiopia, Guatemala, Honduras and Kenya. Each VAR includes 5 variables: the world price of coffee in real terms; an indicator of the relative size of the country's nontradable sector,

[4] For more details, see Bacha (1992) and the Economist Intelligence Unit (1991).

proxied by the share of nontradable GDP or government spending in total GDP; an indicator of the nonbooming tradable sector size, measured as the ratio of non-coffee exports to GDP; the GDP growth rate and the real exchange rate. This is exactly the same ordering used to diagonalize the innovation covariance matrix in each VAR when computing impulse response functions. Point estimates of dynamic response functions are depicted by solid lines, while their corresponding 95 percent confidence intervals are depicted by dashed lines. Details on sample periods, lag lengths, definitions of variables and data sources are included in the appendix. Data availability and reliability represent very serious limitations against structuring VARs in alternative, more disaggregated and rather more meaningful ways, while keeping discipline with an homogeneous treatment across countries.

The main consequences of a positive coffee price shock are summarized as follows: There is a short-lived stimulus on the growth rate of the economy, reflecting the wealth effect of increased transfers from abroad[5]. This response is exhibited by all countries in the sample. However, despite the recognized boom temporariness, there is a persistent tendency to tilt the production structure in favor of nontradable activities (nontradable GDP or government spending) at the expense of the nonbooming tradable sector (non-coffee exports), and to appreciate the real exchange rate. These responses provide evidence in favor of the type of syndrome identified by the core models of the so-called booming sector and Dutch disease economics. In the aftermath of a boom, there is a change in the economic structure towards de-industrialization (decline in the nonbooming tradable sector, also known in the literature as the manufacturing sector) through the loss in competitiveness caused by a persistent appreciation of the real exchange rate.

For the countries in the sample, the Dutch disease outcome is not a curious manner of allocating factors of production to accommodate an export boom. On the contrary, it is a relatively common phenomenon supported by the evidence reported here and also found or reported in the experience of other producer countries and with other primary commodities, though in these cases, the existing evidence is mostly anecdotal[6]. Most of the existing literature is virtually mute on answering the question regarding the efficiency of the response and the appropriate policy intervention in the short- and medium-run to avoid the harmful effects of windfalls, if they exist. To try to answer these questions, it is required to put more structure on Dutch disease models.

3 The Small Open Economy Model

Suppose that the economy is inhabited by two types of agents. The first type corresponds to a large number of identical households, while the second is a

[5] In an alternative specification, the economy's growth rate is replaced by the trade balance to output ratio. In this VAR, a price shock is generally associated with a temporary improvement of the trade balance. Other responses remain qualitatively unchanged.

[6] See some examples in Neary and van Wijnbergen (1986), Gelb (1988), Cooper (1992), Little, Cooper, Corden and Rajapatirana (1993).

stabilization fund. Both types of agents interact through a dynamic Stackelberg game in an environment exhibiting endogenous growth. The engine of growth is a learning-by-doing externality in the nonbooming tradable sector that spills over across the economy.

Households cannot internalize the benefit of higher current tradable activity on the learning-by-doing experience. This implies that the economy's competitive equilibrium is no longer Pareto optimal. As a result, the response of the economy in a Dutch disease manner to accommodate an export boom may be inefficient, and represent a real disease because it slows down the rate of global technological progress. Since Arrow (1962), we know that this kind of inefficient outcome can be improved with the help of government intervention. This paper focuses on a special but very popular type of intervention in developing countries: a domestic price stabilization scheme of the export crop effected through a stabilization fund. It is assumed that in the design of its optimal policy, the fund is able to internalize the effect of its decisions on knowledge capital created as a side product of the nonbooming tradable activity.

Knowledge capital is denoted by E_t. The higher the tradable activity, the more aggregate productivity grows, which in turn, as can be shown, determines the economy's gross rate of growth η_t, where $\eta_t = \frac{E_{t+1}}{E_t}$. Because of the presence of growth, the model economy is nonstationary and does not converge to a steady state. An additional source of nonstationarity is population growth. It is explicitly considered because the economy, whose second moments the model attempts to match, exhibits a high rate of employment growth during the sample period. Population, denoted by S_t, grows at a constant rate $\eta^s - 1$. To induce stationarity and to facilitate the use of computational methods, all growing variables are deflated by $E_t S_t$, i.e., they are expressed in terms of efficiency units of labor, and the discount factor is transformed appropriately. To save on notation, the model is formulated in terms of its stationary representation from the outset.

Each player's decision problem is described in what follows. Then the equilibrium concept is spelled out.

3.1 Households

In each period the fund acts as the Stackelberg leader moving first, and the representative household moves second, taking as given the fund's actions. For the sake of simplicity, assume that the production side of the economy is directly run by households which make, in addition to consumption and portfolio choices, all hiring and investment decisions.

3.1.1 Technologies and Preferences

The economy has three production sectors j, $j \in \Xi$: the nonbooming tradable sector denoted by the superscript T, the nontradable sector N, and the booming sector B[7]. As in the Dutch disease and resource booms literature, the tradable sector properly as such has been divided into two sectors: the booming sector which looms large in total exports and foreign exchange revenues and whose exports temporarily boom because of increases in its world price[8], and the nonbooming tradable sector, sometimes also called the lagging sector, manufacturing or sometimes identified with the industrial sector, whose response to export booms is the focus of the literature.

The production technology is assumed to be Cobb-Douglas in the three sectors:

$$y_t^j = \lambda_t^j \Delta^j \left(\phi_t^j k_t\right)^{\alpha^j} \left(n_t^j\right)^{1-\alpha^j}, \qquad j \in \Xi \tag{1}$$

Here Δ^j is a sectoral scale parameter, λ_t^j is an exogenous stationary shock to industry-j technology, and α^j is the capital share in sector-j output. k_t is the household's total capital stock and $\phi_t^j k_t$ is the amount of capital devoted to produce type-j goods. Total capital is fully allocated across sectors, $\sum_{j\in\Xi} \phi_t^j = 1$, for all t. n_t^j is labor input assigned to produce type-j output as of time t. The choice of the fractions ϕ_t^j of k_t and the allocation of labor across industries looks for the best exploitation of the private possibilities of production.

Gross investment is a composite of tradable $\left(i_t^T\right)$ and nontradable $\left(i_t^N\right)$ goods. Investment flows are aggregated to produce productive capital in the next period:

$$\eta_t \eta^s k_{t+1} = (1-\delta)\, k_t + I(i_t^T, i_t^N) \tag{2}$$

where δ is a constant depreciation rate and the function $I(\cdot,\cdot)$ is an Armington aggregator. It is considered a simple aggregator of the form:

$$I(i_t^T, i_t^N) = \Delta^I \left(i_t^T\right)^{\theta^I} \left(i_t^N\right)^{1-\theta^I} \tag{3}$$

which implies a unitary elasticity of substitution between the two types of investment contents. The relative equilibrium price of the composite investment good in terms of, say, tradables, can be obtained from the marginal rate of substitution in the Armington aggregator. Δ^I is a constant and θ^I is the share of tradable investment in total investment, expressed in terms of tradables. The booming good is not directly used in investment.

The representative household is assumed to maximize its expected lifetime utility:

$$W = \mathcal{E}_0 \left\{ \sum_{t\geq 0} \beta^t \left(\theta^W \cdot \log c_t^T + \left(1-\theta^W\right) \cdot \log c_t^N + \gamma \cdot l_t\right) \right\} +$$

[7] The words "tradable", "nonbooming tradable" and "manufacturing" are used interchangeably in a loose manner in the text. But it is important to keep in mind that they refer to a good that is different from the so called "booming" good, which is also a tradable good in a strict sense.

[8] Natural resource discoveries is an alternative source for export booms. This case is not analyzed in the paper, although it can be easily accomodated in the model economy.

$$\frac{\beta}{1-\beta}\mathcal{E}_0\left\{\sum_{t\geq 0}\beta^t \log \eta_t\right\}+\kappa \quad (4)$$

where κ is a constant given by: $\kappa = \frac{1}{1-\beta}\log E_0$[9] and β is the appropriately transformed discount factor when preferences are logarithmic, with $\beta < 1$ required to ensure $W < \infty$. Households are infinitely-lived and value stochastic streams of consumption of tradable goods $\left(c_t^T\right)$which may be produced domestically or imported from abroad, both being perfect substitutes; nontradable goods $\left(c_t^N\right)$, and leisure (l_t). Consumption of the booming good is not directly valued and the whole production is exported. The utility function specification follows Hansen's (1985) indivisible labor assumption, which allows us to interpret fluctuations in hours worked as occurring exclusively on the extensive margin (employment). $\mathcal{E}_0$ is the mathematical expectations operator conditional on information available at time 0.

The term $\frac{\beta}{1-\beta}\mathcal{E}_0\left\{\sum_{t\geq 0}\beta^t \log \eta_t\right\}+\kappa$ is taken parametrically by households in recognition of their incapacity to internalize the positive benefits of the tradable experience; however, the equilibrium growth rate of the economy must behave in accordance with that experience. This term is related to the externality which is taken parametrically by the private decision maker, so that the perfect competition framework is preserved.

The positive effect of experience is captured every period and accumulated into knowledge capital, assuming no depreciation. The positive effect of experience may come from alternative sources: from the amount of work effort devoted to the tradable sector (learning by working), or from accumulating capital (learning by investing), or from the period production of tradables (learning by producing). The law of motion of accumulated experience is given by:

$$\eta_t = \frac{E_{t+1}}{E_t} = \begin{cases} \omega_0\left[N_t^T\right]^{\omega_1} & \text{(or learning by working)} \\ \omega_0\left[Y_t^T\right]^{\omega_1} & \text{(or learning by producing)} \\ \omega_0\left[\Phi_t^T K_t\right]^{\omega_1} & \text{(or learning by investing)} \end{cases} \quad (5)$$

where tradable output is defined by: $Y_t^T = \lambda_t^T \Delta^T \left(\Phi_t^T K_t\right)^{\alpha^T}\left(N_t^T\right)^{1-\alpha^T}$. Note the distinction between upper- and lower-case letters. The former represent economywide per capita aggregates, while the latter stand for the corresponding household level variables over which the household exerts direct control. In equilibrium, individual decisions and economywide aggregates must be consistent. The notational convention of dropping time subscripts to denote steady state magnitudes is also adopted. Producing, investing or working in a tradable producing firm translates into productivity gains for other firms in other sectors. Firms in sectors B and N have instant access, at zero cost, to spillover benefits arising from the increased activity in the tradable sector.

[9] The term $\frac{\beta}{1-\beta}\mathcal{E}_0\left\{\sum_{t\geq 0}\beta^t \log \eta_t\right\}+\kappa$ arises when the objective function is stationarized, removing the stochastic trend.

The representative household faces the following budget constraint:

$$\eta_t \eta^s \, d^h_{t+1} = (1+r^*)\, d^h_t + c^T_t + i^T_t - y^T_t - p^B_t y^B_t + p^N_t \left(c^N_t + i^N_t - y^N_t\right) + F_t \quad (6)$$

where d^h_t is the household's net foreign debt position and r^* is the constant world interest rate. Households can borrow in a competitive international capital market to finance the excess of domestic absorption over production, paying an interest rate r^* in units of tradable goods per period. F_t represents lump-sum transfers to the stabilization fund.

3.1.2 Relative Prices

The price of tradables is the numéraire. Let p^{B*}_t be the world relative price of the booming sector good and p^N_t the relative price of nontradables. The former is assumed to follow a first order Markov process and the latter is determined endogenously in the rational expectations equilibrium.

An additional relative price is p^B_t, the domestic price of the booming sector good. p^{B*}_t is the price paid to a competitive exporter in the world market while p^B_t is the price paid at producer's gates. In between, there is a stabilization fund or a marketing board acting in the best interest of the whole society[10].

The board is a monopsonist who assesses the general equilibrium effects of its decisions. One of its decisions is the pricing at domestic level of the booming good, p^B_t, given its world price. Hence p^B_t is determined endogenously as well. Because the economy's equilibrium is suboptimal, due to the existence of externalities, optimal second-best stabilization policies may be welfare improving, since the fund is endowed with the gift -denied to the private sector- of taking into account the effect of its actions on sectoral externalities. Forcing the unconditional means of foreign and domestic relative prices of the booming good to be unity, the fund's conceivable objectives are restricted to serve the stabilization aim exclusively[11].

3.1.3 Costly Time-to-Move Factors Across Sectors and Portfolios

The model economy, as specified so far, exhibits some undesirable features. Firstly, it generates counterfactual volatilities because factor allocation across sectors is too responsive to sectoral differences in productivity. To slow down the economy's response, it is assumed that labor and capital are costly to move intersectorially. The cost is expressed in terms of foregone leisure. The time cost of adjusting time t work effort in sector j is given by: $\frac{\xi^j_N}{2}\left(n^j_t - N^j\right)^2$, where N^j is the corresponding steady state level and ξ^j_N is a sectoral parameter.

[10] It is possible to model a stabilization fund concerned solely with the welfare of individual producers of the booming good. However, the aim of this paper is the design and study of optimal policies for meeting macroeconomic objectives.

[11] Domestic price stabilization schemes vary widely in developing countries and may have different objectives, like taxation of producers or consumers, for example.

$\frac{\xi_K^j}{2}\left(\phi_t^j-\Phi^j\right)^2$ is the time cost of the cyclical adjustment of the fraction of capital in place in sector j relative to its steady state share.

Secondly, even though insurance opportunities through international capital markets are restricted to trades in noncontingent real bonds, nothing prevents the representative household from responding in a neoclassical fashion to temporary terms of trade booms by saving the export windfall abroad, generating a current account surplus, and smoothing consumption. To strengthen income and price effects of terms of trade shocks, as highlighted by the Dutch disease literature, which hinges precisely on the developing countries' inability to insure away idiosyncratic risks, this possible course of action is limited by making costly portfolio adjustments. As before, the cost is expressed in terms of foregone leisure. The term $\left(\frac{\xi_D}{2}\right)\left(d_t^h+D_t^f-D^h-D^f\right)^2$ measures the time cost of adjusting the economy's net foreign debt position relative to its steady state level, or more precisely, as will be apparent later on, relative to its steady state debt-output ratio. D_t^f is the fund's net foreign debt position and D^f is its corresponding steady state level. Its introduction in the cost function implies that the fund's portfolio decisions also carry costs for society.

For convenience, the household has one unit of time each period. Leisure equals total available time (normalized to unity), minus time spent working, adjusting portfolios and reallocating production factors. To deal with the mentioned undesirable features, the model economy requires the use of only a few cost parameters; however a general format for the time constraint can be specified as follows:

$$l_t = 1-\sum_{j\in\Xi}n_t^j-\sum_{j\in\Xi}\left(\frac{\xi_N^j}{2}\right)\left(n_t^j-N^j\right)^2-\sum_{j\in\Xi}\left(\frac{\xi_K^j}{2}\right)\left(\phi_t^j-\Phi^j\right)^2- \left(\frac{\xi_D}{2}\right)\left(d_t^h+D_t^f-D^h-D^f\right)^2 \quad (7)$$

This adjustment costs specification implies that along the steady state balanced growth path there is no leisure time sacrifice associated with the reallocation of factors and portfolios.

It is interesting to note that the nonstationary behavior of consumption and the current account proper of unrestricted small open economy models is ruled out with the interest rate being equal to the rate of time preference -taking care of the fact that the economy has been stationarized- and with the introduction of costs associated with the adjustment in the foreign asset position. In absence of such costs, the economy's steady state is compatible with any level of foreign asset holdings. What adjustment costs also do is to pin down the level of foreign holdings and allow for a well defined steady state around which the deterministic version of the economy is linearized. This ad hoc assumption amounts to allowing for imperfect substitutability between domestic and foreign assets.

3.2 The Fund's Problem

The fund is assumed to be the sole domestic buyer of the booming good produced by households and its sole exporter to a world commodity market. The world price p_t^{B*}, per unit of good, is taken parametrically. The fund acts as an export marketing board that does not hold stocks of the commodity, in contrast to a buffer stock scheme. The fund buys whatever quantity is supplied at the ongoing domestic price p_t^B, which is a fund's decision variable revealed to everybody at the beginning of each period and before household decisions are made. The fund does not have access to a storage technology, but to accomplish its stabilization endeavor can borrow and lend in the world capital market, satisfying its budget constraint:

$$\eta_t \eta^s D_{t+1}^f = (1 + r^*) D_t^f + \left(p_t^B - p_t^{B*}\right) Y_t^B - F_t \tag{8}$$

where Y_t^B is the aggregate per household production of the booming good and D_{t+1}^f is the fund's net foreign debt position, expressed in terms of efficiency units of labor, at the beginning of period $t+1$.

The fund is benevolent, in the sense that D_{t+1}^f and p_t^B are chosen so as to maximize the welfare of the representative household. The fund maximization problem is subject to its budget constraint and to the conditions that guarantee that optimal policies support a competitive equilibrium. To solve its problem, the fund uses dynamic programming which ensures time-consistency of optimal policies (cf. Blanchard and Fisher, 1989).

Household allocations may be improved by the fund's optimal policies, since the fund recognizes the importance of having a high current production of tradable goods by internalizing the effect of its decisions on the sector source of the production externality. Like many real world stabilization funds, it can set the producer price of the booming commodity, a decision which also distorts allocations. Second-best policies take into account the intertemporal costs of having distorted prices and allocations and the benefits of inducing a higher production of tradables and a higher level for the externality as well as the benefit of inducing savings of adjustment costs associated with factor reallocation.

Lump-sum transfers (F_t) are required to satisfy the fund's budget constraint. In particular, when domestic and foreign coffee prices are equal along the business cycle, optimal asset accumulation strategies are financed through nondistortionary transfers from households.

3.3 Market Clearing

In equilibrium, at the relative price of nontradables p_t^N, demand and supply of nontradables must be equal:

$$Y_t^N = C_t^N + I_t^N \tag{9}$$

Aggregating the household and fund budget constraints and using the market-clearing condition for the nontradables market, aggregate debt and tradables also satisfy the following equilibrium condition:

$$\eta_t \eta^s D_{t+1} = (1 + r^*)\, D_t + \left(C_t^T + I_t^T - Y_t^T - p_t^{B*} Y_t^B\right) \tag{10}$$

where $D_t = D_t^h + D_t^f$ represent the consolidated stock of debt of the economy.

4 Equilibrium

Information relevant for household decision-making comprises a vector of exogenous state variables[12]

$$Z_t \equiv \left(\ln p_t^{B*}, \ln \lambda_t^T, \ln \lambda_t^N\right)^{'} \tag{11}$$

governed by a first-order autoregressive process:

$$Z_t = Z_{t-1}\boldsymbol{\Omega}^{'} + \epsilon_t^{'} \tag{12}$$

where the matrix $\boldsymbol{\Omega}$ represents the AR(1) component, ϵ_t is a vector of white noise shocks with mean $\mathbf{0}$ and variance-covariance matrix $\mathbf{V}\left[\epsilon\right]$; a vector of endogenous state variables from the perspective of the representative household:

$$s_t^h \equiv \left(k_t, d_t^h\right)^{'} \tag{13}$$

its corresponding aggregate counterpart:

$$S_t^h \equiv \left(K_t, D_t^h\right)^{'} \tag{14}$$

and policy variables under the control of the fund:

$$p_t^B \text{ and } D_t^f \tag{15}$$

The vector of decision variables of the household is $\hbar_t$:

$$\hbar_t \equiv \left(c_t^T, c_t^N, l_t, \phi_t^B, \phi_t^T, \phi_t^N, n_t^B, n_t^T, n_t^N, i_t^T, i_t^N, d_{t+1}^h\right)^{'} \tag{16}$$

The household's sequence problem can be represented by the following stationary dynamic programming problem:[13]

$$v^h\left(Z_t, p_t^B, D_t^f, S_t^h, s_t^h\right) = \max_{\hbar_t} \Big[\theta^W \cdot \log c_t^T + \left(1 - \theta^W\right) \cdot \log c_t^N + \gamma \cdot l_t +$$
$$\frac{\beta}{1-\beta} \log \eta_t + \beta \mathcal{E}_t \left\{ v^h\left(Z_{t+1}, p_{t+1}^B, D_{t+1}^f, S_{t+1}^h, s_{t+1}^h\right)\right\}\Big]$$

subject to:

[12] The model is simplified by assuming that there is no shock to the booming sector technology: $\lambda_t^B = 1$, for all t.

[13] Though time subscripts are not necesary in this representation, this convention is not embraced because it is being used to identify steady state magnitudes.

$$c_t^N + i_t^N = \lambda_t^N \Delta^N \left(\phi_t^N k_t\right)^{\alpha^N} \left(n_t^N\right)^{1-\alpha^N}$$

$$l_t = 1 - \sum_{j\in\Xi}\left[n_t^j + \left(\tfrac{\xi_N^j}{2}\right)\left(n_t^j - N^j\right)^2 + \left(\tfrac{\xi_K^j}{2}\right)\left(\phi_t^j - \Phi^j\right)^2\right] - \left(\tfrac{\xi_D}{2}\right)\left(d_t^h + D_t^f - D^h - D^f\right)^2$$

$$\eta_t\eta^s d_{t+1}^h = (1+r^*)\, d_t^h + \left[c_t^T + i_t^T + F_t - \lambda_t^T \Delta^T \left(\phi_t^T k_t\right)^{\alpha^T} \left(n_t^T\right)^{1-\alpha^T} - p_t^B \Delta^B \left(\phi_t^B k_t\right)^{\alpha^B} \left(n_t^B\right)^{1-\alpha^B}\right]$$

$$\phi_t^B + \phi_t^T + \phi_t^N = 1$$

$$\eta_t\eta^s\, k_{t+1} = (1-\delta)\, k_t + \Delta^I \left(i_t^T\right)^{\theta^I} \left(i_t^N\right)^{1-\theta^I}$$

$$Z_{t+1} = Z_t \mathbf{\Omega}' + \epsilon_{t+1}'$$

$$\eta_t\eta^s K_{t+1} = (1-\delta)\, K_t + \Delta^I \left(I_t^T\right)^{\theta^I} \left(I_t^N\right)^{1-\theta^I}$$

$$\hbar\!\!\!\!H_t = H\left(Z_t, p_t^B, D_t^f, S_t^h\right)$$

$$p_t^B = p^B\left(Z_t, D_t^f, S_t^h\right)$$

$$D_{t+1}^f = D^f\left(Z_t, D_t^f, S_t^h\right)$$

$$\eta_t = \begin{cases} \omega_0\left[N_t^T\right]^{\omega_1} & \text{(or learning by working)} \\ \omega_0\left[Y_t^T\right]^{\omega_1} & \text{(or learning by producing)} \\ \omega_0\left[\Phi_t^T K_t\right]^{\omega_1} & \text{(or learning by investing)} \end{cases} \qquad [P1]$$

and where $H_t = H\left(Z_t, p_t^B, D_t^f, S_t^h\right)$ is the aggregate version of vector $\hbar_t$ and highlights the functional relationship between the vector of aggregate choice variables and the vector of aggregate state variables, as perceived by households. By the same token, $p_t^B = p^B\left(Z_t, D_t^f, S_t^h\right)$ and $D_{t+1}^f = D^f\left(Z_t, D_t^f, S_t^h\right)$ reflect the household's understanding of how the fund's decisions are made. These functions express the relationships between the domestic price of the booming good and the fund's debt, on one hand, and the aggregate state of the economy from which households may forecast their future motion. These relationships reflect the household's beliefs of how these variables are determined endogenously. Similarly, the law of motion for K_t reflects the perception of how this variable evolves with aggregate decision variables. $v^h\left(Z_t, p_t^B, D_t^f, S_t^h, s_t^h\right)$ is the household's optimum value function.

Information relevant for the fund's decisions comprises the vector of exogenous states Z_t, and its law of motion; the endogenous state D_t^f, and the perceived household's aggregate vector S_t^h and its law of motion. The fund believes that the representative household behaves in response to its policies in the manner summarized by the vector of reactions functions $\hbar\!\!\!/_t = \hbar\!\!\!/ \left(Z_t, p_t^B, D_t^f, S_t^h \right)$. The fund's decision variables are p_t^B and D_{t+1}^f. The stationary dynamic programming problem solved by the fund is given by:

$$v^f \left(Z_t, D_t^f, S_t^h \right) = \max_{p_t^B, D_{t+1}^f} \left[\theta^W \cdot \log C_t^T + \left(1 - \theta^W \right) \cdot \log C_t^N + \gamma \cdot L_t + \right.$$
$$\left. \tfrac{\beta}{1-\beta} \log \eta_t + \beta \mathcal{E}_t \left\{ v^f \left(Z_{t+1}, D_{t+1}^f, S_{t+1}^h \right) \right\} \right]$$

subject to:

$$C_t^N + I_t^N = \lambda_t^N \Delta^N \left(\Phi_t^N K_t \right)^{\alpha^N} \left(N_t^N \right)^{1-\alpha^N}$$
$$L_t = 1 - \sum_{j \in \Xi} \left[N_t^j + \left(\tfrac{\xi_N^j}{2} \right) \left(N_t^j - N^j \right)^2 + \left(\tfrac{\xi_K^j}{2} \right) \left(\Phi_t^j - \Phi^j \right)^2 \right] -$$
$$\left(\tfrac{\xi_D}{2} \right) \left(D_t^h + D_t^f - D \right)^2$$
$$\eta_t \eta^s \left(D_{t+1}^h + D_{t+1}^f \right) = (1 + r^*) \left(D_t^h + D_t^f \right) + \left[C_t^T + I_t^T \right.$$
$$\left. - \lambda_t^T \Delta^T \left(\Phi_t^T K_t \right)^{\alpha^T} \left(N_t^T \right)^{1-\alpha^T} - p_t^{B*} \Delta^B \left(\Phi_t^B K_t \right)^{\alpha^B} \left(N_t^B \right)^{1-\alpha^B} \right]$$
$$\Phi_t^B + \Phi_t^T + \Phi_t^N = 1$$
$$Z_{t+1} = Z_t \mathbf{\Omega}' + \epsilon_{t+1}'$$
$$\eta_t \eta^s K_{t+1} = (1 - \delta) K_t + \Delta^I \left(I_t^T \right)^{\theta^I} \left(I_t^N \right)^{1-\theta^I}$$
$$\hbar\!\!\!/_t = \hbar\!\!\!/ \left(Z_t, p_t^B, D_t^f, S_t^h \right)$$
$$\eta_t = \begin{cases} \omega_0 \left[N_t^T \right]^{\omega_1} & \text{(or learning by working)} \\ \omega_0 \left[Y_t^T \right]^{\omega_1} & \text{(or learning by producing)} \\ \omega_0 \left[\Phi_t^T K_t \right]^{\omega_1} & \text{(or learning by investing)} \end{cases} \qquad [P2]$$

It is worth noting that in this latter program, material balances correspond now to overall resource constraints.

In equilibrium, household's and fund's beliefs or perceptions turn out to be accurate and aggregate consistency satisfied.

A *recursive Stackelberg equilibrium* consists of a set of policy rules: $D_{t+1}^f = D^f \left(Z_t, D_t^f, S_t^h \right)$ and $p_t^B = p^B \left(Z_t, D_t^f, S_t^h \right)$; a vector of individual decision rules $\hbar_t = \hbar \left(Z_t, p_t^B, D_t^f, S_t^h, s_t^h \right)$; a vector of aggregate decision rules $\hbar\!\!\!/_t = \hbar\!\!\!/ \left(Z_t, p_t^B, D_t^f, S_t^h \right)$ and a set of value functions $v^h \left(Z_t, p_t^B, D_t^f, S_t^h, s_t^h \right)$ and $v^f \left(Z_t, D_t^f, S_t^h \right)$, such that:

1. The fund optimizes. The fund's decision rules $D^f\left(Z_t, D_t^f, S_t^h\right)$ and $p^B\left(Z_t, D_t^f, S_t^h\right)$ solve the fund's dynamic programming problem $[P2]$.

2. The representative household optimizes. Given policies, aggregate decision rules and pricing functions, $\hbar\left(Z_t, p_t^B, D_t^f, S_t^h, s_t^h\right)$ solves the household's dynamic programming problem $[P1]$.

3. Aggregate consistency. Individual decisions are consistent with their corresponding aggregates: $\hbar\left(Z_t, p_t^B, D_t^f, S_t^h, S_t^h\right) = \bar{H}\left(Z_t, p_t^B, D_t^f, S_t^h\right)$.

4. Markets clear.

The equilibrium relative price of nontradables depends on the aggregate state, $p_t^N = p^N\left(Z_t, D_t^f, S_t^h\right)$, and can be recovered from allocations:

$$p_t^N = \left(\frac{1-\theta^W}{\theta^W}\right)\frac{C_t^T}{C_t^N} \tag{17}$$

as well as the price of the composite investment good, $p_t^I = p^I\left(Z_t, D_t^f, S_t^h\right)$:

$$p_t^I = \frac{1}{\Delta^I\theta^I}\left(\frac{I_t^T}{I_t^N}\right)^{1-\theta^I} \tag{18}$$

5 Calibration and Solution Method

Disaggregation increases the dimensions along which the model economy may be evaluated and also increases the requirements of information. Due to difficulties in obtaining detailed and reliable data, the model is calibrated to Colombian yearly data covering the 1951-1992 period. This country is a good example because historically it has faced large and repeated terms of trade shocks, largely originating from the behavior of the world coffee price, and has had a long tradition in the use of a domestic price stabilization scheme for the crop. The booming sector of the model economy is represented by the coffee sector of the Colombian economy. The fund began to operate in 1940 and its action has been motivated by a variety of objectives. Price stabilization became an explicit objective after 1958. The country's production and trade structure are consistent with most of the features assumed to characterize this class of economies. Coffee exports accounted for 77.7% of total exports and coffee output represented 9.6% of total GDP during the 1950's. These shares have been continuously falling, but still represent a substantial portion of output and foreign exchange revenues during the remaining sample period.

The lack of empirical evidence on the possible values that most of the model parameters may take on in the case of the Colombian economy prevents the use of the methodology commonly employed in the literature since Kydland and

Prescott's (1982) work. Except for the adjustment cost parameters and the specification of the exogenous shock processes, the strategy followed here is to pick parameter values that are consistent with the model economy hitting certain quantitative targets observed in the Colombian economy. Specifically, with the help of the first order conditions for the household maximization problem and resource constraints -conditions evaluated at the steady state- and some quantitative targets, it is possible to parameterize the model economy. The following calibration targets are imposed[14]:

- Gross rate of growth of per capita output, $\eta = 1.0138$, and population, $\eta^s = 1.0326$.
- Capital-output ratio, $\frac{K}{Y} = 2.48$.
- Investment-output ratio, $\frac{I}{Y} = 0.29$, and nontradable investment to output ratio, $\frac{I^N}{Y} = 0.14$.
- Foreign interest rate, $r^* = 0.065$.
- Sectoral composition of GDP: $\frac{Y^N}{Y} = 0.50$, $\frac{Y^T}{Y} = 0.43$ and $\frac{Y^B}{Y} = 0.07$.
- Sectoral distribution of employment: $\frac{N^N}{N} = 0.56$, $\frac{N^T}{N} = 0.36$ and $\frac{N^B}{N} = 0.08$.
- Steady state level of hours worked, $N = 0.33$.
- Net foreign debt to output ratio, $\frac{D}{Y} = 0.26$, from which the fund's debt is: $\frac{D^f}{Y} = 0.05$.

In addition, the production function scale constant Δ^B is normalized at $\Delta^B = 1$.

Table 1 summarizes the calibrated parameter values consistent with the described parameterizing strategy. Assigned parameter values imply that the tradable sector is the most capital-labor intensive, followed by the nontradable and coffee sectors, respectively. The calibration of the remaining parameter values, $\mathbf{\Omega}$, $\mathbf{V}[\epsilon]$ and those in the adjustment cost function, will be discussed in the next section when the baseline simulation experiment is described.

The equilibrium of the model economy can be computed with the numerical method developed by Ambler and Paquet (1997), in which the Hansen and Prescott (1995) technique is extended to deal with dynamic Stackelberg games. The solution method used here is also an extension of the value function iteration of Hansen and Prescott, but the method is implemented within the algorithm for heterogeneous-agent economies described by Hansen and Prescott. Here is how to implement the algorithm:

Step 1. Choose linear policies: p^{Bj} and D^{fj}, with $j = 0$, as functions of the fund's state.

[14]See data sources and variable definitions in the appendix.

Step 2. Initialize v^{hj-1}, and using p^{Bj} and D^{fj} to figure out their law of motion, solve the household's problem using the Hansen and Prescott algorithm to obtain equilibrium linear decision rules $\bar{H}^j$ and a value function update v^{hj}, as functions of p^{Bj} and D^{fj}, and the other household's states, with $j = 0$.

Step 3. Initialize v^{fj-1}, and using $\bar{H}^j$, solve the fund's problem with the Hansen and Prescott algorithm of successive approximations, to obtain new policy rules p^{Bj} and D^{fj} and an updated value function v^{fj}.

Step 4. Iterate over j to convergence of policy and decision rules or value functions.

6 Quantitative Results

6.1 Baseline Experiment: Exogenous Growth

In this section, the base-case scenario is spelled out and quantitatively evaluated. The economy is characterized by a constant growth rate given exogenously at $\eta_t = \eta$. In consequence, ω_1 is set equal to zero and $\omega_0 = \eta$. The base-case scenario is a useful benchmark to compare the effects of optimal policies, because the competitive equilibrium is efficient and no room for second best policies is allowed. Before generating artificial time series from the model economy, it is necessary to choose values for the remaining parameters.

Disturbances are assumed to follow first order Markov processes. As a first approximation, the process for the relative world price of coffee is calibrated to match the observed persistence and volatility of the corresponding Hodrick-Prescott filtered price. Because no reliable data on sectoral Solow residuals are available, productivity processes are treated symmetrically and hence a value commonly used in the literature is chosen for the persistence parameter of technology shocks (0.95). By the same token, equal variances $\left(0.0178^2\right)$ are set to match the standard deviation of aggregate GDP.

Coffee price and Solow residual innovations are assumed to be correlated, correlation also assumed to be equal across sectors[15]. Off-diagonal elements of the covariance matrix $\mathbf{V}[\epsilon]$ are set to match the observed correlation between terms of trade[16] and aggregate GDP, which is close to zero[17]. The autocorrelation and the variance-covariance matrices consistent with the described parameterizing

[15] This implies: $corr\left(\epsilon_t^p, \epsilon_t^T\right) = corr\left(\epsilon_t^p, \epsilon_t^N\right)$ where $corr$ is the correlation coefficient.

[16] Over the 1951-1992 sample period, the share of coffee exports in total exports was 45%, on the average. Terms of trade (TOT_t) are calculated as follows:

$$TOT_t = \left(p_t^{B*}\right)^{0.45}(1)^{1-0.45} = \left(p_t^{B*}\right)^{0.45}$$

Aggregate GDP, in per capita terms, terms of trade and the relative price of coffee have been logged before computing the mentioned second moments.

[17] The contemporaneous correlation of terms of trade and aggregate output is 0.07 for the 1951-1992 sample period and -0.03 for the 1970-1992 period.

strategy are:

$$\mathbf{\Omega} = \begin{bmatrix} 0.737 & & \\ & 0.95 & \\ & & 0.95 \end{bmatrix}$$

$$\mathbf{V}[\epsilon] = \begin{bmatrix} (0.2046)^2 & 0.000135 & 0.000135 \\ 0.000135 & (0.0178)^2 & \\ 0.000135 & & (0.0178)^2 \end{bmatrix}$$

Adjustment cost parameters remain to be determined. From the general specification of the cost function only ξ_N^B, ξ_N^T and ξ_D take on non-zero values. These parameters are pinned down by forcing the model economy roughly to match the volatilities of employment shares in coffee and tradable sectors and the volatility of the net exports to output ratio, respectively.

Table 3 presents the cyclical behavior of the artificial economy as summarized by its second moment implications. The table reports relative standard deviations to that of output and averages of standard deviations and contemporaneous correlations across 300 simulations, each being 242 periods long and where the first 200 periods are ultimately discarded so that in each simulation, the effective number of periods is 42. In building time series stochastic trends are reinstated. Simulated time series associated with each simulation are Hodrick-Prescott filtered before computing second moments. Table 2 reports the corresponding statistics for the Colombian economy for two sample periods, 1951-1992 and 1970-1992.

The ability of the model economy to mimic key qualitative and some quantitative aspects of aggregate and sectoral cyclical behavior of the Colombian economy is remarkable. As in the data, aggregate consumption is as volatile as output, and consumption and investment are procyclical. At the sectoral level, the model is also successful in predicting broad facts with regard to the dissimilar behavior of the three industries over the business cycle. The model correctly predicts that each of the three sectors is more volatile than aggregate output and that the coffee sector is by far the most volatile of all. By the same token, the model correctly predicts the disposition of the booming sector output to behave countercyclically and the strong procyclical nature of the two other industries. Sectoral employment behaves in a different fashion also captured by the model: employment shares in the booming and nontradable sectors are countercyclical, while that of the tradable sector is procyclical.

The relative price of nontradables is not as volatile and countercyclical as in the actual economy, but the model accounts for the qualitative observation that the relative price is more volatile than output. The model predicts that the ratio of net exports to output is highly procyclical, which is in line with what is found for the shorter data set (1970-1992). This property of the Colombian business cycle, also shared by the model economy, is not usual in RBC models and is at odds with the stylized fact reported in the literature of a countercyclical trade balance[18].

[18] See for example Backus, Kehoe and Kydland (1994).

Despite the generally good performance of the model economy, there are numerous dimensions along which predictions miss targets. A salient failure is the inability of the model to generate as much volatility of aggregate investment as the actual data. The reason, as discussed below, is that the degree of portfolio adjustment costs required to mimic the observed volatility of the trade balance to output ratio is not strong enough to depart the economy from a neoclassical response to an export boom. In fact, most of an export windfall is invested in the internationally traded bond, and the impact on domestic investment is considerably lessened.

Sensitivity Analysis. Against the symmetric treatment of technology shocks, Stockman and Tesar (1995) report, for a sample of OECD countries, that the standard deviation of Solow residual disturbances to the tradable industry is higher than that to the nontradable one by a factor of 1.35. A similar figure is reported by Mendoza (1995) for a sample of developing countries. The model economy is simulated setting relative standard deviations to 1.35 and adjusting the standard deviation of tradable sector innovations to match the volatility of aggregate output, as in the benchmark case. Results are contained in table 3. The new covariance structure of shocks does not alter the basic business cycle properties of the economy, with the exception of inducing a counterfactual feature: a highly procyclical relative price of nontradables. To capture this feature (i.e., countercyclical price), innovations to the nontradable technology must be more volatile than that to the tradable sector. The results of this experiment are also reported in table 3, where no effort is spent to match the observed relative price-output correlation.

Impulse Response Functions. The experiment conducted in this section is to study the dynamic response of the economy to a coffee bonanza -to a two-standard-deviation coffee price shock- while ignoring innovations to tradable and nontradable technologies.

Panel A of figure 2 shows that the export windfall persists for a number of periods, reflecting the high Markov coefficient (0.737) calibrated for the stochastic process of the relative price of coffee. Given the assumed covariance and autocorrelation matrices of shocks, the price shock is associated also with a persistent productivity gain in the production of tradables and nontradables (panel C). The degree to which costly portfolio adjustment is required to mimic the volatility of the trade balance to output ratio is not incompatible with a behavior close to a neoclassical response. As shown in panel I the windfall is mostly accumulated abroad (lower foreign debt), while domestic capital, expressed in terms of efficiency units of labor, is kept relatively constant. Increases in the cost parameter ξ_D restrict savings in foreign assets but reduce, counterfactually, the volatility of the trade balance. In addition, investment volatility moves slightly in the right direction but remains far from the observed level.

It is generally optimal to reduce both types of debts, because the fund acts in the best interest of society. But since the initial amount of the fund's debt is lower than the household's, society minimizes the cost of adjusting the portfolio by repaying relatively more of the fund's debt (panel J). When initial debts are equal, repayments are more uniform. When foreign and domestic coffee prices behave identically (panel B), the fund's budget constraint is satisfied via lump-sum transfers from households.

In terms of flows, savings, which by definition are equal to the trade balance plus investment, rise on impact. Net exports (panel D) increase despite the increase in imports of consumption and capital goods. On the other hand, aggregate investment and its nontradable and tradable components also rise on impact (panel K). However this increase is weakened next period when investment turns into productive capital, expressed in terms of efficiency units of labor which are growing rapidly at an exogenous rate. Aggregate output growth (panel D) also booms, giving rise to a procyclical trade balance.

It is worth noting that a nearly neoclassical response does not prevent intersectoral movements of resources. A transient coffee shock gives rise to a shift in the production structure towards the booming, and to a lesser degree, the nontradable sectors. Panels G and H reveal the squeeze on tradables, as capital, and to a lesser degree labor, are drawn away and employed in other sectors. This reallocation occurs in combination with an increase in the relative price of nontradables and an appreciation of the real exchange rate, calculated with the implicit output deflator (panel F).

The model economy response conforms exactly to the pattern of resource allocation predicted by simple Dutch disease and booming sector models. But here, the symptoms of Dutch disease arise as an equilibrium outcome, as the optimal response of agents facing a stochastic and intertemporal environment. The idea, popular among development economists, that deindustrialization and real appreciation are the appropriate responses only when the increase in commodity prices is permanent, needs to be considered equally valid and the right course of action when terms of trade shocks are temporary.

6.2 Optimal Policy Design

Optimal domestic pricing at cyclical frequencies is described by the volatility of the domestic relative to the world price of the commodity as well as by the structure of dynamic correlations with the world price. These second moments are computed by running the benchmark experiment for the case of the exogenous growth model under the conditions framed in the preceding section. On the other hand, to conduct the experiments for the three models with endogenous growth, only parameters ω_1 and ω_0 need to be adjusted. ω_1 is calibrated to match the observed growth rate–output correlation, $corr\left(Y_t, \eta_t\right)$ -in the $0.53 - 0.61$ range-, while ω_0 is calibrated to match the steady state growth rate of the economy: $\omega_0 = \eta / \left(N^T\right)^{\omega_1}$ or $\omega_0 = \eta / \left(Y^T\right)^{\omega_1}$, or alternatively, $\omega_0 = \eta / \left(\Phi^T K\right)^{\omega_1}$, depending on the assumed accumulation law for knowledge capital.

For the benchmark experiment, we know in advance that there is no role for second-best stabilization policies. As a consequence, the behavior of the domestic and the world prices of coffee must be identical. Table 4 reports the business cycle properties of optimal policies as well as the average autocorrelation function for the exogenous process followed by the world price of the commodity, reckoned across 300 simulations. In the exogenous growth model, the optimal domestic price must inherit the same structure of dynamic correlations with the world price as the world price exhibits with itself. In addition, the relative volatility of both prices is close to unity. The small reported discrepancy (0.98, with standard deviation of 0.01,versus 1) is explained by our approximation technique. Figure 2, panel B corroborates the extent to which the endogenous optimal price closely resembles the cyclical behavior of the world price after the economy is hit by a world price innovation. In summary, the model economy correctly conforms with theoretical priors.

Table 4 also reports the stochastic properties of optimal policies in models with endogenous growth. In all of the three models considered, the autocorrelation function of the world price is again replicated by the structure of dynamic correlations between world and domestic prices. Similarly, the volatility of the world price is also fully incorporated in optimal domestic prices. These results indicate that despite having the capacity to smooth prices, the fund's optimal decision is to give up its stabilization objective. Stabilization policies of the type analyzed in this paper introduce a wedge of inefficiency between world and domestic prices, acting like a tax, whose distortionary effect on allocations outweighs the beneficial effect of a smoothed price on growth and on savings of adjustment costs. Optimal policies do not look for a reversal of the symptoms of Dutch disease when the economy is hit by an export boom (impulse-response functions for the economies with endogenous growth, not reported, are very close to those depicted in figure 2).

Actual domestic pricing policies (see table 4) executed by Colombia's National Coffee Fund share with optimal policies the property of tracking down the autocorrelation function of the exogenous world price. The dynamic correlation between domestic and world prices has an inverted V shape close to that exhibited by the estimated autocorrelation function. This resemblance is more apparent in the 1970-1992 sample period. However, actual policies depart from optimal behavior in their effort to excessively smooth producer prices: only 65%-66% of world market volatility is transmitted to domestic prices.

Robustness. The calibration of ω_1 is questionable because its size, or more generally, the properties of optimal policies are unknown. The choice in the paper is based on the conjecture that observed policies are close to optimal and they yield a highly procyclical growth rate. However, two of the models with endogenous growth, those with learning by working and learning by investing externalities, cannot match the observed growth rate-output correlation (see table 4). Ample experimentation with ω_1, while maintaining plausible predictions for other second moments, at most yielded a correlation in the $0.16-0.18$ range with very small volatility for the economy's growth rate. In general, optimal policies for these types of models rendered a relatively constant rate of growth, uncorrelated with cyclical output. However, among the mentioned experiments, the properties of optimal policies remained practically unchanged. On the other hand, the model with a learning by producing externality rendered a procyclical enough rate of growth but also pushed toward a stable rate. Again, experimentation with ω_1 did not alter the model's policy prescriptions.

The sensitivity of the model's behavior is further evaluated by changing key features of the economy. Simulations with an economy facing a wide range of alternative steady state growth rates of per capita output (from 1% to 6% per year), fund sizes measured by the fund's debt to output ratio (from 3% to 20% of output) and relative importance of the booming sector (from 3% to 30% of total output) were performed. Remarkably, none of these experiments altered the model's solution in a noticeable way. The most important change in policy prescriptions arises when the booming sector represents as much as 30% of total output and employment. But in this case, the optimal producer price must inherit 95% (0.004) of the world price volatility without change in the structure of dynamic correlations.

7 Concluding Remarks

The results presented in this paper have important implications. At least for a pure domestic price stabilization scheme, the empirical predictions are very robust: a commodity price stabilization fund designed to stabilize behavior cannot improve the functioning of the economy. A stabilization fund is not the appropriate policy instrument to deal with export price instability; nor do the harmful effects of the Dutch disease associated with commodity export booms call for the use of offsetting policies performed through this type of stabilization device. The best policy for domestic producer pricing is to replicate the stochastic properties of its world market counterpart.

The research program aimed at studying the design of policy interventions in developing countries, their dynamic implications and their relative performance in response to export price instability is at a very preliminary stage. The model and the techniques presented in this paper represent an appropriate tool to answer many of the unsolved questions. The empirical literature on Dutch disease has disregarded the use of recursive numerical methods developed by the RBC literature.

Extending the model to evaluate alternative policy instruments or alternative specifications for the stabilization scheme, for instance international commodity agreements, trade taxes, quantitative restrictions, buffer stock schemes, etc., or alternative rationales for government intervention, for instance credit market failures, seems an interesting and relevant agenda for future research.

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APPENDICES

A Description of the Data Used in VARs

Country, sample period and lag length: 1) Colombia, 1951-1995, 2; 2) Costa Rica, 1970-1992, 2; 3) El Salvador, 1968-1995, 1; 4) Ethiopia, 1968-1992, 1; 5) Guatemala, 1968-1995, 1; 6) Honduras, 1968-1995, 1 and 7) Kenya, 1967-1993, 2.

Data sources: yearly data on aggregate and sectoral output, governmentc spending, total exports and trade balance are taken from the UN National Account Statistics, ECLAC and IMF. Data on nominal exchange rates (domestic currency/dollar rate) and CPIs are from the International Financial Statistics of the IMF. Colombian data are from DANE and Banco de la República. Non-coffee exports and world coffee price figures are from F.O. Litchs International Coffee Yearbook and Colombia's National Federation of Coffee Growers. Kenya's non-coffee exports are from IMF.

Some variable definitions: To construct the world price of coffee in real terms for each country, the appropriate coffee price indicator expressed in terms of domestic currency is deflated by the CPI. The proxy for nontradable sector output is defined as total GDP minus value added from agriculture, mining and manufacturing sectors. The real exchange rate is calculated using domestic and U.S. CPIs. U.S. CPI is taken from the Economic Report of the President.

B Description of the Data Used in Calibration and Business Cycle Properties of the Colombian Economy

Calibration. Calibration is based on Colombian yearly data. The rate of growth of per capita output is calculated as the geometric rate of growth of per capita GDP between 1952 and 1992. GDP data are taken from the NIPA and expressed in per capita terms using employed population; its source being the Departamento Nacional de Planeación (DNP). Capital-output and investment-output ratios correspond to average ratios for the 1952-1992 and 1970-1992 periods, respectively. Capital stock figures are from the DNP and investment from the NIPA. Investment is defined as total gross capital formation plus durables consumption. The share of nontradable investment in total investment is proxied by the average share of nontradable investment in gross fixed capital formation for the 1970-1992 period. Nontradable investment includes the following items of the NIPA's gross fixed capital formation: residential buildings, nonresidential buildings, other constructions and land improvement and plantation and orchard development.

Sectoral categorization of GDP data by kind of activity is realized by freely following Kravis et al. (1982). Value added from agriculture (excluding coffee output), manufacturing (excluding coffee threshing) and mining make up the nonbooming tradable sector, while the remaining (non-coffee related) activities constitute the nontradable producing industry. Average sectoral shares in total output are calculated for the 1952-1992 period. Sectoral shares in employment correspond to average shares for the 1970-1992 period. Employment data are constructed from DNP, Errázuriz (1987) and Errázuriz et al. (1994).

Foreign debt to output ratio is the average for the 1970-1992 period. The source of total foreign debt and exchange rate is the database of the Banco de la República, central bank of Colombia. There is no reliable data to calculate the National Coffee Fund's share in total foreign assets. The fund's debt to output ratio was set to 5% in the baseline parameterization. The fraction of time spent working correspond to a standard choice in RBC calibration.

Business Cycle Properties. Most variable definitions and data sources are described in the preceding paragraphs. Consumption (I) in table 2 corresponds to total final household consumption, while consumption (II) includes only nondurables. Data, except ratios, employment shares and relative prices have been expressed in per capita terms by using employed population. All variables, except employment shares and net exports ratio, have been logged; and all have been detrended using the Hodrick-Prescott filter with smoothing parameter set at 100.

C Tables and Figures

Table 1: **Calibration**

	Parameters	Values
Growth Rates	η	1.0138
	η^s	1.0326
Preferences	β	0.9830
	Θ^W	0.4896
	γ	2.8572
Technologies	Δ^B	1.0000
	Δ^T	0.7769
	Δ^N	0.9880
	α^B	0.2400
	α^T	0.4433
	α^N	0.2552
Armington Aggregator	Δ^I	1.9988
	Θ^I	0.5172
Depreciation Rate	δ	0.0701
World Interest Rate	r^*	0.0650
Other Steady State Values	Φ^B	0.0502
	Φ^T	0.5689
	Φ^N	0.3809
	N^B	0.0264
	N^T	0.1188
	N^N	0.1848
	D^h	0.0950
	D^f	0.0226

Note: a period in the model is meant to represent one year

Table 2: **Business Cycle Properties of the Colombian Economy**

	Sample period: 1951-1992		Sample period: 1970-1992	
Output Volatility (%)	1.42		1.44	
	Relative Standard Deviation	Correlation with Output	Relative Standard Deviation	Correlation with Output
Basic Aggregates				
Consumption (I)	1.14	0.54	0.84	0.73
Consumption (II)	na	na	0.84	0.75
Investment	na	na	2.07	0.31
Net Exports-Output Ratio	1.77	-0.02	1.52	0.34
Growth Rate	1.08	0.53	1.26	0.61
Sectoral Output				
Coffee (agriculture)	4.98	-0.27	5.50	-0.29
... including threshing	5.52	0.19	5.38	0.13
Tradable	1.56	0.50	1.90	0.66
Nontradable	1.63	0.73	1.21	0.71
Employment Shares				
Coffee	0.29	-0.19	0.14	-0.11
Tradable	0.60	0.25	0.49	0.40
Nontradable	0.58	-0.16	0.44	-0.41
Relative Prices				
Nontradables	2.21	-0.43	2.19	-0.32
Investment	4.32	-0.30	2.95	0.04

Notes: na=not available. Yearly data. Data, except ratios, employment shares and relative prices have been expressed in per capita terms by using employed population. All variables, except employment shares and net exports ratio, have been logged; and all detrended using the Hodrick-Prescott filter with smoothing parameter set at 100. See appendix for variable definitions

Table 3: **Stochastic Properties of the Exogenous Growth Model**

	Benchmark Case		$\frac{SD(\epsilon^T)}{SD(\epsilon^N)} = 1.35$		$\frac{SD(\epsilon^T)}{SD(\epsilon^N)} = \frac{1}{1.35}$	
Output Volatility (%)	1.43		1.43		1.43	
	Relative Standard Deviation	Correlation with Output	Relative Standard Deviation	Correlation with Ouput	Relative Standard Deviation	Correlation with Output
Basic Aggregates						
Consumption	1.09	0.68	1.08	0.69	1.14	0.71
Investment	1.19	0.82	1.18	0.82	1.23	0.83
Net Exports-Output Ratio	1.55	0.22	1.65	0.33	1.36	0.10
Growth Rate	0.00	0.00	0.00	0.00	0.00	0.00
Sectoral Output						
Coffee	5.42	-0.09	5.39	-0.08	5.40	-0.05
Tradable	2.50	0.56	2.59	0.65	2.29	0.43
Nontradable	1.50	0.54	1.27	0.45	1.72	0.68
Employment Shares						
Coffee	0.14	-0.14	0.14	-0.16	0.14	-0.08
Tradable	0.51	0.17	0.50	0.21	0.50	0.09
Nontradable	0.37	-0.18	0.37	-0.23	0.36	-0.09
Relative Prices						
Nontradables	1.75	0.06	1.65	0.32	1.80	-0.22
Investment	0.85	0.06	0.79	0.32	0.87	-0.22

Notes: SD(·)= standard deviation. Reported statistics correspond to averages across 300 simulations of 42 observations each. Simulated time series associated with each simulation are Hodrick-Prescott filtered (with smoothing parameter set at 100) before computing the corresponding moments.

Table 4: **Stochastic Properties of Optimal Pricing Policies**

	Dynamic Correlations of Prices $corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$ or $corr\left(p^{B*}_{t+J}, p^B_t\right)$ $J=$											Relative Standard Deviation	Correlation Output and Growth Rate
	-5	-4	-3	-2	-1	0	1	2	3	4	5	$\frac{SD(p^B)}{SD(p^{B*})}$	$corr\left(Y_t, \eta_t\right)$
COLOMBIAN DATA													
Sample Period: 1951-1992													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.51	−0.45	−0.20	0.05	0.44	1.00	0.44	0.05	−0.20	−0.45	−0.51		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.39	−0.24	−0.06	0.07	0.42	0.81	0.38	0.03	−0.21	−0.36	−0.49	0.66	0.53
Sample Period: 1970-1992													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.56	−0.54	−0.25	0.04	0.44	1.00	0.44	0.04	−0.25	−0.54	−0.56		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.53	−0.39	−0.13	0.15	0.54	0.89	0.42	0.01	−0.33	−0.52	−0.62	0.65	0.61
OPTIMAL POLICIES													
Exogenous Growth Model													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.25	−0.22	−0.11	0.10	0.45	1.00	0.45	0.10	−0.11	−0.22	−0.25		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.25	−0.22	−0.11	0.10	0.45	1.00	0.45	0.10	−0.11	−0.22	−0.25	0.98 (0.01)	0.01 (0.24)
Endogenous Growth Model: Learning by Working Externality													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.24	−0.21	−0.11	0.09	0.45	1.00	0.45	0.09	−0.11	−0.21	−0.24		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.24	−0.20	−0.11	0.09	0.45	1.00	0.45	0.09	−0.11	−0.21	−0.24	0.98 (0.01)	0.18 (0.22)
Endogenous Growth Model: Learning by Producing Externality													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.24	−0.18	−0.08	0.09	0.44	1.00	0.44	0.09	−0.08	−0.18	−0.24		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.24	−0.18	−0.08	0.09	0.44	1.00	0.44	0.09	−0.08	−0.18	−0.24	0.98 (0.01)	0.55 (0.17)
Endogenous Growth Model: Learning by Investing Externality													
$corr\left(p^{B*}_{t+J}, p^{B*}_t\right)$	−0.23	−0.20	−0.10	0.09	0.44	1.00	0.44	0.09	−0.10	−0.20	−0.23		
$corr\left(p^{B*}_{t+J}, p^B_t\right)$	−0.23	−0.20	−0.10	0.09	0.44	1.00	0.44	0.09	−0.10	−0.20	−0.23	0.98 (0.01)	0.16 (0.21)

Notes: SD(·)= standard deviation. corr(·,·)= correlation coefficient. Reported statistics correspond to averages across 300 simulations of 42 observations each. Simulated time series associated with each simulation are logged and Hodrick-Prescott filtered (smoothing parameter set at 100) before computing the corresponding moments. When reported, standard deviations of average statistics are in parentheses.

Figure 1: Response Functions to World Coffee Price Shocks in Seven Producer Countries

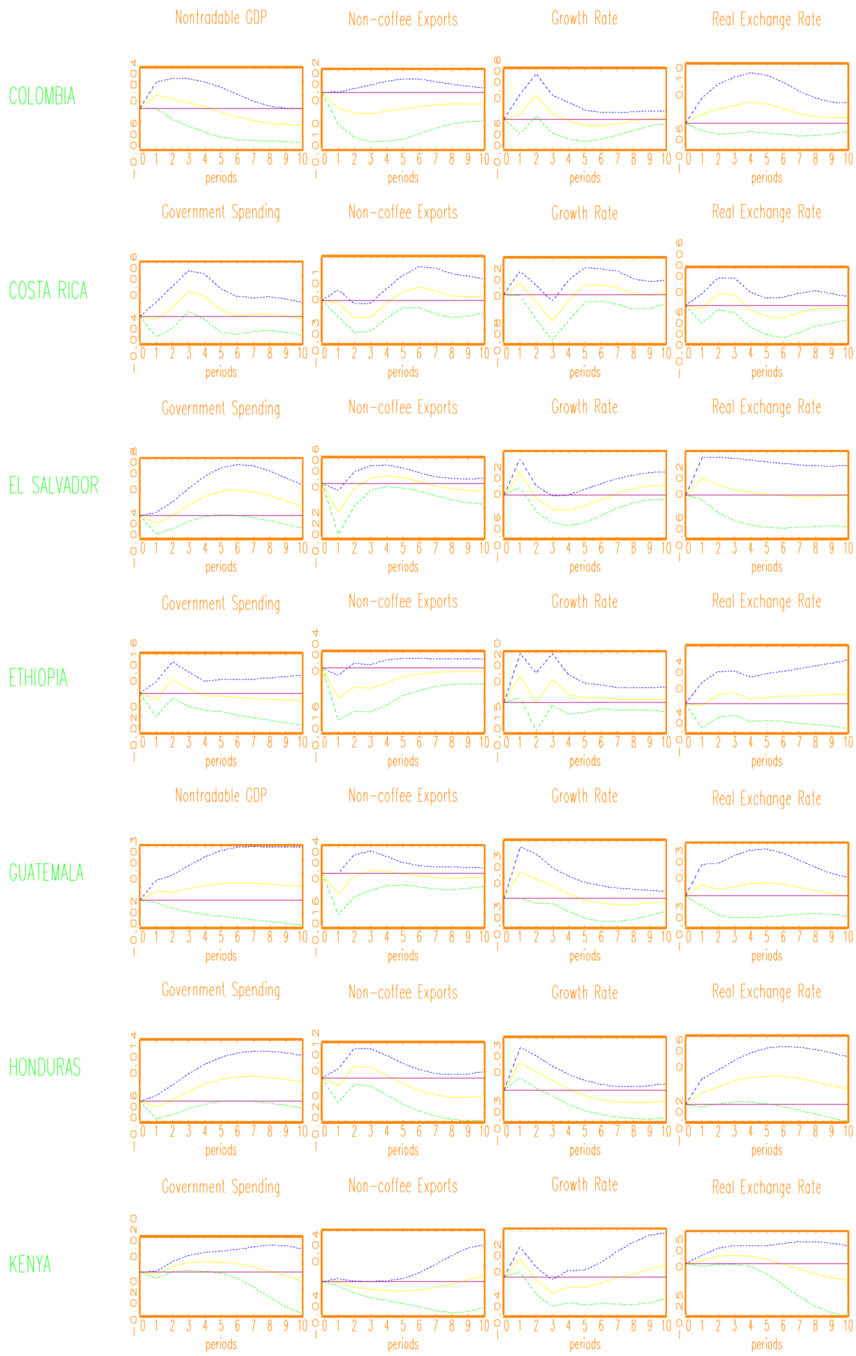

Figure 2: Dynamic Responses to a Coffee Boom