Do financial frictions amplify commodity price shocks in commodity exporting countries? Evidence from Côte d'Ivoire using a DSGE model

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Abstract

This paper aims to analyze how commodity price volatility spreads throughout the economy in exporting countries, and the role of the financial sector in the propagation of these shocks. To do so, we develop a Dynamic Stochastic General Equilibrium (DSGE) model applied to Ivorian economy that integrates the financial accelerator mechanism as formulated by Bernanke et al. (1999). In the model, information asymmetries in household-banker and banker-non-financial firm relationships generate frictions in the economy. Our simulations show evidence that positive cocoa price shocks enable the country to improve its economic performance via a positive growth rate, an increase in demand following a rise in household disposable income. Furthermore, our results indicate that the existence of financial frictions in the economy significantly reduces the potential gains from the commodity price boom.

Keywords: DSGE, Commodity Price, Volatility, Financial Accelerator, Côte d'Ivoire, Developing Countries

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Introduction

Most developing countries are highly dependent on commodity exports. For example, more than 60% of export earnings for at least two-thirds of developing countries came from commodities during 2013-2017. As a result, business cycles in most of these countries are correlated with commodity price cycles. For example, Céspedes and Velasco (2012) have established that much of the variation in aggregate output and investment in developing countries can be attributed to commodity price shocks. Unfortunately, macroeconomic aggregates that should enable these economies to deal effectively with the adverse effects of commodity price fluctuations very often (capital flows, political institutions, monetary and fiscal policy, and factor markets) end up producing opposite effects (Frankel, 2011).

Moreover, commodities are not only a source of funding for the conduct of government policies. They are also an important source of income for most private households. It follows then that any movement in commodity prices can impact their revenue and in fine affect their wellness. A prolonged decline in commodity prices can be detrimental to social cohesion. For example, Brückner and Ciccone (2010) examined the extend to which exogenous downturns in commodity prices can be a starting point for social conflicts in Sub Sahara Africa exporting countries and found empirical evidence that civil wars are more likely to occur after negative commodity price shocks.

It turns out that commodity price fluctuations are able to simultaneously affect all sectors of an economy, from private households to the central government. Consequently, to better appreciate the real effect of volatility on the economy, it would be interesting to adopt a general equilibrium approach. However, most of the work on the subject adopt a partial equilibrium strategy by evaluating the impact of price fluctuations on some key macroeconomic variables such as quality of institutions (), economic growth (Addison et al., 2016; Céspedes and Velasco, 2012, 2014), conflict and social cohesion (Brückner and Ciccone, 2010), public and private debt, financial sector (Kablan et al., 2017; Mlachila and Ouedraogo, 2020; Moreno et al., 2014; Yuxiang and Chen, 2011). Then, a question arises: how does commodity price volatility spread throughout the economy in exporting countries?

To address the question, this paper adopts a dynamic stochastic general equilibrium (DSGE) approach to assess the effect of commodity price volatility on the different sectors of an open commodity exporting economy. DSGE models emerged from Friedman's and Lucas' critique of Keynesian modeling[1]. This breakthrough gave rise to Real Business Cycle (RBC) models in the renewal of applied macroeconomic modeling and were considered

[1]

as true models of general equilibrium, with coherent dynamic behaviors and rational forecasts of agents (Epaulard et al., 2008). They have been enriched over the years by economists, (by introducing economic rigidities and necessary imperfections for a better understanding of the economy) to obtain DSGE models. The use of this class of model is beneficial when it comes to analyzing the behavior of an economy following shocks.

For the empirical implementation, we selected the Ivorian economy. The choice of Côte d'Ivoire is justified by two main reasons. First, Côte d'Ivoire, like most developing countries, depends heavily on the export of commodities, the main one being cocoa followed by coffee. In 2017, for example, 85% of the country's export revenue was made up of commodities (35% of which was cocoa). In the same year, commodities alone accounted for 24.8% of GDP (UNCTAD, 2019). As a result, the country's economic performance is strongly affected by fluctuations in commodity prices. This characteristic is typical of developing countries and the case study of Côte d'Ivoire should provide interesting lessons for developing economies. Second, Côte d'Ivoire is member of regional organizations (such as WAEMU[2] and ECOWAS[3]) in which certain common objectives require common policy target, facilities for intra-regional trade, common monetary policy and many others. In these regional groupings, the country occupies a strategic position in terms of economic weight. For example, in 2020, Côte d'Ivoire's GDP represented about 40% of WAEMU GDP and about 9% of the overall GDP of ECOWAS. These statistics place the country as the largest economy of WAEMU and the third largest economy of ECOWAS. Thus, any exogenous factor capable of disrupting the dynamics of Ivorian economy may also have unfortunate consequences for these regional organizations.

[2]West African Monetary and Economic Union was established with the Treaty signed in Dakar on 10 January, 1994 by the Heads of State and Government of eight West African countries using the CFA Franc in common : Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo.

[3]Economic Community of West African States is made up of fifteen member countries located in the Western African region which have both cultural and geopolitical ties and shared common economic interest.

1 Stylized facts

In this section, we provide some stylized facts about Côte d'Ivoire economy and its agricultural sector. We also highlight some evidence on cocoa production and exportation as well as the potential link between cocoa price and some macroeconomic aggregates.

1.1 Description of Ivorian economy

The development of Côte d'Ivoire economy can be summarized into [three] phases since its independence in 1960 as highlighted in figure 1. The first period, 1960-1980, corresponds to a phase of rapid growth, with the real GDP per capita rising from about $1,567 to $3,161 in 1978, an average annual growth rate of about 3.8% over the period. Given its position as a world leader in cocoa export, Côte d'Ivoire benefited from the rise in commodity prices such as cocoa - which rose from about $3 per kilogram in 1960 in 1960 to $8.3 per kilogram by 1980. The second period, which ended in 2011, was characterized by a collapse in cocoa prices that led to a series of economic and social crises. This second period was characterized by anemic economic growth resulting in a significant decline in real GDP per capita, which reached its lowest historical value of $1,560 in 2011[4]. Finally, starting in 2012, the government's efforts are reflected in a substantial increase in real GDP from US$32.8 billion in 2011 to more than US$61 billion in 2020, an average annual growth rate of 6.4%, despite fluctuations in cocoa prices.

Furthermore, the graphs suggest a positive correlation between cocoa price and the indicators presented since 1960. This is explained by the relative importance of cocoa sector in Ivorian economy, which will be presented in the next subsection. We also notice that the period from 1996 is characterized by relatively controlled inflation, corresponding to the period of implementation of WAEMU monetary union policies and where monetary policy was devoted to price stabilization.

1.2 Cocoa sector in Côte d'Ivoire

Cocoa sector is one of the pillars of Ivorian economy. Given its importance, the Ivorian government has put in place incentives and a stabilization fund to guarantee farmers a minimum price. The country is the world's leading cocoa producer accounting for nearly 40% of world production and it earns about [40]% of its export revenue from cocoa.

[4]It is worth noting that the country has not benefited from the second super-cycle in commodity prices which lasted from 2000 to 2008 due to the military-political crisis.

Figure 1: Some key indicators of Ivorian economy during 1960-2021

(a) Real GDP per capita (b) GDP Growth rate

(c) Real cocoa annual price (d) CPI-based Inflation Rate

Source: World Development Indicators

The sector is composed of farmers, cooperatives, exporters, industries, financial intermediaries and is regulated by the *Conseil Café Cacao*, a platform in which the government plays an important role. Given the limited amount of credit to agriculture (6% of commercial bank credit and 9.5% of microfinance credit) and the fact that commercial bank credit is mainly oriented towards agribusiness groups and large producers integrated into value chains[5], we will not discuss in this section nor model in this chapter the link between financial intermediaries and cocoa production. Therefore, this section will be limited to describing the value chain and government interventions.

[5]These numbers are from a ”Diagnosis and action plan for the development of agricultural finance in Côte d’Ivoire” published by the World Bank Group and accessed on April 6, 2023.

1.2.1 Cocoa value chain in Côte d'Ivoire

In Côte d'Ivoire, cocoa is produced by thousands of small farms[6], most of which are planter households whose main role is the production of fresh or dried cocoa. To achieve this, they often use a workforce made up of young people and can be helped by cooperative collectors who facilitate the collection, especially in the most remote areas, by collecting the cocoa by camp or by village in exchange for payment.

Then, the cocoa is sold to buyers who constitute the second link in the value chain. They can be producers, exporting or processing companies or individuals. They are linked by campaign contracts to an exporter or a miller and it is they who buy the cocoa beans from the producers. The buyers, in turn, sell the cocoa to exporters who can be agricultural cooperatives or commercial companies, both of which are subject to licensing. They buy the merchant cocoa, process part of it locally into final (a very small part so far) or semi final products. Then, they transport the rest of the merchant cocoa and part of the semi-finished products outside the country. The approved exporters are among others SACO, International Cocoa Production, CARGILL, OLAM, CEMOI and TOUTON (Zahonogo, 2017).

1.2.2 Government interventions and support institutions

Government intervention in the cocoa sector in Côte d'Ivoire takes place at two levels: regulation of the domestic market and price setting. In terms of regulation, the government first set up the *Caisse de Stabilisation et de Soutien des Prix des Produits Agricoles (CAISTAB)* in 1962, whose main role was to supervise the entire process of buying and selling coffee and cocoa, in order to smooth out the income of those involved in the sector while seeking to improve it. Liquidated 38 years later in 1999, CAISTAB was the instrument of management of the cocoa sector and of the Ivorian national agricultural policy, and the prime contractor for the development of coffee and cocoa crops (BCEAO, 2014). Then, the sector has undergone several institutional reforms. The current one started in 2011 and was sanctioned by the establishment of the Council for the Regulation, Stabilization and Development of the Coffee-Cocoa Sector known as the *Conseil Cofé-Cacao (CCC)*, whose main role is to promote a sustainable cocoa economy.

In addition, at the beginning of each cocoa season, the government sets the minimum purchase price of cocoa. This price represents the minimum price guaranteed to producers and is announced in the Council of Ministers. The government also sets the export tax

[6] In 2018, Conseil Café-Cocoa (CCC) estimated the number of Ivorian cocoa producers at more than 800,000 and the number of Ivorians who derive their income from this product exceeded 6 million.

rate, which is one of its sources of revenue.

2 Model

This section presents the methodology used in evaluating channel through which shocks on commodity price affect exporting countries and the role of the financial sector. As mentioned above, we use a Dynamics Stochastic General Equilibrium (DSGE) model developed by Christiano et al. (2005) instead of a reduced form. DSGE models are particularly interesting for building robust scenarios following shocks such as commodity price volatility in a small economy such as Côte d'Ivoire. They also offer the possibility of dissociating the short term analysis from that of the medium and long term. As an extension of real business cycle (RBC) models, DSGE models have micro-foundations based on optimization and rationality of economic agents' behavior. They are able to integrate frictions, inefficiencies, price stickiness making them structural and integrating Lucas criticism (Gürkaynak and Tille, 2017).

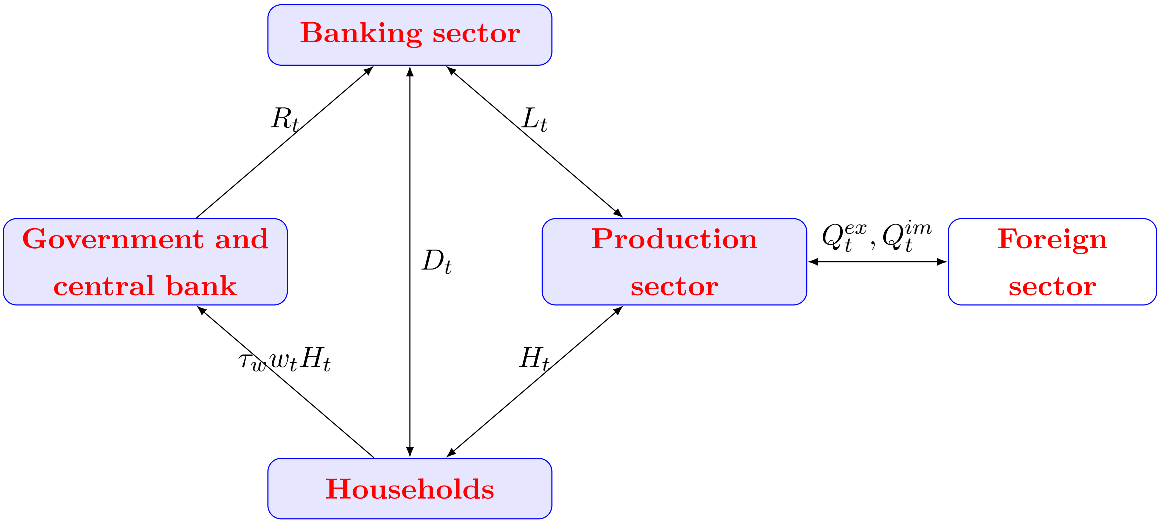
DSGE modeling starts with the setting of the framework. Our framework is inspired by Rannenberg (2016), with the difference that we have included a foreign sector, as shown in Figure 2. We therefore consider an economy made up of five sectors: households, production sector, government and central bank, the banking and the foreign sectors. This framework is similar to those used by other authors (Kollmann, 2001; Dagher et al., 2010; Bondzie et al., 2014; Malakhovskaya and Minabutdinov, 2014; Ferraro and Peretto, 2018 and others) and appears to be the most appropriate for the purpose of this paper.

We consider the economy is populated by an infinite number of households ($h \in]0, 1[$) that offer a non-differentiated labor force to the production sector in exchange for a wage. They own all domestic firms and derive part of their income from the dividends they receive. Production in the economy is carried out by different types of firms capable to lend from the banking sector to finance their production process. The local economy imports also goods for consumption and exports a part of local production abroad. The production side of the economy will be described later in this section.

As for the banking sector, it is made up of bankers who collect household savings in the form of bank deposits against remuneration, which they use to exclusively finance the production sector of the economy via two types of loans: risk-free intra-period and risky loans. We assume the existence of information asymmetry in both household-banker and banker-producer relationships, which create friction in the economy. Finally, the government and the central bank are responsible for fiscal and monetary policy respectively.

In the next sub-sections, we present the behavior of each agent in detail, in order to derive the equations that derive the overall functioning of the economy.

Figure 2: Overview of the economy



Source: Author

2.1 Household

The economy is made up of a continuum of households on the interval [0,1] who own firms, consume goods and services and derive a part of their income from labor.

Households optimize the following expected inter-temporal utility function over their life-cycle, which is assumed to be infinite:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_h^t u_t(C_t, H_t) \tag{1}$$

where $\mathbb{E}_0$ denotes the expectation operator, u_t is the instantaneous utility function, β_h is the exogenous discount factor; H_t and C_t represent aggregate labor supplied (hours worked) by households to private sector and their real consumption. Their objective is to maximize their life-time expected discounted utility.

Preferences are described by a constant relative risk aversion (CRRA) function with a habit persistence parameter denoted by $h > 0$. Household aggregate utility function is then defined as follows :

$$u_t(C_t, H_t) = \frac{(C_t - hC_{t-1})^{1-\nu_c}}{1-\nu_c} - \varphi_h \frac{(H_t)^{1+\nu_l}}{1+\nu_l}. \tag{2}$$

where $1/\nu_c$ denotes the inter-temporal elasticity of substitution, ν_l is the elasticity of labor dis-utility with respect to hours worked and $\varphi_h > 0$ is a scale parameter .

To meet their current expenditures, which include consumption (P_tC_t) and deposits (D_t), households draw resources from labor income $((1-\tau_W)W_tH_t)$, return on bank deposits from the previous period ($R_{t-1}D_{t-1}$) and the profits from domestic firms (intermediate and final goods producers, capital goods producers and cocoa producers) they own (Π_t). Hence, the household budget constraint is written as follows:

$$P_tC_t + D_t = (1-\tau_W)W_tH_t + R_{t-1}D_{t-1} + \Pi_t \tag{3}$$

where τ_W is the personal income tax rate paid to the government.

The problem of each household is to solved (1) under the constraints (3). First order conditions of this problem are given by:

$$u_{c_t} = (C_t - hC_{t-1})^{-\nu_c} - h\beta_h\mathbb{E}_t\left[(C_{t+1} - hC_t)^{-\nu_c}\right] \tag{4a}$$

$$\beta_h\mathbb{E}_t\frac{u_{c_{t+1}}}{\pi_{t+1}}R_{t+1} = u_{c_t} \tag{4b}$$

$$H_t = \left(\frac{1-\tau_w}{\varphi_h}\frac{W_t}{P_t}u_{c_t}\right)^{1/\nu_l} \tag{4c}$$

where u_{c_t} is the marginal utility of consumption and $\pi_t = \frac{P_t}{P_{t-1}}$ represents the inflation rate in the domestic economy between $t-1$ and t.

2.2 Banking sector

Bankers do essentially two things: they collect savings from agents with financing capacity and redistribute them to those in need. In order to attract more savings, they offer a remuneration on savings and borrowers must also pay a remuneration on borrowed funds. The problem is that there are imperfections in either bank deposit and loan markets due to asymmetric information (Stiglitz and Weiss, 1981). These imperfections lead agents to take into account their financial situations before resorting to external financing. Firms and banks financial situations are represented respectively by firms' balance sheet and banks' capital equity. These two elements are the basis for shocks amplification and propagation in the real economy according to Bernanke et al. (1999).

Modeling these imperfections becomes more complicated as banks manage two completely different types of contracts. First, they mobilize savings of agents with financing capacity in exchange for a credit interest rate. In this case banks behave like borrowers and their ability to mobilize savings depends on their financial health, which is captured by their equity. Banks with more equity would therefore be more creditworthy than their counterparts with less equity. When bankers collect deposits from households, they can choose to divert a part of the funds for their own consumption. Therefore, there is a risk that bankers will not be able to pay depositors back. In this case, households will have an incentive to make deposits if the share diverted by bankers is small enough that it does not prevent bankers from effectively meeting their obligations to households.

Second, banks lend to agents in need of financing. In this second type of contract, they behave as lenders. They must therefore evaluate entrepreneurs' investment projects and choose to finance those that seem more credible to them. The credibility of an investment project being intrinsically linked to that of its bearer, the financial health of firms carrying investment projects becomes an element of arbitration for banks since it determines the risk that the bank is willing to take.

How do these two types of contracts affect interest rates determination in the economy, and to what extent do financial market frictions contribute to propagating effects of cocoa price volatility in Côte d'Ivoire? To answer these questions, we consider the BGG financial accelerator model as postulated by Bernanke et al. (1999). In this framework, information asymmetries between firms (borrowers) and banks (lenders) lead to frictions in credit market and firms' demand for external borrowing depends on their leverage ratio. We follow Rannenberg (2016) by considering that a portion of households in the economy are bankers. They are risk-neutral and die with a fixed probability of $1-\theta$ after earning interest income on the loans they made in the previous period. Before dying, banker q consumes its accumulated real net worth at the end of period t, $N_t^b(q)$. And in each period new bankers enter the market to replace those who are no longer able to operate. They receive a transfer N_n^b from households[7]. In our framework, bankers lend exclusively to non-financial firms, and that is the only way they derive income.

In line with the framework described above, we assume that the banker grants two types of loans. Firstly, he finances the acquisition of new capital by granting risky inter-period loans $L_t^e(q)$ to entrepreneurs. These loans are used to acquire the capital stock of period $t+1$. Secondly, the banker supports the intermediate goods producer who needs to pre-finance part of the labor and capital service used in his production process. These loans are denoted $L_t^i(q)$ and are paid back at the end of period t.

We assume that once the deposits have been collected from households, bankers can choose to divert a part $0 \leq \lambda \leq 1$ of their assets (loans to entrepreneurs) and add them to their own wealth. If they do so, the bankers declare bankruptcy and households recover the remaining assets. Consequently, households will only have an incentive to make deposits with the bankers if the latter have no incentive to default, which means if $V_t^b \geq \lambda L_t^e(q)$.

[7]In the calibration, the share of transfers received by the new bankers, N_n^b, is considered to be very small

In equilibrium, this conditions can be expressed as follows:

$$V_t^b(q) = \lambda L_t^e(q) \tag{5}$$

where $V_t^b(q)$ represents the banker's present value of the expected real final wealth defined by:

$$V_t^b = \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} (1-\theta)\theta^i \left(\frac{1}{\prod_{j=0}^{i} R_{t+1+j}^r} \right) N_{t+1+i}^b(q) \right\}, \tag{6}$$

with $R_{t+1}^r = \frac{R_t}{i_{t+1}}$.

Let $D_t(q)$ denote the total amount of nominal deposits collected by the banker q to finance inter-period loans to entrepreneurs. It follows that $P_t L_t^e(q) = P_t N_t^b(q) + D_t(q)$. The law of motion of the banker's net worth at the beginning of period t is given by:

$$\begin{aligned} P_t N_t^b(q) &= [R_t^b P_{t-1} L_{t-1}^e(q) - R_{t-1} D_{t-1}(q)] exp(\varepsilon_t^x) \\ &= P_{t-1}[(R_t^b - R_{t-1}) L_{t-1}^e(q) + R_{t-1} N_{t-1}^b(q)] exp(\varepsilon_t^x) \end{aligned} \tag{7}$$

where R_t^b is the average return on loans to entrepreneurs made in period $t-1$ earned by the banker net of any costs associated with entrepreneurial bankruptcy. $exp(\varepsilon_t^x)$ is an exogenous shock to the capital of existing banks assumed to be independent and identically distributed. It captures the effect of a sudden decline in the value of the assets on the bank's balance sheet for reasons unexplained by the model.

By replacing equation (7) in (6) and posing respectively :

$$a_t = \mathbb{E}_t \left\{ (1-\theta) \frac{(R_{t+1}^b - R_t)}{R_t} + \frac{\theta g_{t,t+1} \pi_{t+1} a_{t+1}}{R_t} \right\} \tag{8a}$$

$$b_t = \mathbb{E}_t \left\{ (1-\theta) + \frac{\theta x_{t,t+1} \pi_{t+1} b_{t+1}}{R_t} \right\}, \tag{8b}$$

with $g_{t,t+1} = \dfrac{L_{t+1}^e(q)}{L_t^e(q)}$ is the net worth gross growth rate between t and $t+1$, and $x_{t,t+1} = \dfrac{N_{t+1}^b(q)}{N_t^b(q)}$ represents the assets gross growth rate between t and $t+1$. Equation (6) can be rewritten as follows:

$$V_t^b(q) = a_t L_t^e(q) + b_t N_t^b(q) \tag{9}$$

which leads to the following equation considering (5):

$$L_t^e(q) = \frac{b_t}{\lambda - a_t} N_t^b(q) = \phi_t^b(q) N_t^b(q) \tag{10}$$

in which $\phi_t^b(q) = \frac{b_t}{\lambda - a_t} = \frac{L_t^e(q)}{N_t^b(q)}$ is the bank leverage ratio. As both members of the above equation are positive, the constraint binds as soon as $0 < a_t < \lambda$. Note that in this case, ϕ_t^b is increasing in a_t: the larger a_t is, the higher the opportunity cost to the banker of being forced into bankruptcy.

Finally, we can replace equation (7) into $g_{t,t+1}$ and $x_{t,t+1}$. We obtain then:

$$x_{t,t+1} = \frac{1}{\pi_{t+1}}\left[(R_{t+1}^b - R_t)\phi_t^b(q) + R_t\right] exp(\varepsilon_t^x) \tag{11}$$

and

$$g_{t,t+1} = \frac{\phi_{t+1}^b(q)}{\phi_t^b(q)} x_{t,t+1} \tag{12}$$

Above relationships indicate that a_t, b_t, $x_{t,t+1}$, $g_{t,t+1}$ and $\phi_t^b(q)$ do not depend on banker q specific variables but solely on economy-wide variables. Hence, in equilibrium, all bankers use the same ratio between loans to entrepreneurs and their own net worth ($\phi_t^b = \dfrac{L_t^e}{N_t^b}$). This allows us to drop the subscript q in these variables.

At each time period t, the total net wealth N_t^b of the banking sector is made up of the net wealth N_{et}^b of bankers who operated in previous period and remained alive at the beginning of period t, and transfers received by the new bankers N_n^b ($N_t^b = N_{et}^b + N_n^b$). As for N_{et}^b, it consists of the part θ of total net worth of period $t-1$ adjusted by the rate of growth $x_{t-1,t}$ of the real net worth of bankers already operating in period $t-1$ who remained alive at the beginning of period t so that:

$$N_{et}^b = \theta x_{t-1,t} N_{t-1}^b \tag{13}$$

Moreover, as mentioned above, before dying default banker consumes all his net wealth accumulated at period t. Thus, the consumption of dying bankers is defined as follows :

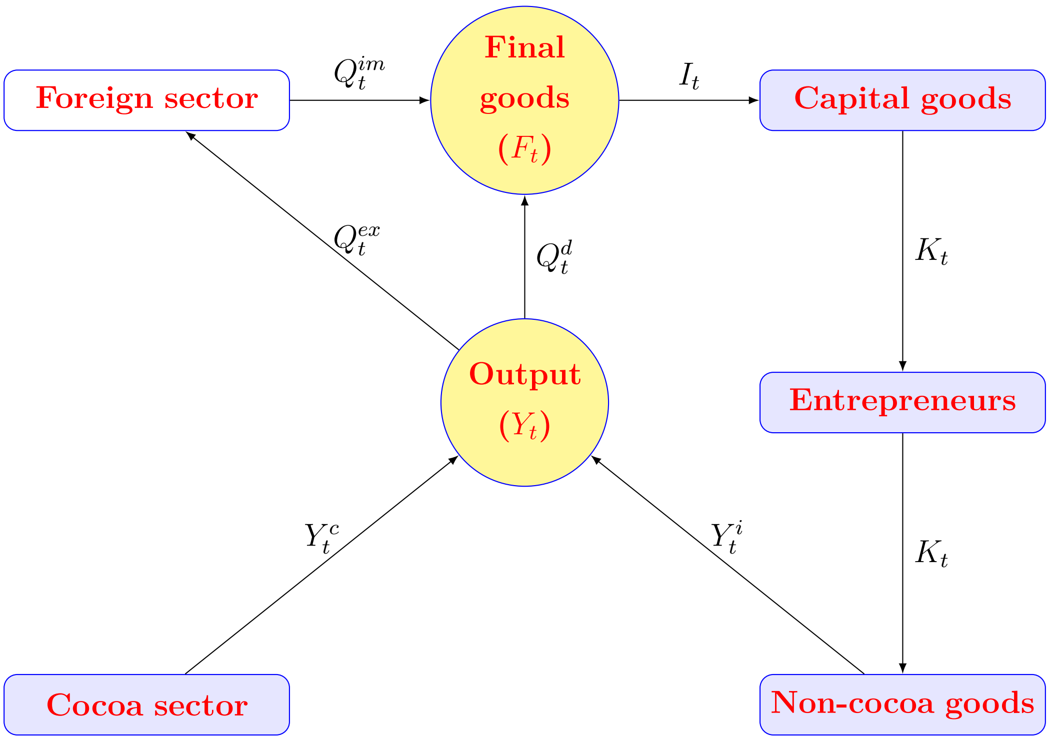
$$C_t^b = (1-\theta) x_{t-1,t} N_{t-1}^B \tag{14}$$

2.3 Domestic firms

Production within the local economy is carried out by several groups of firms as presented in Figure 3. This framework is inspired by Malakhovskaya and Minabutdinov (2014), to which we include the cocoa production sector. First, non-cocoa goods are produced by agents that operate in monopolistic competition. They use capital rented from entrepreneurs at rental rate r_t^k and labor provided by households as inputs. Cocoa is also produced by a set of small production units owned by households using mainly labor as input. The available labor force is divided between the two production sectors (cocoa and non-cocoa). For simplicity, we assume that the share of labor in the non-cocoa sector is constant and denote it as h_i. Both non-cocoa goods and cocoa are aggregated into the overall output used in the domestic market or exported abroad. In their production process, cocoa and non-cocoa goods producers may resort to bank loans that are used to pay for working capital or labor.

In the economy, there are also final good producers. They combine part of the intermediate goods produced in the economy and goods imported from the rest of the world to produce a final good intended exclusively for consumption and investment.

Figure 3: Description of the production side of the economy



Source: Author

2.3.1 Aggregate output

Overall cocoa and non-cocoa goods produced within the economy are combined to produce an intermediate good using the following technology:

$$Y_t = \left(\frac{1}{\eta_{yi}} Y_t^i\right)^{\eta_{yi}} \left(\frac{1}{\eta_{yc}} Y_t^c\right)^{\eta_{yc}}, \quad 0 < \eta_{yc} < 1, \eta_{yi} = 1 - \eta_{yc} \tag{15}$$

Y_t denotes the domestic intermediate goods index, Y_t^i and Y_t^c are indices of aggregate cocoa and non-cocoa goods sold respectively at price P_t^i and P_t^c. The intermediate good price index is determined by a weighted geometric mean of cocoa and non-cocoa products aggregate price index.

$$P_t^d = \left(P_t^i\right)^{\eta_{yi}} \left(P_t^c\right)^{\eta_{yc}} \tag{16}$$

We assume that intermediate goods produced within the domestic economy are either sold on domestic markets (Q_t^d) or exported abroad (Q_t^{ex}).

$$Y_t = Q_t^{ex} + Q_t^d \tag{17}$$

2.3.2 Cocoa producers

Cocoa production is carried out by a large number of small producers producing homogeneous goods (perfectly substitutable) and free to decide whether to produce cocoa or not. In fact, they are free to replace cocoa trees with other crops at any time and thus leave the cocoa production process. Thus, the structure of cocoa production sector can be considered as in perfect competition. In this structure, producers have no individual influence on the price setting mechanism and are obliged to sell their production at the market price. At any time t, a quantity Y_t^c of cocoa is produced using capital and labor in the following production function:

$$Y_t^c = A_t^c \left(H_t^c\right)^{\eta_c}, \tag{18}$$

in which $H_t^c = (1-h_i)H_t$ denotes the use of labor in cocoa sector; and A_t^c is a technological parameter assumed to follow a AR(1) process.

$$A_t^c = \left(A_{t-1}\right)^{\alpha_c} exp(\varepsilon_t^c) \tag{19}$$

The cocoa produced is sold at the price P_t^c which represents the price to producer, set exogenously by the government according to the evolution of the international cocoa price. As for the non-cocoa sector, we assume that the cocoa producer has the option of pre-financing part of the remuneration of its working labor force through intra-period bank loans. Let ψ_C be the share of labor remuneration pre-financed by the cocoa farmer via bank loans.

The representative cocoa producer maximizes its profit and first order conditions associated to its optimization problem yield:

$$W_t^c(1 + \psi_C(R_t - 1)) = \eta_c A_t^c P_t^c (H_t^c)^{\eta_c - 1} \tag{20}$$

where W_t^c is the wage of labor force in cocoa sector.

We assume that the producer price is an autoregressive adjustment of its value and the international price which can be written in the form:

$$P_t^c = \left(P_{t-1}^c\right)^{1-\gamma_o} (O_{t-1})^{\gamma_o} \varepsilon_t^c \tag{21}$$

where γ_o represents the degree of transmission from the international price to the domestic price, and ε_t^c follows a log-normal distribution.

2.3.3 Non-cocoa goods sector

We consider that non-financial firms owned by households and operating under monopolistic competition produce non-cocoa goods indexed by j intended for sale. They are owned by households. The demand for good j is given by:

$$Y_t^i(j) = \left(\frac{p_t^i(j)}{P_t^i}\right)^{-\varepsilon} Y_t^i \tag{22}$$

in which $\varepsilon > 1$ represents the elasticity of substitution between varieties.

At the end of each period t, each producer acquires a quantity $K_t^s(j)$ of physical capital that will be used for period $t+1$ production. The output of firm j at each period t, denoted by $Y_t^i(j)$, is produced by firms by combining capital and labor $H_t^i(j)$ using a Cobb-Douglas production technology with constant returns to scale according to the following equation:

$$Y_t^i(j) = (K_t^s(j))^{\eta_k}(exp(a_t^i)(H_t^i(j)))^{1-\eta_k},\, 0 < \eta_k < 1 \tag{23}$$

where a_t^i is a productivity factor, exogenous to the sector and identical for all producers; η_k denotes the share of capital in the production process; K_t^S is the stock of capital (the rate of capital utilization is assumed to be equal to unity). Following Rannenberg (2016), we assume that in during the production process, the producer must pay in advance fractions ψ_H and ψ_K of his labor and capital expenses, which are financed entirely by bank loans. The producer j's working capital loan, $L_t^i(j)$, paid back at the end of period t at the risk-free rate R_t^D is given by:

$$L_t^i(j) = \psi_H w_t^i H_t^i(j) + \psi_K r_t^k K_t^s(j) \tag{24}$$

With this assumption, the total expenditure faced by the producer of intermediate goods j is made up of the full remuneration of capital and labor, and debt service. They are given by :

$$TC_t(j) = w_t^i(1 + \psi_H(R_t - 1))h_t^i(j) + r_t^k(1 + \psi_K(R_t - 1))K_t^s(j) \tag{25}$$

The producer problem comes back to minimizing its total cost defined in equation (25) under the production function (23). Assuming economy wide-factor and $\int K_t^s(j)dj = K_{t-1}$ leads to these first order conditions with respect to labor force and capital are given by:

$$w_t^i(1+\psi_H(R_t-1)) = (1-\eta_k)\, mc_t\, \frac{Y_t^i}{h_t^i} \tag{26a}$$

$$r_t^k(1+\psi_K(R_t-1)) = \eta_k\, mc_t\, \frac{Y_t^i}{K_{t-1}} \tag{26b}$$

$$L_t^i = \psi_H\, w_t^i\, H_t^i + \psi_K\, r_t^k\, K_{t-1} \tag{26c}$$

where mc_t is the marginal cost and represents the Lagrange multiplier associated with the constraint.

Non-cocoa goods producers are subject to nominal rigidities *à la Calvo (1983).* That is, at each period t, only a fraction $1-\varpi_{ig}$ of intermediate goods producers are allowed to re-optimize their price while the remaining producers, the fraction ϖ_{ig}, keep the price of the previous period. The new price of the intermediate producer after updating the price is $\tilde{p}_t^i(j)$. The intermediate producers' program is then given by:

$$\max \mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ig}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(\frac{p_t^i(j)}{P_{t+s}^i} - mc_{t+s} \right) Y_{t+s}^i(j) \right\} \tag{27}$$

subject to (22). the first order condition is given by:

$$\tilde{p}_t^i(j) = \frac{\varepsilon}{\varepsilon-1} \frac{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ig}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^i\right)^{\varepsilon} Y_{t+s}^i\, mc_{t+s} \right\}}{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ig}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^i\right)^{\varepsilon-1} Y_{t+s}^i \right\}} \tag{28}$$

As we can see, the left-hand side of equation (28) does not depend on the subscript j. Thus, producers who are allowed to re-optimize their price choose the same price. This result allows us to skip the j index and simply write $\tilde{p}_t^i$. The price dynamics of aggregate intermediate goods is given by:

$$P_t^i = \left[(1-\varpi_{ig}) \left(\tilde{p}_t^i\right)^{1-\varepsilon} + \varpi_{ig} \left(P_{t-1}^i\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{29}$$

2.3.4 Final goods production

The final good sector is represented by firms (or retailers), owned exclusively by households. They are specialized in buying wholesale goods obtained in the intermediate goods sector or abroad, and then reselling them on the retail market. They simply repackage intermediate output by taking one unit of intermediate or imported good to make a unit of final good. The final good is sold at price P_t. The final good is devoted to consumption and investment (the final good is not tradable). It is produced using the following production technology:

$$F_t = \left(\frac{1}{\alpha_d} Q_t^d\right)^{\alpha_d} \left(\frac{1}{1-\alpha_d} Q_t^{im}\right)^{1-\alpha_d} \tag{30}$$

where F_t is the final good, Q_t^d and Q_t^{im} are the aggregate domestic and foreign inputs and assumed to be Dixit–Stiglitz aggregate so that:

$$Q_t^d = \left(\int_0^1 q_t^d(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \text{ and } Q_t^{im} = \left(\int_0^1 q_t^{im}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{31}$$

$q_t^d(j)$ and $q_t^{im}(j)$ are individual quantities of variety $j's$ domestic and foreign intermediate good.

The final good producer's program is to minimize its total cost defined as follows:

$$\int_0^1 p_t^d(j) q_t^d(j) dj + \int_0^1 p_t^{im}(j) q_t^{im}(j) dj \tag{32}$$

under constraints defined in equations 30 and 31 where $p_t^d(j)$ and $p_t^{im}(j)$ are expressed in local currency and denote the price index of domestic and foreign intermediate good j.

Noting P_t^d and P_t^{im} the composite price indices of domestic intermediate goods and those produced in the foreign economy, and P_t the price index of the final good, demand functions from the final good producer program of are given by:

$$q_t^d(j) = Q_t^d \left(\frac{p_t^d(j)}{P_t^d}\right)^{-\varepsilon} \; ; \; q_t^{im}(j) = Q_t^{im} \left(\frac{p_t^{im}(j)}{P_t^{im}}\right)^{-\varepsilon} \tag{33}$$

and

$$Q_t^d = \alpha_d \frac{P_t}{P_t^d} F_t \qquad ; \qquad Q_t^{im} = (1-\alpha_d) \frac{P_t}{P_t^{im}} F_t \tag{34}$$

Since firms in final good production sector operate in a competitive environment, the total revenue is equal to their total costs for both domestic and foreign goods so that the following equations:

$$P_t^d Q_t^d = \int_0^1 p_t^d(j) q_t^d(j) dj \text{ and } P_t^{im} Q_t^{im} = \int_0^1 p_t^{im}(j) q_t^{im}(j) dj \tag{35}$$

which imply

$$P_t^d = \left(\int_0^1 p_t^d(j)^{1-\varepsilon} dj\right)^{-\frac{1}{\varepsilon-1}} \text{ and } P_t^{im} = \left(\int_0^1 p_t^{im}(j)^{1-\varepsilon} dj\right)^{-\frac{1}{\varepsilon-1}} \tag{36}$$

Finally, the pure and perfect competition assumption in the sector implies the following condition:

$$P_t^d Q_t^d + P_t^{im} Q_t^{im} = P_t F_t \tag{37}$$

and the composite price index of the final good is given by:

$$P_t = (P_t^d)^{\alpha_d} (P_t^{im})^{1-\alpha_d}. \tag{38}$$

2.3.5 Capital goods producers

Households own capital goods units which produce new capital goods using the following technology:

$$K_t = (1-\delta)K_{t-1} + I_t\left(1 - \frac{\Phi}{2}\left(\frac{I_t}{I_{t-1}} - \delta\right)^2\right) \tag{39}$$

in which $(1-\delta)K_{t-1}$ denotes the remaining capital at the end of period $t-1$, I_t the investment. We assume the existence of internal adjustment costs $\frac{\Phi}{2}\left(\frac{I_t}{I_{t-1}} - \delta\right)^2$. These costs reflect the fact that, for each new unit of capital introduced into the production process, the firm must bear an adjustment cost, linked to the adaptation of the capital purchased on the market to its own production needs (Semenescu-Badarau, 2009). Capital is sold at price P_tQ_t to non-financial firms and the producer program is to maximize its expected profit defined by:

$$\mathbb{E}_t\left\{\sum_{i=0}^{\infty}\frac{u_{c_{t+1}}}{u_{c_t}}\beta_h^i I_{t+i}\left[Q_{t+i}\left(1-\frac{\Phi}{2}\left(\frac{I_{t+i}}{I_{t+i-1}}-1\right)^2\right)-1\right]\right\} \tag{40}$$

where u_{c_t} represents the marginal utility of household real income.

First order condition with respect to investment is given by:

$$Q_t\left(1-\frac{\Phi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right) = 1 + Q_t\Phi\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}} - \mathbb{E}_t\left\{\beta_h\frac{u_{c_{t+1}}}{u_{c_t}}Q_{t+1}\Phi\left(\frac{I_t}{I_{t-1}}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{41}$$

2.3.6 Entrepreneurs

The domestic economy contains risk-neutral entrepreneurs who are responsible for the capital accumulation process. At the end of period t, entrepreneur j acquires capital K_t^j at price P_tQ_t. Part of this capital is rented to the producer of intermediate goods at price $P_{t+1}r_t^k$. The remaining non-depreciated capital is sold back to the capital goods producer at price $P_{t+1}Q_{t+1}$. The average return to capital across entrepreneurs is given by:

$$R_{t+1}^k = \pi_t\frac{r_{t+1}^k + Q_{t+1}(1-\delta)}{Q_t} \tag{42}$$

To finance its investment in new capital, entrepreneur j can either use its own equity E_t^j or borrow from the financial intermediary. Let L_t^{ej} denote the bank loan and R_t^L its gross return such that:

$$P_tL_t^{ej} = P_t(Q_tK_{t+1}^j - E_t^j) \tag{43}$$

The problem is that there is a risk ω_{t+1}^j linked to the firm's activity which affects the capital return so that the entrepreneurs' gross revenue from its investment in capital is $\omega_{t+1}^j R_{t+1}^k P_tQ_tK_{t+1}^j$.

In the case their investment in new capital is successful, entrepreneurs repay the entire loan to the banking sector and their income will therefore be equal to: $\omega_{t+1}R^k_{t+1}P_tQ_tK^j_{t+1} - R^L_{t+1}P_tL^{ej}_t$. But the information related to the specific risk is available only from the entrepreneurs and to obtain it, financial intermediaries need to undertake a costly audit of the type *Costly State Verification* proportional to the profitability, the results of which will only be revealed to the financial intermediaries (Townsend, 1979). This audit takes place only when the entrepreneur is in default. Let μ denote the proportionality ratio of cost verification. The verification cost will be:

$$\mu\omega^j_{t+1}R^k_{t+1}P_tQ_tK^j_{t+1} \text{ for } \omega^j_{t+1} < \overline{\omega}^j_{t+1} \tag{44}$$

in which ω^j_{t+1} follows a log-normal distribution with mean $-\frac{\sigma^2_\omega}{2}$ and variance σ^2_ω, and i.i.d across firms. $\overline{\omega}^j_{t+1}$ represents the level of firms specific risk below which they fail and default on their debt. At this specific risk level, the firms' return on capital is only used to repay bank loans:

$$\overline{\omega}^j_{t+1}R^k_{t+1}P_tQ_tK^j_t = R^L_tP_tL^{ej}_t \tag{45}$$

At the end of the audit procedure, when initiated, the financial intermediaries obtain:

$$(1-\mu)\omega^j_{t+1}R^k_{t+1}P_tQ_tK^j_{t+1} \tag{46}$$

In addition, after realizing $\omega^j_{t+1}R^k_{t+1}$, entrepreneurs die with fixed probability $1-\gamma_e$ after consuming their equity V_t. At each time period, dying entrepreneurs are replaced by new ones who receive a transfer W^e from households.

Each agent participates in the relationship according to the benefit it expects to derive from it. The bankers' expected revenue from their loan P_tL_t to the entrepreneur has two components: the revenue in the case of a successful investment and the revenue in the case that the entrepreneurs default. Their expected revenue can therefore be written as follows:

$$\mathbb{E}_t\left\{R^L_tP_tL^{ej}_t\int_{\overline{\omega}^j_{t+1}}^{\infty} f(\omega^j)d\omega^j + (1-\mu)R^k_{t+1}P_tQ_tK^j_t\int_0^{\overline{\omega}_{t+1}} \omega f(\omega^j)d\omega^j\right\} \tag{47}$$

Bankers will take part to the contract if their expected income is at least equal to the expected return on the loan, $\mathbb{E}_tR^b_{t+1}$. Their constraint can be then expressed as follows:

$$\mathbb{E}_t\left\{R^L_tP_tL^{ej}_t\int_{\overline{\omega}^j_{t+1}}^{\infty} f(\omega^j)d\omega^j + (1-\mu)R^k_{t+1}P_tQ_tK^j_t\int_0^{\overline{\omega}^j_{t+1}} \omega^j f(\omega^j)d\omega^j\right\} = P_tL^{ej}_t\mathbb{E}_tR^B_{t+1} \tag{48}$$

Using the relationships described in equations (43) and (45) and after some algebraic arrangements, the bankers participation constraint can be written as follows:

$$(\phi_t^{ej} - 1)\mathbb{E}_t R_{t+1}^b = \phi_t^{ej}\mathbb{E}_t \left\{ R_{t+1}^k [\Gamma(\overline{\omega}_{t+1}^j) - \mu G(\overline{\omega}_{t+1}^j)] \right\} \tag{49}$$

where

$$\phi_t^{ej} = \frac{Q_t K_t^j}{E_t^j} \tag{50a}$$

$$\Gamma(\overline{\omega}_{t+1}^j) = \int_0^{\overline{\omega}_{t+1}^j} \omega f(\omega^j) d\omega^j + \overline{\omega}_{t+1}^j \int_{\overline{\omega}_{t+1}^j}^{\infty} f(\omega^j) d\omega^j \tag{50b}$$

$$G(\overline{\omega}_{t+1}^j) = \int_0^{\overline{\omega}_{t+1}^j} \omega^j f(\omega^j) d\omega^j \tag{50c}$$

In turn, the entrepreneur's expected profit from its loan with the banks is:

$$\mathbb{E}_t \left\{ \int_{\overline{\omega}_{t+1}^j}^{\infty} f(\omega^j) \left(\omega^j R_{t+1}^k P_t Q_t K_t^j - R_t^L P_t L_t^{ej} \right) d\omega^j \right\} \tag{51}$$

Using the same notations as before, the fact that $\mathbb{E}_t(\omega_{t+1}^j) = 1$ and after some arrangements, the entrepreneur's expected profit can be rewritten as follows:

$$\phi_t^{ej} E_t^j \mathbb{E}_t \left\{ R_{t+1}^k [1 - \Gamma(\overline{\omega}_{t+1}^j)] \right\} \tag{52}$$

But what makes entrepreneurs heterogeneous is their equity E_t^j. Therefore, as $\overline{\omega}_{t+1}^j = \frac{R_t^L (1 - \frac{1}{\phi_t^{ej}})}{R_{t+1}^k}$, the value of ϕ_t^{ej} and R_L that maximizes $\phi_t^{ej} E_t^j \mathbb{E}_t \left\{ R_{t+1}^k [1 - \Gamma(\overline{\omega}_{t+1}^j)] \right\}$ under equation (49) is the same for all entrepreneurs, and so it is for $\overline{\omega}_{t+1}^j$. It follows that all entrepreneurs choose the same leverage $\phi_t^e = \frac{Q_t K_t}{E_t}$, which implies that $\overline{\omega}_{t+1}^j$ is also the same across all of them.

Based on these preliminary results, the entrepreneur's objective will be to maximize

$$\phi_t^e E_t \mathbb{E}_t \left\{ R_{t+1}^k [1 - \Gamma(\overline{\omega}_{t+1})] \right\} \tag{53}$$

under the banks' participation

$$(\phi_t^e - 1)\mathbb{E}_t R_{t+1}^b = \phi_t^e \mathbb{E}_t \left\{ R_{t+1}^k [\Gamma(\overline{\omega}_{t+1}) - \mu G(\overline{\omega}_{t+1})] \right\}. \tag{54}$$

Let κ_t be the Lagrange multiplier associated with the banks' participation constraint. First order conditions based on this maximization problem with respect to ϕ_t^E, $\overline{\omega}_{t+1}$ and Λ_t yields respectively to:

$$\mathbb{E}_t \left\{ R_{t+1}^k [1 - \Gamma(\overline{\omega}_{t+1})] \right\} + \kappa_t \mathbb{E}_t \left\{ R_{t+1}^k \left[\Gamma(\overline{\omega}_{t+1}) - \mu G(\overline{\omega}_{t+1}) \right] - R_{t+1}^b \right\} = 0 \tag{55a}$$

$$\mathbb{E}_t \left\{ -\Gamma'(\overline{\omega}_{t+1}) + \kappa_t \left[\Gamma'(\overline{\omega}_{t+1}) - \mu G'(\overline{\omega}_{t+1}) \right] \right\} = 0 \tag{55b}$$

$$\mathbb{E}_t \left\{ \phi_t^e R_{t+1}^k \left[\Gamma(\overline{\omega}_{t+1}) - \mu G(\overline{\omega}_{t+1}) \right] - R_{t+1}^b (\phi_t^e - 1) \right\} = 0 \tag{55c}$$

At the end of each period t, the total net wealth of the entrepreneurial sector is made up of the share of equity of entrepreneurs still alive ($\gamma_e V_t$) and the transfer W^e paid by households to the entrepreneurial sector:

$$E_t = \gamma_e V_t^e + W^e \tag{56}$$

where

$$V_t^e = \left\{ \int_{\overline{\omega}_t}^{\infty} f(\omega)(\omega R_t^k Q_{t-1} K_{t-1} - R_{t-1}^L) d\omega \right\} \exp(e_t^E) \tag{57}$$

in which e_t^E is an exogenous i.i.d shock to aggregate entrepreneurial equity. Entrepreneurial consumption is then given:

$$C_t^e = (1 - \gamma_e) V_t \tag{58}$$

Using (43) and after some arrangements, we can rewrite the entrepreneurial equity as:

$$V_t^e = \frac{R_t^k}{\pi_t} Q_{t-1} K_{t-1} [1 - \Gamma(\overline{\omega}_t)] \exp(\varepsilon_t^e) \tag{59}$$

2.4 Foreign sector

The local economy interacts with the foreign one through exports and imports of goods. A part of local produced intermediate goods is exported abroad while part of household consumption is derived from imports of goods abroad. We assume that the structure of the foreign economy is identical to that of the domestic one. Thus, export and import activities are governed by a calvo pricing mechanism. To this end, we adopt the Dixit-Stiglitz strategy (Dixit and Stiglitz, 1977), assuming that each firm is a monopolistic supplier of the good it produces. A continuum of firms specializing in exports and owned by households purchase part of the domestic intermediate goods and transform them through a process of differentiation[8]. As for importing, this is carried out by an infinite number of foreign firms, which also buy intermediate goods produced in the rest of the world, differentiate them through the same differentiation process and resell them to final goods producers. Below, we present the composition of the domestic exchanges with the rest of the world. At any time period t the trade balance of the local economy is given by:

$$P_t^{ex} Q_t^{ex} - P_t^{im} Q_t^{im} = TB_t \tag{60}$$

where TB_t represents the trade balance at time t.

[8]Product differentiation can be defined as a set of actions by which a firm modifies one or more characteristics of its product (quality, brand image, appearance, etc.) to distinguish it from those of its competitors, thus striving to approach a monopoly situation (Dixit and Stiglitz, 1977).

2.4.1 Exporting firms

Export activities consist of exporting cocoa produced as well as a proportion of intermediate goods produced within the economy. Equations related to cocoa sector are presented above. The export behavior presented in this section are related to export of intermediate goods. A continuum of firms owned by household buy a part of the final domestic good and differentiate it by brand naming and sell differentiated goods to importers from the rest of the world. We assume that aggregate export demand is a function of final goods produced in the foreign economy as follows:

$$Q_t^{ex} = \alpha_{ex} \left(\frac{P_t^{ex}}{P_t^f} \right)^{-\eta} Y_t^f \tag{61}$$

where P_t^{ex} is the aggregate price index of intermediate goods exported abroad, P_t^f is an aggregate price level in the foreign economy. As in Malakhovskaya and Minabutdinov (2014), we assume that both P_t^{ex} and P_t^f are expressed in foreign currency.

Similar to the demand for intermediate good, each exporting firm faces the following demand function:

$$q_t^{ex}(j) = \left(\frac{p_t^{ex}(j)}{P_t^{ex}} \right)^{-\varepsilon} Q_t^{ex} \tag{62}$$

in which $\varepsilon > 1$ represents the elasticity of substitution between varieties.

Similar to domestic firms, exporters are also subject to nominal rigidities *à la Calvo (1983)*. At each period t, only a fraction $1 - \varpi_{ex}$ of exporting firms are allowed to re-optimize their price. The new price of exporting firms after updating the price is $\tilde{p}_t^{ex}(j)$. The exporter's program is then given by:

$$\max \mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ex}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(\frac{S_t p_t^{ex}(j)}{P_{t+s}^{ex}} - mc_{t+s} \right) q_{t+s}^{ex}(j) \right\} \tag{63}$$

subject to the export demand function which leads to the following first order condition:

$$S_t \tilde{p}_t^{ex}(j) = \frac{\varepsilon}{\varepsilon - 1} \frac{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ex}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^{ex} \right)^{\varepsilon} Q_{t+s}^{ex} mc_{t+s} \right\}}{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ex}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^{ex} \right)^{\varepsilon - 1} Q_{t+s}^{ex} \right\}} \tag{64}$$

and the price dynamics of aggregate intermediate goods exported abroad is given by:

$$P_t^{ex} = \left[(1 - \varpi_{ex}) \left(\tilde{p}_t^{ex} \right)^{1-\varepsilon} + \varpi_{ex} \left(P_{t-1}^{ex} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{65}$$

where S_t is a nominal exchange rate defined as a domestic currency price of foreign currency.

2.4.2 Importing firms

Intermediate goods produced in the foreign sector are imported by foreign firms operating in monopolistic competition. The importing firm j buys intermediate goods in the foreign sector at price $S_t P_t^f$ (expressed in local currency) and resells them to producers of final goods at price $p_t^{im}(j)$. P_t^f is the aggregate price index of intermediate goods produced in the foreign sector and S_t is the exchange rate. Domestic prices of imported goods are also rigid *a la Calvo*. At each time period t, a proportion $1-\varpi_{im}$ of importing firms receives price-changing signal. When the importing firm j receives the price-changing signal, it chooses the optimal price level so that to to optimize its expected discount income expressed in foreign sector:

$$\max \mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{im})^s \lambda_{t,t+s}^f \left(p_{t+s}^{im}(j) - S_{t+s} P_{t+s}^f \right) q_{t+s}^{im}(j) \right\} \tag{66}$$

where $q_t^{im}(j)$ is defined in (33), $\lambda_{t,t+s}^f$ is the discount factor of importing firms set at the international risk-free rate and defined by:

$$\lambda_{t,t+s}^f = \prod_{j=t}^{t+s-1} \frac{1}{R_j^f} \tag{67}$$

in which R_j^f denotes the international risk-free rate set in the model exogenously. Optimizing above problem leads to the following first order condition:

$$\tilde{p}_t^{im}(j) = \frac{\varepsilon}{\varepsilon - 1} \frac{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{im})^s \lambda_{t,t+s}^f \left(P_{t+s}^{im} \right)^{\varepsilon} Q_{t+s}^{im} P_{t+s}^f \right\}}{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{im})^s \lambda_{t,t+s}^f \frac{1}{S_{t+s}} \left(P_{t+s}^{im} \right)^{\varepsilon} Q_{t+s}^{im} \right\}} \tag{68}$$

The dynamics of aggregate imported goods is given by:

$$P_t^{im} = \left[(1 - \varpi_{im}) \left(\tilde{p}_t^{im} \right)^{1-\varepsilon} + \varpi_{im} \left(P_{t-1}^{im} \right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{69}$$

2.5 The central bank

Monetary policy is a set of means implemented by a Central Bank to act on economic activity by regulating its currency. To this end, the Central Bank defines one or more objectives and the instruments to be used to achieve them. For that purpose, monetary authorities have the choice of pursuing a discretionary monetary policy or a rule-based monetary policy. The former consists of trying to act on the economy in the short term by using information and tools available to influence the economic equilibrium in a favorable direction, whereas the latter consists of setting a medium to long-term objective and sticking to it. But because of the credibility of monetary policy, several authors have developed arguments in favor of the rule-based policy (Barro and Gordon, 1983; Kydland and Prescott, 1977; etc).

Among rule-based policies, inflation targeting is one of the most used by central banks. It consists of maintaining a sufficiently low and slow inflation rate so as not to effectively modify the decisions of economic agents. There is a theoretical and empirical literature in favor of inflation targeting and most of them have shown that rule-based policy improves economic performance either in developed and developing countries (Corbo et al., 2001; Diaw and Sall, 2019; Lin and Ye, 2009; Mishkin and Schmidt-Hebbel, 2007...). Because of its many advantages, most of central banks, including the BCEAO, have made inflation targeting an attractive and useful option (Diaw and Sall, 2019).

In fact, WAMU and BCEAO undertook an institutional reform that culminated in 2010, making inflation targeting the primary objective of the union's monetary policy. As a result, the monetary institution has defined its operational objective of price stability as *"an annual inflation rate of the Union, within a range of plus or minus one percentage point (1%) around a central value of of 2% over a 24-month horizon"*. Then, we assume in this paper that the nominal rate of interest is adjusted after the monetary authority forecasts both inflation and output gap. Following Litsios et al., 2021, we define the monetary policy rule as :

$$\frac{R_t}{R} = R_{t-1}^{\rho_r} \left(\frac{\pi_t}{\pi}\right)^{\theta_\pi(1-\rho_r)} \left(\frac{Y_t}{Y}\right)^{\theta_y(1-\rho_r)} \tag{70}$$

where the notations without the subscript t indicate the value of the corresponding variable at the steady state.

2.6 Resource constraint of the wide domestic economy

The resource constraint of the whole economy is derived from the popular accounting relationship which states that in an open economy, the aggregate output generated is used for household consumption, government spending, investment and to finance or offset the trade balance. Then, the resource constraint can be written as follows:

$$Y_t = C_t + C_t^b + C_t^e + I_t + G_t + Q_t^{ex} - Q_t^{im} + \frac{R_t^k}{\pi_t} Q_{t-1} K_{t-1} \mu \int_0^{\bar{\omega}_t} \omega f(\omega) d\omega \tag{71}$$

2.7 Market clearing conditions

Aggregate wage in the economy is made up wages in non-cocoa and cocoa sectors.

$$\frac{W_t}{P_t} = h_i \frac{W_t^{nc}}{P_t} + (1 - h_i) \frac{W_t^c}{P_t} \tag{72}$$

The final good produced within the economy is used either for consumption or investment:

$$F_t = C_t + C_t^b + C_t^e + I_t \tag{73}$$

From supply side, aggregate output is either exported or used in the domestic economy:

$$Y_t = Q_t^{ex} + Q_t^d. \tag{74}$$

2.8 Model variant: model without financial frictions

In line with our research question of whether financial frictions amplify commodity price shocks in commodity exporting countries, we developed a simplified version of the model in which we assume that there are no financial frictions either in the relationship between households and bankers or between bankers and entrepreneurs. In this simplified model, we assume that the capital stock produced by capital goods producers is purchased by households in order to rent it to intermediate goods producers. The household budget constraint then becomes:

$$P_t C_t + D_t + Q_t(K_t - K_{t-1}) = (1 - \tau_W) W_t H_t + R_{t-1}^D D_{t-1} + \Pi_t \tag{75}$$

This modification leaves the first order conditions derived in equation (4) unchanged, but adds the following FOC with respect to K_t:

$$Q_t = \mathbb{E}_t \left\{ \beta_h \frac{u_{c_{t+1}}}{u_{c_t}} [k_t^k + Q_{t+1}(1 - \delta)] \right\} \tag{76}$$

3 Calibration

This section presents the calibration process of our dynamic stochastic general equilibrium model. Calibration consists of determining the set of parameter values in order to have the best possible fit between the behavior of the theoretical model and the object of study. In our case, it is a matter of adjusting the model to the Ivorian economy in order to analyze the propagation mechanism of a shock on cocoa price. To do so, we use the literature and our knowledge of the Ivorian economy to calibrate the values of certain parameters and deduce the others from the behavioral equations. This step is based on the determination of the steady state of the model. Next, we will analyze the local dynamics of the model around this predetermined steady state. To do so, we need to characterize the steady state of the system.

Steady state equations are presented in Appendix C. Let X_t be a variable of the model, we denote X (without the subscript t) its value at the steady state. We calibrate the model to Côte d'Ivoire economy as mentioned above. Data sources and time period are described in Appendix D. Overall our model consists of 32 parameters listed in table 1 with their respective values in both the full and the reduced model. Some of these parameters are calibrated using standard values from the literature while others are calibrated to meet the target values of certain variables for the Ivorian economy. The model calibration steps are presented in the sequential procedure described below.

Table 1: Description of the main parameters and their values

Parameters	Full model	Reduced model	Description
h	0.600	0.600	Household habit persistence
ν_c	2.000	2.000	Inverse of inter-temporal elasticity of substitution for consumption
β_h	0.973	0.973	Household discount rate
ν_h	0.250	0.250	Inverse Frisch elasticity of labor supply
φ_h	4.340	2.869	Scale parameter
δ	0.056	0.056	Depreciation rate
Φ	10.000	10.000	Adjustment cost
ψ_H	1.000	1.000	Fraction of non-cocoa labor costs paid in advance
ψ_K	1.000	1.000	Fraction of non-cocoa capital rental costs paid in advance
ψ_C	1.000	1.000	Fraction of labor costs paid in advance in cocoa sector
h_i	0.900	0.900	Share of labor force in non-cocoa sector
η_k	0.300	0.350	Capital elasticity of non-cocoa output
α_{ai}	0.900	0.900	AR-coefficient of productivity shock
ϖ_i	0.800	0.800	Probability of keeping domestic intermediate good price unchanged
η_{yc}	0.240	0.400	Elasticity of aggregate output to cocoa production
α_d	0.400	0.400	Elasticity of final goods to domestic demand of intermediate goods
λ	0.366	–	Fraction of capital the banker can divert
θ	0.962	–	Banker survival probability
μ	0.020	–	Bankruptcy costs
α_{ac}	0.900	0.900	AR-coefficient of productivity shock in cocoa sector
γ_o	0.348	0.348	International cocoa price persistence

Table 1 – Continued

Parameters	**Full model**	**Reduced model**	**Description**
α_o	0.900	0.900	
η_c	0.600	0.600	Labor elasticity of cocoa output
ρ_{rd}	0.900	0.958	Interest rate persistence parameter
θ_π	2.500	2.500	Coefficient on the inflation in the Taylor rule
θ_y	0.095	0.095	Coefficient on the output gap in the Taylor rule
ρ_{yf}	0.950	0.950	AR-coefficient of aggregate output in foreign sector
ϖ_{ex}	0.650	0.650	Probability of keeping export goods price unchanged
ρ_{π_f}	0.950	0.950	AR-coefficient of inflation rate in foreign sector
ϖ_{im}	0.650	0.650	Probability of keeping import goods price unchanged
ρ_{Rf}	0.950	0.950	AR-coefficient of foreign interest rate
ρ_g	0.900	0.900	AR-coefficient of government expenditure

First, we set the annual discount rate β_h such that the deposit rate R equals the central bank key interest rate 2.75%[9]. For the rate of capital depreciation, we follow Assemien et al. (2019) by setting its value at $\delta = 0.056$.

Next, we determine μ, R^b and R^k. To do so, we refer to equations (55) and set exogenously the value of $\frac{E}{K}$ which represents firms' self-financing ratio using the literature. Solving the system of three equations gives the following value for μ:

$$\mu = \frac{(1-\Gamma(\overline{\omega}))(\phi^e - 1)\Gamma'(\overline{\omega}) - \Gamma(\overline{\omega})\Gamma'(\overline{\omega})}{G'(\overline{\omega})(1-\Gamma(\overline{\omega}))(\phi^e - 1) - G(\overline{\omega})\Gamma'(\overline{\omega})}$$

with $\phi^e = \frac{K}{E} = \frac{1}{E/K}$.

For the credit market steady-state, the preliminary calculations in the Appendix (B) indicate that:

$$G(\overline{\omega}) = \Phi(J - \sigma_\omega) \tag{77a}$$

$$\Gamma(\overline{\omega}) = \Phi(J - \sigma_\omega) + \overline{\omega}[1 - \Phi(J)] \tag{77b}$$

$$G'(\overline{\omega}) = \overline{\omega} f(\overline{\omega}) \tag{77c}$$

$$\Gamma'(\overline{\omega}) = 1 - \Phi(J) \tag{77d}$$

$$F(\overline{\omega}) = \Phi(J) \tag{77e}$$

where $J = \frac{ln(\overline{\omega}) + \sigma_\omega^2/2}{\sigma_\omega}$ and the form of the log normal distribution defining $\overline{\omega}$ is given by:

$$f(\overline{\omega}) = \frac{1}{\overline{\omega}\sigma_\omega\sqrt{2\pi}} \exp\left(-\frac{(ln(\overline{\omega}) - \sigma_\omega^2/2)^2}{2\sigma_\omega^2}\right)$$

To obtain the numerical values of $G(\overline{\omega})$ $\Gamma(\overline{\omega})$, $G'(\overline{\omega})$ and $\Gamma'(\overline{\omega})$, at the steady state, we need to determine the values of $\overline{\omega}$ and σ_ω. Next, we set the probability of firms' bankruptcy exogenously using values close to the literature. Thus, equation (77e) implies $J = \Phi^{-1}(F(\overline{\omega})) = \frac{ln(\overline{\omega}) + \sigma_\omega^2/2}{\sigma_\omega}$. The positive root associated with this second degree equation in σ_ω is:

$$\sigma_\omega = \Phi^{-1}(F(\overline{\omega})) + \sqrt{[\Phi^{-1}(F(\overline{\omega}))]^2 - 2\ln(\overline{\omega})}.$$

Following this step, we can now calculate:

$$\frac{R^k}{R^b} = \frac{\phi^e - 1}{\phi^e(\Gamma(\overline{\omega}) - \mu G(\overline{\omega}))}.$$

[9]The Monetary Policy Committee (MPC) of the Central Bank of West African States (BCEAO) decided on December 9th, 2022, to raise the Central Bank's key rates by 25 basis points, effective December 16, 2022. Thus, the main policy rate at which the Central Bank lends its resources to banks increased from 2.50% to 2.75%. This value was used to calibrate the discount rate (https://www.financialafrik.com/2022/12/09/la-bceao-releve-son-taux-directeur/).

$\frac{R^b}{R}$ is calibrated so that:

$$R^b = \left(\frac{R^b}{R}\right) R$$

$$R^k = \left(\frac{R^k}{R^b}\right) R^b$$

$$R^l = \frac{\overline{\omega} R^k}{1 - \frac{1}{\phi^e}}$$

Given R^k, we can now calculate most of the steady state values of the real side of the economy:

$$\frac{K}{H} = h_i \left(\frac{\eta_k mc}{r^k\left(1 + \psi_K(R-1)\right)}\right)^{\frac{1}{1-\eta_k}}$$

where $r^k = R^k - (1-\delta)$ and $mc = \frac{\varepsilon - 1}{\varepsilon}$. In the same vein, we have the following ratios:

$$\frac{Y^i}{K} = \frac{r^k(1 + \psi_K(R-1))}{\eta_k mc}$$

$$w^i = \left(\frac{1}{h_i}\right)^{\eta_k} \frac{(1-\eta_k) mc k^{\eta_k}}{1 + \psi_H(R-1)}$$

H is calibrated using real data. We then have:

$$K = \left(\frac{K}{H}\right) H$$

$$Y^i = \left(\frac{Y^i}{K}\right) K$$

$$Y^c = ((1-h_i)H)^{\eta_c}$$

$$w^c = \left(\frac{Y^c}{\eta_{yc}}\right)^{\eta_{yc}} \left(\frac{Y^i}{\eta_{yi}}\right)^{\eta_{yi}}$$

From the capital accumulation equation, we have: $I = \delta K$. Then we calculate:

$$V^e = K R^k [1 - \Gamma(\overline{\omega})]$$

$$E = K - E$$

$$L^i = \psi_H w^i H^i + \psi_K r^k K$$

$$L^c = \psi_C w^c H^c$$

$$L = L^e + L^i + L^c$$

Given γ_e, we can now calculate W^e:

$$W^e = E - \gamma_e V^e > 0$$

Next, we turn to the banks' side. We calibrated the bank leverage ϕ^b and given this value, we can calculate the following quantities:

$$x = (R^b - R)\phi^b + R$$

$$b = \frac{1-\theta}{1-\beta_h \theta x}$$

$$a = \frac{(1-\theta)(\frac{R^b - R}{R})}{1-\beta_h \theta x}$$

which leads to:

$$\lambda = \frac{b + \phi^b a}{\phi^b}$$

$$N_e^b = \theta x N^b$$

$$W^b = N_n^b = N^b - N_e^b > 0$$

We can now calculate the steady-state value of entrepreneurs and bankers consumption:

$$C^e = (1-\gamma_e)V^e$$

$$C^b = (1-\theta)xN^b$$

To calculate the steady-state value of the remaining variables, we calibrate the trade balance $\frac{tb}{Y}$ and the ratio of government spending to GDP (G/Y) of Côte d'Ivoire using real data. Then using $tb = \frac{tb}{Y}Y$ and economic equilibrium relationships, we have:

$$F = \frac{Y - G - \frac{tb}{pex} - R^k K \mu G(\overline{\omega})}{1 + \frac{\alpha_{im}}{pex} - \frac{\alpha_{im}}{pim}}.$$

We can now calculate the steady-state value of all the other variables in the model. They are presented bellow:

$$u_c = C^{-\nu_c}(1-h)^{-\nu_c}(1-h\beta_h)$$

$$C = F - C^e - C^b - I$$

$$Q^{ex} = \frac{tb + p^{im}Q^{im}}{pex}$$

$$Q^{im} = \frac{1-\alpha_d}{pim}F$$

$$Y^f = \frac{p^{ex}Q^{ex}}{\alpha_{ex}}$$

$$w = h_i w^i + (1-h_i)w^c$$

$$\varphi_h = \frac{wu_c}{H^{\nu_h}}$$

Table 1 and 2 present respectively the calibrated values of the parameters and the steady state values of the main variables.

Table 2: Steady state: fixed and calculated values

Variables	**Full model**	**Red. model**	**Definition**
Fixed values			
E/K	0.4500	–	Firms' self-financing ratio
$F(\overline{\omega})$	0.7363	–	Probability of firms' bankruptcy
R	1.0275	–	Domestic risk-free rate
R^b	1.0295	–	Average return on bank loans
Calculated values			
$\overline{\omega}$	0.5500	–	Firms' bankruptcy threshold
σ_ω	0.9157	–	Standard deviation of the idiosyncratic shock
Y	1.1102	1.4294	Overall Output
K	1.0810	5.2791	Capital
I	0.0605	0.2956	Investment
C^b/Y	0.0067	–	Ratio banks' consumption to GDP
C^e/Y	0.1062	–	Ratio entrepreneurs' consumption to GDP
C/Y	0.5593	0.6616	Ratio of households' consumption to GDP
ϕ^e	2.2222	–	Firm's leverage
ϕ^b	3.1800	–	Banks' leverage
w^i	0.6205	1.0188	Real wage rate in non-cocoa goods sector
w^c	1.5348	1.5771	Real wage rate in cocoa sector
w	0.7120	1.0746	Overall wage rate

4 Results

This section presents the results of our simulations of cocoa price shocks. But before analyzing the dynamics of both the full and the reduced models following a cocoa price shock, we need to verify the consistency of theuir dynamic behavior. This verification will consist in analyzing the reaction of the models to different known shocks such as a productivity and a budget shock.

4.1 Verification of the model dynamics

Before moving on to the discussion of the effects of cocoa price shocks on the economy, it is important to make sure that the dynamic behavior of the model is consistent. This is the purpose of this sub section. We summarize below the reaction of the economy to two types of shocks: fiscal and technological (productivity).

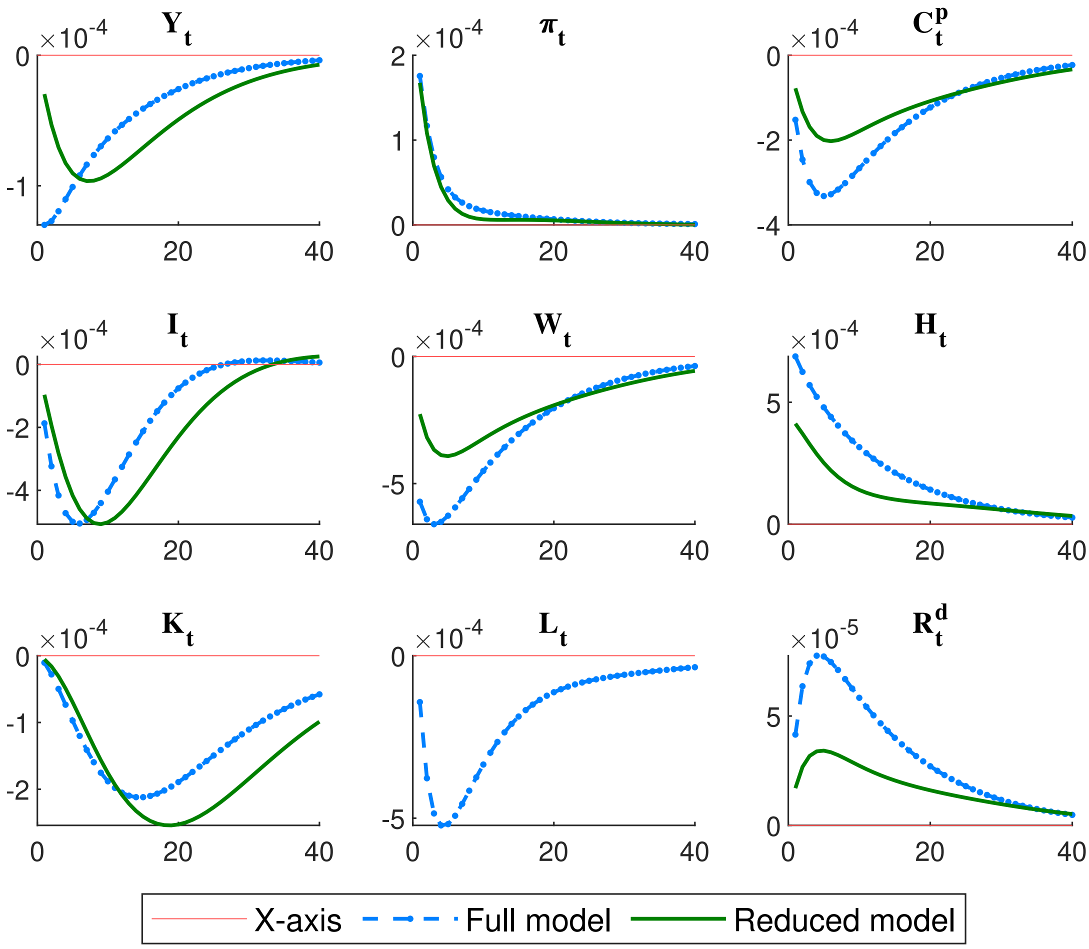
4.1.1 Model dynamics following a productivity shock

We first submit the models to a negative productivity shock of zero mean, unit variance, described by an autoregressive coefficient equal to 0.850. Figure 4 presents the propagation of the shock through some key variables. As shown on the graphs, both models seem to have the same dynamics. In both cases, the shock leads to a fall in the overall output, and therefore a fall in the supply of goods and services in the economy. As a result, domestic prices rise and demand gradually adjusts to supply, which explains the decline in private consumption. The fall in output in turn leads to a fall in wage rates in the economy, causing households to work a little harder in order to maintain a certain standard of living.

On the other side, to deal with the surge in prices in the economy, the central bank, in its stabilizing role, increases its keys interest rates. In response to the increase in the central bank's key interest rates, banks raise their borrowing rates, thereby tightening bank lending conditions. As a result, bank loans to the private sector fall, leading to a decline in capital production and investment.

Furthermore, although both models present similar dynamics, there are some differences in the magnitude of the shock in both cases. In fact, both models are subjected to a technological shock of the same characteristics, and as we can see, the shock seems to have a more pronounced effect in the case of the model with financial frictions. Indeed, the fall in output, private consumption and investment, for example, is greater in the full model than in the reduced form of the model. Nevertheless, the return to steady-state occurs

Figure 4: Impulse response functions to a productivity shock (ε^{ai}).



Source: Authors' calculations

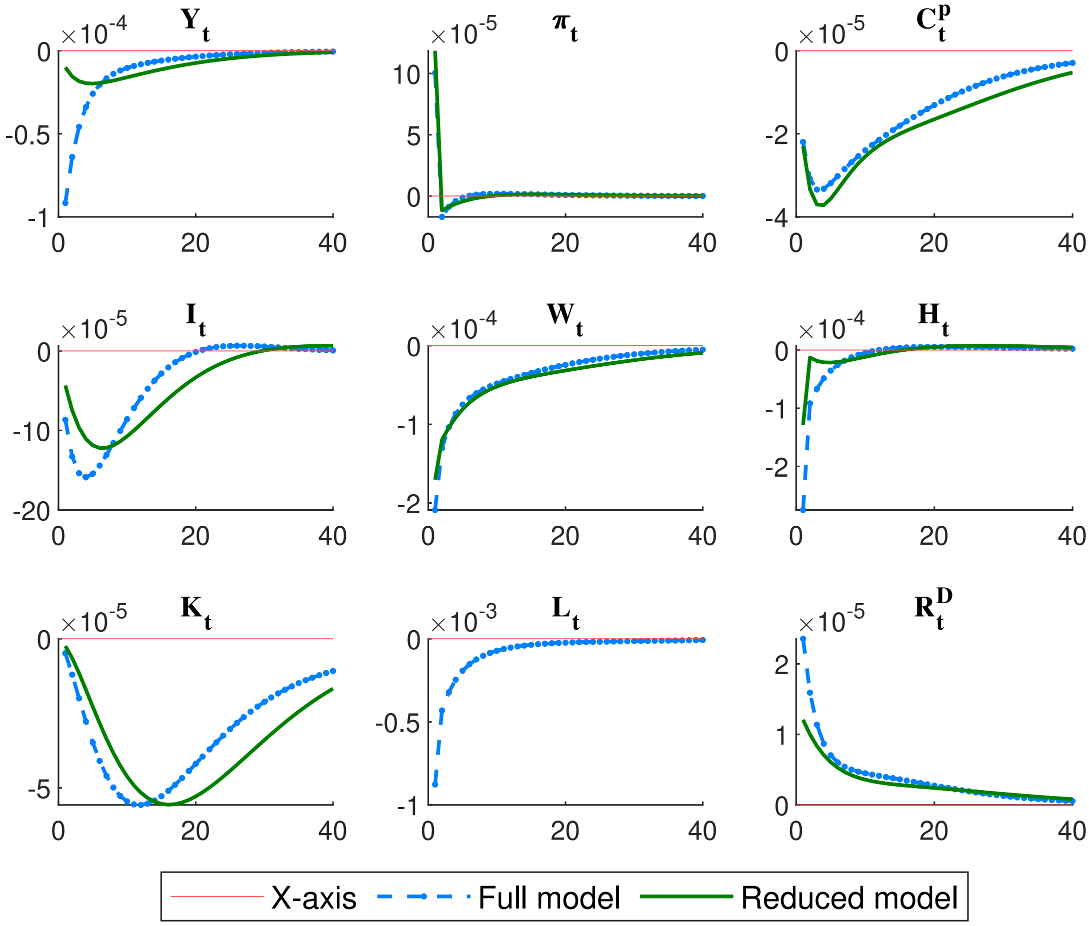
more quickly in the model with financial frictions. The amplification of the productivity shock in the model with financial frictions is well in line with the results of Rannenberg, 2016 and some other authors who explain that this amplifying effect is due to the increase in the spread between the expected return on capital and the risk-free rate in the economy.

4.1.2 Model dynamics following a fiscal policy shock

Next, we submit the models to a negative fiscal policy shock of zero mean and unit variance characterized by an autoregressive coefficient $\rho_g = 0.95$. Figure 5 presents the impulse response functions of some key variables following this shock in both models.

The impulse response analysis shows that the fiscal policy shock induced by the decline in government spending leads to a decline in output in both full and reduced models, reflecting the positive effect of government spending on aggregate output. This negative supply shock leads to an increase in price level and therefore a rise in the inflation rate.

Figure 5: Impulse response functions to a fiscal shock (ε^g).



Source: Authors' calculations

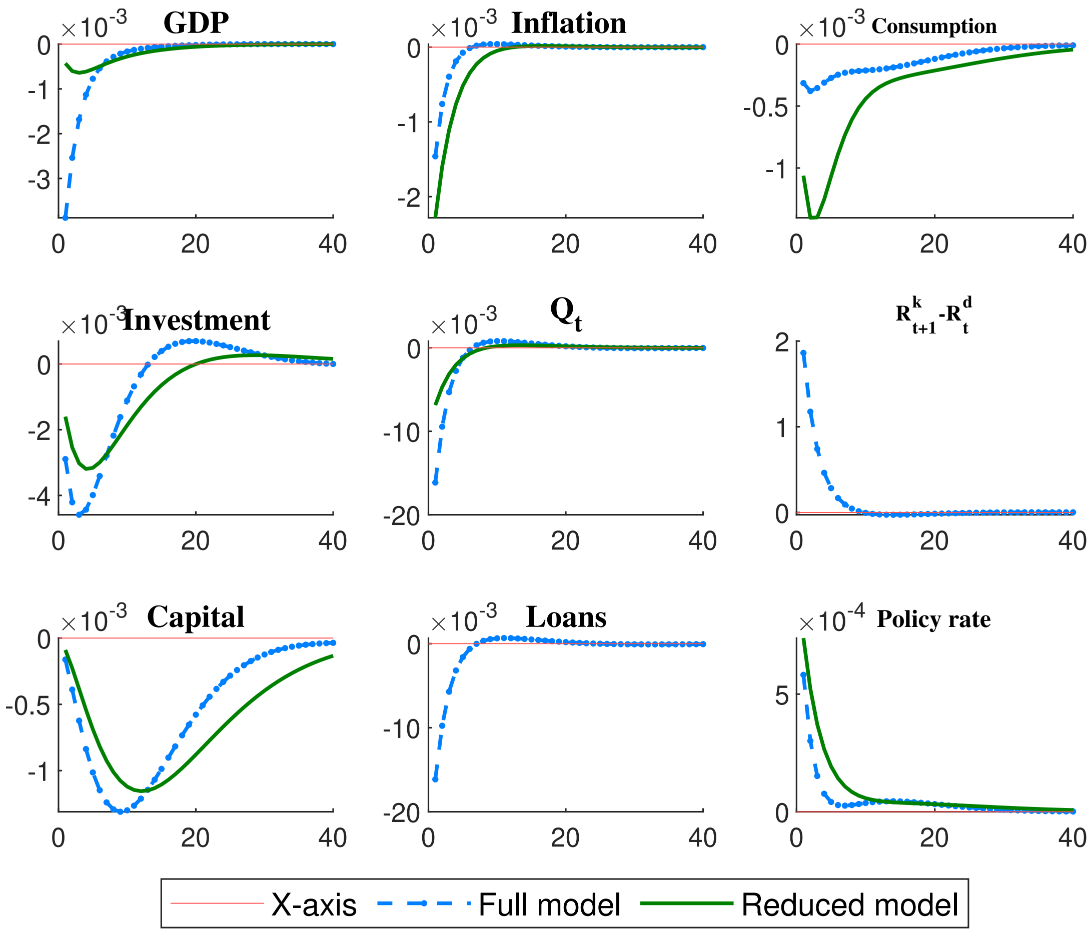
As in the case of the technology shock, the fall in production leads to a fall in the wage rate in the economy, causing households to work a little harder. In addition, demand gradually adjusts to the level of supply, justifying the fall in private consumption. In response to the rise in price level in the economy, the central bank raises its key interest rates. As a result, credit conditions tightened, leading to a fall in bank lending to the private sector and in investment.

As before, the magnitude of the shock has an amplifying effect on aggregate output and other macroeconomic variables in the case of the model with financial frictions. As expected, these results indicate that credit market frictions have an amplifying effect on the economy.

4.1.3 Model dynamics following a monetary policy

Figure 6 shows the response of both full and reduced models to a contractionary monetary shock characterized by a sudden rise in central bank policy rates. As we indicated in the previous section, the monetary rule used is such that the central bank is primarily interested in stabilizing inflation, not real activity. As can be seen from the graph, both models react in the same way to the shock. Indeed, as expected, the rise in the nominal interest rates leads to a fall in economic activity. This drop in economic activity follows a fall in investment and consumption and leads to a decline in inflation rate.

Figure 6: Impulse response functions to a negative monetary shock (ε^{rd}).



Source: Authors' calculations

Moreover, the fall in GDP is much greater in the full model than in the reduced one. This difference in the path of GDP between the two models is mainly due to differences in the drop in investment. We therefore notice an amplification of the response of the overall output to the shock in the model with financial frictions. This amplification is due to the fact that the increase in the interest rate lowers the implicit price of capital goods Q_t, as future rental income from capital r_t^k is discounted more heavily. This fall in the implicit price directly reduces investment in both models. Nevertheless, in the full model, it reduces the net wealth of entrepreneurs and increases leverage ϕ_t^e, which increases the risk of bankruptcy as $\mathbb{E}_t R_{t+1}^k - R_t$. As a result, Q_t and investment fall more rapidly.

4.2 Simulation of the effect of shock on cocoa price

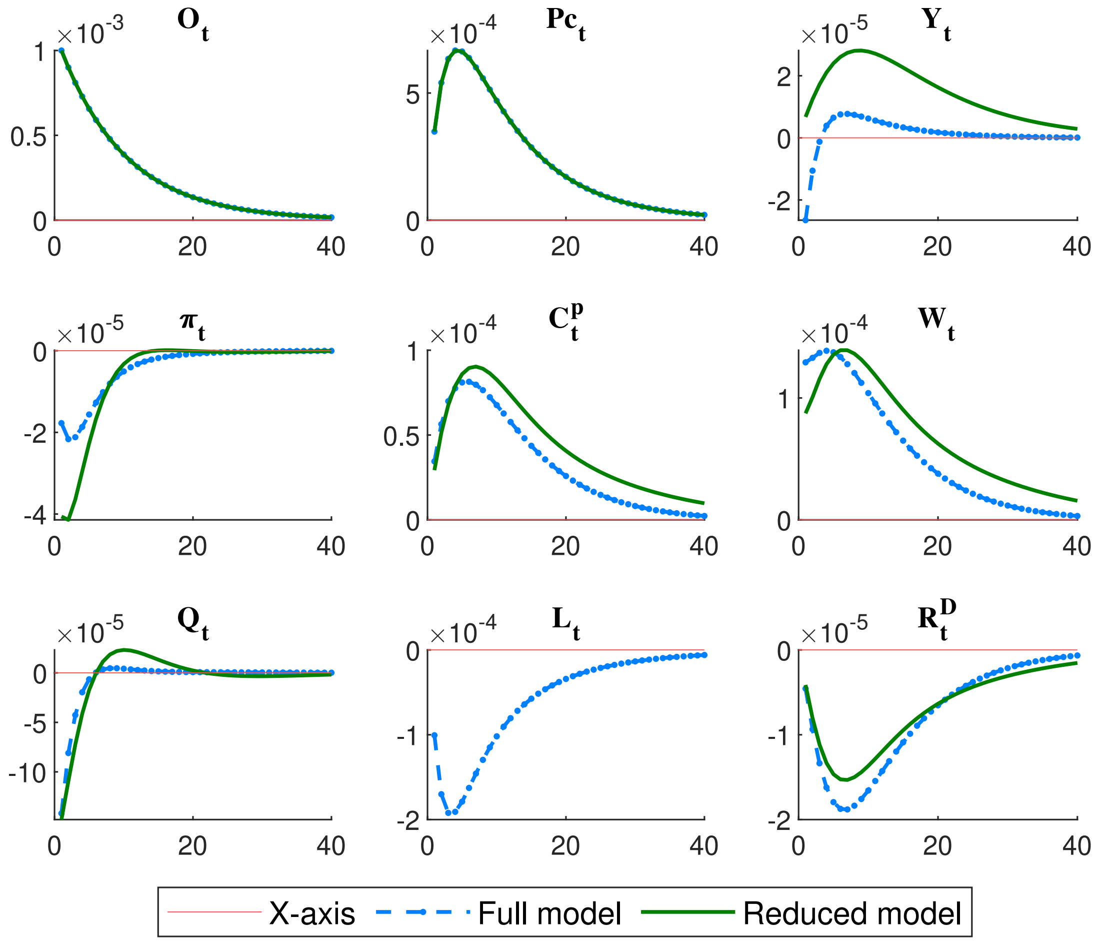
In the previous subsection, we evaluated the characteristics of our two models. We showed that both models (without and with financial friction) react in line with economic theory to the various standard shocks. We also highlighted the financial accelerator mechanism as postulated by Bernanke et al. (1999). Following this verification and in line with our objective, we simulate the dynamics of both models following a shock on international cocoa price. We simulated a negative shock and a positive one, and both appear to have symmetrical effects on all our economic aggregates. In other words, the negative shock seems to produce opposite effects to a positive shock. We will therefore only present here the dynamics of the model following a positive shock. Bellow, we first analyze the impulse responses and then present the dynamics of some key variables.

4.2.1 Cocoa price shocks propagation

To analyze the propagation of cocoa price shocks in the Ivorian economy, we submitted the model to a positive cocoa price shock with mean zero and unit variance characterized by an autoregressive coefficient equal to 0.90. Figure 7 shows the impulse response functions of some key economic variables. As it can be seen from the graphs, the positive shock has the direct impact of increasing cocoa producer prices and boosting GDP. The rise in GDP generates the classic effects of a supply shock, including a fall in prices. From the households side, the increase in profit from cocoa sector and the rise in wages in the economy enable them to adjust their consumption behavior upwards. The result is a gradual increase in private consumption, resulting in an increase in household disposable income.

In response to the fall in the price level, the central bank lowers its gross key interest rates, thereby easing the constraints on access to bank credit market. Unfortunately, the monetary rule used is such that the reaction of the central bank to inflation is slow and does not ultimately produce the desired result of price stabilization in the full model. The result is an increase in real interest rates in the economy, and a drop in bank loans to private sector.

Figure 7: Impulse response functions to a positive cocoa price shock (ε^O).



Source: Authors' calculations

These effects are observed in both the model without and with financial friction, even if the magnitude of the increase induced by the shock on GDP seems to be greater in the reduced model than in the full one. Our results are well in line with those found by Malakhovskaya and Minabutdinov (2014) in the context of Russia. In fact, he showed that a positive shock on oil export revenue induced an increase in household income and in aggregate output accompanied by an increase in demand for labor, investment, capital, wage rates and other economic aggregates.

4.2.2 Is there any financial accelerator mechanism?

To analyze the role of the financial sector in the propagation of cocoa price shocks, we re-examine the impulse response functions in Figure 7, comparing the effects of the simulated shock on the full model and the model without financial friction. As the graphs in Figure 8 show, the shock with the same characteristics has differentiated effects on the two models. Indeed, while we observe an improvement in total output in the reduced model following the positive shock, the amplitude of the shock seems very low in the case of the model with financial friction. It also turns out that the shock-induced increase in private consumption is smaller in the full model than in the reduced model. This result indicates that the benefit of cocoa price booms could be reduced in the presence of financial friction.

Concluding remarks

This paper aims to empirically examine the role of financial frictions in the propagation of commodity price shocks in commodity exporting countries. To this end, we developed a Dynamic Stochastic General Equilibrium (DSGE) model with financial frictions. in this model, frictions in both household-banker and banker-non-financial firm relationships influence the level of bank loans in the economy and hence aggregate demand. This model has been calibrated for Côte d'Ivoire and includes cocoa and non-cocoa goods production sectors. However, the model is general and may be estimated or calibrated for any commodity exporting country. In addition to financing the process of capital accumulation, banking sector contributes to pre-financing working labor and capital leasing through risk-free loans in both production sectors. Also, for the sake of comparison, we have developed a reduced version of the model that ignores the existence of these financial frictions.

Impulse response function analysis indicates that positive cocoa price shocks lead to an improvement in overall output, household welfare and the trade balance. Cocoa price booms would therefore enable Côte d'Ivoire to improve its economic performance via a positive growth rate, an increase in demand following a rise in household disposable income. This result seems to confirm the stylized facts about the Ivorian economy and the evolution of cocoa price. In fact, when cocoa price rose from \$4.83 to \$8.29 between 1976 and 1977 (an increase of almost 72%), Côte d'Ivoire's GDP rose from around \$4.66 billion to almost \$6.3 billion, representing a growth rate of around 34% over the same period. Over the same period, private consumption rose from \$3.3 billion to around \$4.2 billion (an increase of over 24%)[10].

Regarding the role of the financial sector, our results do not show evidence that financial frictions amplify negative commodity price shocks in Côte d'Ivoire. Nevertheless, they suggest that financial frictions would prevent the country from fully benefiting from commodity price booms. The key lesson we can learn from these results is that, despite the strong link between resource abundance and GDP, commodity price volatility is detrimental to all economic agents within the economy.

This paper is a contribution to business cycle analysis in commodity-exporting countries. To our best knowledge, it is one of the first to examine the role of financial frictions in the propagation of commodity price shocks in developing countries, using a dynamic stochastic general equilibrium model. These models are widely used by central banks and international institutions to simulate the impact of policies and external shocks.

[10]Data in this paragraph are from World Development Indicators)

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A Normalization

We use the following notations:

$p_t^d = \frac{P_t^d}{P_t}$
$p_t^i = \frac{P_t^i}{P_t}$
$\tilde{p}_t^i = \frac{\tilde{P}_t^i}{P_t}$
$p_t^c = \frac{P_t^c}{P_t}$
$p_t^{im} = \frac{P_t^{im}}{P_t}$
$\tilde{p}_t^{im} = \frac{\tilde{P}_t^{im}}{P_t}$

$p_t^{ex} = \frac{P_t^{ex}}{P_t^f}$
$\tilde{p}_t^{ex} = \frac{\tilde{P}_t^{ex}}{P_t^f}$
$mc_t = \frac{MC_t}{P_t}$
$o_t = \frac{O_t}{P_t}$
$\pi_t^d = \frac{P_t^d}{P_{t-1}^d}$

$\pi_t^f = \frac{P_t^f}{P_{t-1}^f}$
$\varrho_t = \frac{S_t P_t^f}{P_t}$
$w_t = \frac{W_t}{P_t}$
$w_t^i = \frac{W_t^i}{P_t}$
$w_t^c = \frac{W_t^c}{P_t}$
$tb_t = \frac{TB_t}{P_t}$

B Steady state in credit market

We recall that ω_t follows a log-normal distribution with mean $-\frac{\sigma_\omega^2}{2}$ and variance σ_ω^2 so that $E(\omega_t) = 1$. The threshold $\overline{\omega}_t$ defined by the debt contract between the entrepreneur and the bank determines the probability of bankruptcy of the firm. In the formalization of the debt contract, we wrote the following quantities:

$$\Gamma(\overline{\omega}_t) = \int_0^{\overline{\omega}_t} \omega f(\omega) d\omega + [1 - F(\overline{\omega}_t)]\overline{\omega}_t \text{ and } G(\overline{\omega}_t) = \int_0^{\overline{\omega}_t} \omega f(\omega) d\omega.$$

Their derivatives are given by:

$$\Gamma'(\overline{\omega}_t) = 1 - F(\overline{\omega}_t) \text{ and } G'(\overline{\omega}_t) = \overline{\omega}_t f(\overline{\omega}_t).$$

The probability that ω_t is higher than a certain threshold $\overline{\omega}_t$ corresponds to the probability that a variable x which follows a standard normal distribution $\mathcal{N}(0, 1)$ is higher than the threshold $J_t = \frac{ln(\overline{\omega}_t) + \sigma_\omega^2/2}{\sigma_\omega}$. It results that

$$P(\omega_t > \overline{\omega}_t) = 1 - \Phi(J_t)$$

where $\Phi(.)$ represents the distribution function of a standard normal distribution. Finally, after some arrangements, we obtain the following expressions for Γ and G, and their derivatives:

$$G(\overline{\omega}_t) = \Phi(J_t - \sigma_\omega) \text{ and } \Gamma(\overline{\omega}_t) = \Phi(J_t - \sigma_\omega) + \overline{\omega}_t[1 - \Phi(J_t)]$$

$$G'(\overline{\omega}_t) = \overline{\omega}_t f(\overline{\omega}_t) \text{ and } \Gamma'(\overline{\omega}_t) = 1 - \Phi(J_t)$$

where the density probability of the log-normal distribution is given by:

$$f(\overline{\omega}_t) = \frac{1}{\overline{\omega}_t \sigma_\omega \sqrt{2\pi}} \exp\left(-\frac{(ln(\overline{\omega}_t) - \sigma_\omega^2/2)^2}{2\sigma_\omega^2}\right)$$

C Full model equations and steady state

Table 3: *Summary*

Equations	**Steady State**
Households	
$u_{c_t} = (C_t - hC_{t-1})^{-\nu_c} - h\beta_h \mathbb{E}_t\left[(C_{t+1} - hC_t)^{-\nu_c}\right]$	$C^{-\nu_c}(1-h)^{-\nu_c}(1-h\beta_h) = \varrho$
$\beta_h \mathbb{E}_t \frac{u_{c_{t+1}}}{\pi_{t+1}} R_{t+1} = u_{c_t}$	$\beta_h R^D = 1$
$H_t = \left(\frac{1-\tau_w}{\varphi_h}\frac{W_t}{P_t} u_{c_t}\right)^{1/\nu_l}$	$H = \left(\frac{1-\tau_w}{\varphi_h} w\varrho\right)^{1/\nu_l}$
Banks	
$L_t^e = \phi_t^b N_t^b$	$L = \phi^B N^B$
$\phi_t^b = \frac{b_t}{\lambda - a_t}$	$\phi^B = \frac{b}{\lambda - a}$
$a_t = \mathbb{E}_t\left\{(1-\theta)\frac{(R_{t+1}^b - R_t)}{R_t} + \frac{\theta g_{t,t+1}\pi_{t+1} a_{t+1}}{R_t}\right\}$	$(R^D - g\theta)a = (1-\theta)(R^B - R^D)$
$b_t = \mathbb{E}_t\left\{(1-\theta) + \frac{\theta x_{t,t+1}\pi_{t+1} b_{t+1}}{R_t}\right\}$	$(R^D - x\theta)b = (1-\theta)R^D$
$x_{t,t+1} = \frac{N_{t+1}^b}{N_t^b}$	$x = 1$
$g_{t,t+1} = \frac{\phi_{t+1}^b}{\phi_t^b} x_{t,t+1}$	$g = x$
$N_{et}^b = \theta x_{t-1,t} N_{t-1}^b$	$N_e^b = \theta N^b$
$N_t^b = N_{et}^b + N_{nt}^b$	$N^b = N_e^b + N_n^b$
$C_t^b = (1-\theta) x_{t-1,t} N_{t-1}^b$	$C^b = (1-\theta)N^b$
Aggregate output	
$Y_t = \left(\frac{1}{\eta_{yi}} Y_t^i\right)^{\eta_{yi}} \left(\frac{1}{\eta_{yc}} Y_t^c\right)^{\eta_{yc}}$	$Y = \left(\frac{1}{\eta_{yi}} Y^i\right)^{\eta_{yi}} \left(\frac{1}{\eta_{yc}} Y^c\right)^{\eta_{yc}}$
$P_t^d = (P_t^i)^{\eta_{yi}} (P_t^c)^{\eta_{yc}}$	$P^d = (P^i)^{\eta_{yi}} (P^c)^{\eta_{yc}}$
$Y_t = Q_t^{ex} + Q_t^d$	$Y = Q^{ex} + Q^d$
Cocoa sector	

$Y_t^c = A_t^c \, (H_t^c)^{\eta_c}$	$Y^c = (H^c)^{\eta_c}$
$W_t^c(1+\psi_C(R_t-1)) = \eta_c A_t^c P_t^c (H_t^c)^{\eta_c - 1}$	$W^c(1+\psi_C(R-1)) = \eta_c (H^c)^{\eta_c-1}$
$P_t^c = \left(P_{t-1}^c\right)^{1-\gamma_o} \left(O_{t-1}\right)^{\gamma_o} \varepsilon_t^c$	$P^c = 1$
$A_t^c = (A_{t-1}^c)^{\alpha_c} \exp(\varepsilon_t^{Ac})$	$A^c = 1$
$O_t = (O_{t-1})^{\alpha_O} \exp(\varepsilon_t^{O})$	$O = 1$
Non-cocoa goods sector	
$W_t^i(1+\psi_H(R_t-1)) = (1-\eta_k)\, MC_t \, \frac{Y_t^i}{H_t^i}$	$W^i(1+\psi_H(R-1)) = (1-\eta_k)\, MC \, \frac{Y^i}{H^i}$
$r_t^k(1+\psi_K(R_t-1)) = \eta_k \, mc_t \, \frac{Y_t^i}{K_{t-1}}$	$r^k(1+\psi_K(R-1)) = \eta_k \, MC \, \frac{Y^i}{K}$
$L_t^i = \psi_H \, W_t^i \, H_t^i + \psi_K \, r_t^k \, K_{t-1}$	$L^i = \psi_H \, W^i \, H^i + \psi_K \, r^k \, K$
$MC_t =$	
$A_t^i = A_{t-1}^i exp(\varepsilon_t^{Ai})$	$A^i = 1$
$\tilde{P}_t^i = \frac{\varepsilon}{\varepsilon-1} \frac{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ig}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^i\right)^{\varepsilon} Y_{t+s}^i \, mc_{t+s} \right\}}{\mathbb{E}_t \left\{ \sum_{s=0}^{+\infty} (\varpi_{ig}\beta_h)^s \frac{u_{c_{t+s}}}{u_{c_t}} \left(P_{t+s}^i\right)^{\varepsilon-1} Y_{t+s}^i \right\}}$	
$P_t^i = \left[(1-\varpi_{ig}) \left(\tilde{P}_t^i\right)^{1-\varepsilon} + \varpi_{ig} \left(P_{t-1}^i\right)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$	$P^i = \tilde{P}^i$
Final goods producers	
$Q_t^d = \alpha_d \frac{P_t}{P_t^d} F_t$	$Q^d = \alpha_d \frac{P}{P^d} F$
$Q_t^{im} = (1-\alpha_d) \frac{P_t}{P_t^{im}} F_t$	$Q^{im} = (1-\alpha_d) \frac{P}{P^{im}} F$
$P_t = (P_t^d)^{\alpha_d} (P_t^{im})^{1-\alpha_d}$	$P = (P^d)^{\alpha_d} (P^{im})^{1-\alpha_d}$
$F_t = C_t + I_t + C_t^b + C_t^e$	$F = C + I + C^b + C^e$
$K_t = (1-\delta) K_{t-1} + I_t \left(1 - \frac{\Phi}{2} \left(\frac{I_t}{I_{t-1}} - \delta\right)^2\right)$	$\delta K = I$

$Q_t\left(1-\frac{\Phi}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)=$ $1+Q_t\Phi\left(\frac{I_t}{I_{t-1}}-1\right)\frac{I_t}{I_{t-1}}-\mathbb{E}_t\left\{\beta_h\frac{u_{c_{t+1}}}{u_{c_t}}Q_{t+1}\Phi\left(\frac{I_t}{I_{t-1}}-1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\}$	$Q=1$
Entrepreneurs	
$R^k_t=\pi_t\frac{r^k_t+Q_t(1-\delta)}{Q_{t-1}}$	$R^k=r^k+(1-\delta)$
$\phi^e_t=\frac{Q_tK_t}{E_t}$	$\phi^e=\frac{K}{E}$
$\mathbb{E}_t\left\{R^K_{t+1}[1-\Gamma(\overline{\omega}_{t+1})]\right\}+\kappa_t\mathbb{E}_t\left\{R^k_{t+1}\left[\Gamma(\overline{\omega}_{t+1})-\mu G(\overline{\omega}_{t+1})-R^b_{t+1}\right]\right\}=0$	$[1-\kappa(\overline{\omega})]+\Lambda[\Gamma(\overline{\omega})-\mu G(\overline{\omega})-R^b]=0$
$\mathbb{E}_t\left\{-\Gamma'(\overline{\omega}_{t+1})+\kappa_t\left[\Gamma'(\overline{\omega}_{t+1})-\mu G'(\overline{\omega}_{t+1})\right]\right\}=0$	$-\Gamma'(\overline{\omega})+\kappa[\Gamma'(\overline{\omega})-\mu G'(\overline{\omega})]=0$
$\mathbb{E}_t\left\{\phi^e_tR^k_{t+1}\left[\Gamma(\overline{\omega}_{t+1})-\mu G(\overline{\omega}_{t+1})\right]-R^b_{t+1}(\phi^e_t-1)\right\}=0$	$\phi^eR^k[\Gamma(\overline{\omega})-\mu G(\overline{\omega})]-R^b(\phi^e-1)=0$
$\overline{\omega}_{t+1}R^k_{t+1}Q_tK_t=R^l_tL_t$	$\overline{\omega}R^kK=R^lL$
$E_t=\gamma_eV^e_t+W^e$	$E=\gamma_eV^e+W^e$
$C^e_t=(1-\gamma_e)V_t$	$C^e=(1-\gamma_e)V$
$V^e_t=\frac{R^k_t}{\pi_t}Q_{t-1}K_{t-1}[1-\Gamma(\overline{\omega}_t)]\exp(\varepsilon^e_t)$	$V^e=R^kK[1-\Gamma(\overline{\omega})]$
Foreign sector	
$Q^{ex}_t=\alpha_{ex}\left(\frac{P^{ex}_t}{P^f_t}\right)^{-\eta}Y^f_t$	$Q^{ex}=\alpha_{ex}\left(\frac{P^{ex}}{P^f}\right)^{-\eta}Y^f$
$S_t\tilde{P}^{ex}_t=\frac{\varepsilon}{\varepsilon-1}\frac{\mathbb{E}_t\left\{\sum_{s=0}^{+\infty}(\varpi_{ex}\beta_h)^s\frac{u_{c_{t+s}}}{u_{c_t}}\left(P^{ex}_{t+s}\right)^{\varepsilon}Q^{ex}_{t+s}MC_{t+s}\right\}}{\mathbb{E}_t\left\{\sum_{s=0}^{+\infty}(\varpi_{ex}\beta_h)^s\frac{u_{c_{t+s}}}{u_{c_t}}\left(P^{ex}_{t+s}\right)^{\varepsilon-1}Q^{ex}_{t+s}\right\}}$	d
$P^{ex}_t=\left[(1-\varpi_{ex})\left(\tilde{P}^{ex}_t\right)^{1-\varepsilon}+\varpi_{ex}\left(P^{ex}_{t-1}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$	$P^{ex}=\tilde{P}^{ex}$

$\tilde{P}_t^{im}(j) = \frac{\varepsilon}{\varepsilon-1}\frac{\mathbb{E}_t\left\{\sum_{s=0}^{+\infty}(\varpi_{im})^s\lambda^f_{t,t+s}\left(P^{im}_{t+s}\right)^{\varepsilon}Q^{im}_{t+s}P^f_{t+s}\right\}}{\mathbb{E}_t\left\{\sum_{s=0}^{+\infty}(\varpi_{im})^s\lambda^f_{t,t+s}\frac{1}{S_{t+s}}\left(P^{im}_{t+s}\right)^{\varepsilon}Q^{im}_{t+s}\right\}}$	d
$P_t^{im} = \left[(1-\varpi_{im})\left(\tilde{P}_t^{im}\right)^{1-\varepsilon} + \varpi_{im}\left(P_{t-1}^{im}\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$	$P^{im} = \tilde{P}^{im}$
$P_t^{ex}Q_t^{ex} - \frac{1}{S_t}P_t^{im}Q_t^{im} = TB_t$	$P^{ex}Q^{ex} - \frac{1}{S}P^{im}Q^{im} = TB$
The central bank	
$\frac{R^D_{t+1}}{R^D} = \left(\frac{1+\mathbb{E}_t(i_{t+1})}{1+i}\right)^{\Theta_i}\left(\frac{\mathbb{E}_t(Y_{t+1})}{Y}\right)^{\Theta_y}$	$--$
Economy wide constraint	
$Y_t = C_t + C_t^b + C_t^e + I_t + G_t + Q_t^{ex} - Q_t^{im} + \frac{R_t^k}{\pi_t}Q_{t-1}K_{t-1}\mu G(\bar{\omega}_t)$	$Y = C + C^b + C^e + I + G + Q^{ex} - Q^{im} + R^k K\mu G(\bar{\omega})$
Other relationships	
$H_t^i = h_i H_t$	$H^i = h_i H$
$\pi_t = \frac{P_t}{P_{t-1}}$	$\pi = 1$
$\frac{W_t}{P_t} = h_i\frac{W_t^i}{P_t} + (1-h_i)\frac{W_t^c}{P_t}$	$\frac{W}{P} = h_i\frac{W^i}{P} + (1-h_i)\frac{W^c}{P}$

D Data sources

➥ We use data from the FAOSTAT database, from which we took the producer price index and the World Bank's pink sheet for the international cocoa price. The data covers the period 1991-2021. The estimation of a constrained linear model allowed us to calculate the values of γ_o.

Table 4: Endogenous variables

Variable	LaTeX	Description
Ct	$\widehat{c}_t$	Household consumption
Uct	$\widehat{u}_{c_t}$	Marginal utility of consumption
Pit	$\widehat{\pi}_t$	Inflation rate
Rdt	$\widehat{r}_t$	Gross return on bank deposits
Ht	$\widehat{h}_t$	Labor supply
Wt	$\widehat{w}_t$	Real wage rate
Kt	$\widehat{k}_t$	Capital
It	$\widehat{i}_t$	Investment
Qt	$\widehat{q}_t$	Tobin Q
Wit	$\widehat{w}_t^i$	Real wage rate in intermediate good sector
Mct	$\widehat{mc}_t$	Marginal cost
Yit	$\widehat{y}_t^i$	Intermediate good sector production
rkt	$\widehat{r}_t^k$	Capital rental rate
Lit	$\widehat{l}_t^i$	Total loan to intermediate goods sector
Ait	$\widehat{a}_t^i$	Intermediate good producer productivity
Qdt	$\widehat{q}_t^d$	Domestic demand for intermediate goods
Qext	$\widehat{q}_t^{ex}$	Intermediate goods exported abroad
pidt	$\widehat{p}_t^{id}$	Aggregate price of non-cocoa intermdiate price
Pidt	$\widehat{\pi}_t^d$	Domestic inflation
pdt	$\widehat{p}_t^d$	Domestic price
Let	$\widehat{l^e}_t$	Bank loans
Nbt	$\widehat{n}_t^b$	Bankers net wealth
Phibt	$\widehat{\phi}_t^b$	Bank leverage
Rbt	$\widehat{r}_t^b$	Return on loans to entrepreneurs
Cbt	$\widehat{c}_t^b$	Bank consumption
Rkt	$\widehat{R}_t^k$	Capital price

Table 4 – Continued

Variable	LaTeX	Description
Phiet	$\widehat{\phi}_t^e$	Firms leverage
Et	$\widehat{e}_t$	Firms equity
Mt	$\widehat{m}_t$	Mt
Rlt	$\widehat{r}_t^l$	Return rate on bank loans
Vet	$\widehat{V}_t^e$	
Cet	$\widehat{c}_t^e$	Entrepreneurs consumption
Yct	$\widehat{y}_t^c$	Cocoa Production
Wct	$\widehat{w}_t^c$	Wage rate in cocoa production sector
Pct	$\widehat{p}_t^c$	cocoa price to price to producers
Ot	$\widehat{o}_t$	International coca price
Act	$\widehat{a}_t^c$	Cocoa producer productivity
Lct	$\widehat{l}_t^c$	Bank loans to cocoa sector
Ft	$\widehat{f}_t$	Final goods
Qimt	$\widehat{q}_t^{im}$	Demand for goods imported abroad
pimt	$\widehat{p}_t^{im}$	Aggregate price index of goods imported abroad
Yft	$\widehat{y}_t^f$	Aggregate output in foreign sector
Pift	$\widehat{\pi}_t^f$	Aggregate price index in foreign sector
Tbt	$\widehat{tb}_t$	Trade balance
pext	$\widehat{p}_t^{ex}$	Aggregte price index of goods exported abroad
Rft	$\widehat{r}_t^f$	International risk-free rate
Gt	$\widehat{g}_t$	Government expenditure
Tt	$\widehat{t}_t$	Other government revenue
Yt	$\widehat{y}_t$	Aggregate output
Lt	$\widehat{l}_t$	Total bank loans
Cpt	$\widehat{c}_t^p$	Private consumption

Table 5: Exogenous variables

Variable	LaTeX	Description
epsPc	ε_t^{Pc}	Shock on cocoa producers price
epsAi	ε_t^{Ai}	Productivity shock in non-cocoa goods sector
epsAc	ε_t^{Ac}	Productivity shock in cocoa sector

Table 5 – Continued

Variable	LaTeX	Description
`epsO`	ε_t^O	Shock on international cocoa price
`epsRd`	ε_t^{Rd}	Shock on monetary policy
`epsRb`	ε_t^{Rb}	Shock on bank loan return
`epsG`	ε_t^G	Shock on fiscal policy
`epsE`	ε_t^E	epsE
`epsX`	ε_t^X	epsX
`epsYf`	ε_t^{yf}	
`epsPif`	$\varepsilon_t^{\pi f}$	
`epsRf`	ε_t^{Rf}	

Table 6: Parameter Values

Parameter	Full model	Reduced model
h	0.600	0.600
ν_c	2.000	2.000
β_h	0.973	0.973
ν_h	0.250	0.250
φ_h	4.340	2.869
δ	0.056	0.056
Φ	10.000	10.000
ψ_H	1.000	1.000
ψ_K	1.000	1.000
η_k	0.300	0.350
α_{ai}	0.900	0.900
ϖ_i	0.800	0.800
η_{yc}	0.240	0.400
α_d	0.400	0.400
λ	0.366	–
θ	0.962	–
μ	0.020	–
γ_e	0.795	–

Table 6 – Continued

Parameter	Full model	Reduced model
α_{ac}	0.900	0.900
γ_o	0.348	0.348
α_o	0.900	0.900
η_c	0.600	0.600
ψ_C	1.000	1.000
ρ_{rd}	0.900	0.958
θ_π	2.500	2.500
θ_y	0.095	0.095
ρ_{yf}	0.950	0.950
ϖ_{ex}	0.650	0.650
ρ_{π_f}	0.950	0.950
ϖ_{im}	0.650	0.650
ρ_{Rf}	0.950	0.950
ρ_g	0.900	0.900

E Equations of the log-linearized model

$$\widehat{u}_{c_t} = \frac{h\,\nu_c\,\widehat{c}_{t-1} - \nu_c\,(1+h^2\,\beta_h)\,\widehat{c}_t + h\,\nu_c\,\beta_h\,\widehat{c}_{t+1}}{(1-h)\,(1-h\,\beta_h)} \tag{78}$$

$$\widehat{r}_{t+1} = \widehat{u}_{c_t} - \widehat{u}_{c_{t+1}} + \widehat{\pi}_{t+1} \tag{79}$$

$$\widehat{h}_t = \frac{\widehat{u}_{c_t} + \widehat{w}_t}{\nu_h} \tag{80}$$

$$W\,\widehat{w}_t = h_i\,W^i\,\widehat{w}_t^i + (1-h_i)\,W^c\,\widehat{w}_t^c \tag{81}$$

$$\widehat{k}_t = (1-\delta)\,\widehat{k}_{t-1} + \delta\,\widehat{i}_t \tag{82}$$

$$\widehat{i}_t = \frac{\widehat{i}_{t-1} + \beta_h\,\widehat{i}_{t+1} + \frac{\widehat{q}_t}{\Phi}}{1+\beta_h} \tag{83}$$

$$\widehat{w}_t^i + \frac{\psi_H\,R^d}{1+\psi_H\,\left(R^d-1\right)}\,\widehat{r}_t = \widehat{mc}_t + \widehat{y}_t^i - \widehat{h}_t \tag{84}$$

$$\widehat{r}_t^k + \frac{R\,\psi_K}{1+\left(R-1\right)\,\psi_K}\widehat{r}_t = \widehat{mc}_t + \widehat{y}_t^i - \widehat{k}_{t-1} \tag{85}$$

$$L^i\,\widehat{l}_t^i = W^i\,\psi_H\,H^i\,\left(\widehat{h}_t + \widehat{w}_t^i\right) + \psi_K\,r^k\,K\,\left(\widehat{k}_{t-1} + \frac{\widehat{r}_t^k}{r^k}\right) \tag{86}$$

$$\widehat{mc}_t = \widehat{w}_t^i\,\left(1-\eta_k\right) - \widehat{a}_t^i + \widehat{r}_t^k\,\eta_k \tag{87}$$

$$\widehat{a}_t^i = \alpha_{ai}\,\widehat{a}_{t-1}^i - \varepsilon_t^{Ai} \tag{88}$$

$$\widehat{p}_t^{id} - \varpi_i\,\widehat{p}_{t-1}^{id} + \varpi_i\,\widehat{\pi}_t = \widehat{mc}_t\,\left(1-\varpi_i\right)\,\left(1-\beta_h\,\varpi_i\right) + \beta_h\,\varpi_i\,\left(\widehat{\pi}_{t+1} + \widehat{p}_{t+1}^{id} - \widehat{p}_t^{id}\,\varpi_i\right) \tag{89}$$

$$Y\,\widehat{y}_t = Q_d\,\left(\widehat{p}_t^d + \widehat{q}_t^d\right) + P^{ex}\,Q_{ex}\,\left(\widehat{p}_t^{ex} + \widehat{q}_t^{ex}\right) \tag{90}$$

$$\widehat{y}_t = \eta_{yc}\,\left(\widehat{y}_t^c + \widehat{p}_t^c\right) + \eta_{yi}\,\left(\widehat{y}_t^i + \widehat{\pi}_t\right) \tag{91}$$

$$\widehat{p}_t^d = \eta_{yc}\,\widehat{p}_t^c + \widehat{p}_t^{id}\,\eta_{yi} \tag{92}$$

$$\widehat{q}_t^d = \widehat{f}_t - \widehat{p}_t^d \tag{93}$$

$$\widehat{q}_t^{im} = \widehat{f}_t - \widehat{p}_t^{im} \tag{94}$$

$$\alpha_d\,\widehat{p}_t^{id} + \alpha_{im}\,\widehat{p}_t^{im} = 0 \tag{95}$$

$$F\,\widehat{f}_t = C\,\widehat{c}_t + C^e\,\widehat{c}_t^e + C^b\,\widehat{c}_t^b + I\,\widehat{i}_t \tag{96}$$

$$\widehat{l^e}_t = \widehat{\phi}_t^b + \widehat{n}_t^b \tag{97}$$

$$\widehat{\phi}_t^b = \theta\,{\beta_h}^2\,x^2\,\widehat{\phi}_{t+1}^b + \beta_h\,\phi^b\,R^b\,\left(\widehat{r}_{t+1}^b - \widehat{r}_t\right) \tag{98}$$

$$\widehat{x}_t = \frac{1}{x}\,\left(R\,\widehat{r}_{t-1} + \phi^b\,\left(R^b\,\widehat{r}_t^b - R\,\widehat{r}_{t-1}\right) + \phi^b\,\left(R^b - R\right)\,\widehat{\phi}_{t-1}^b\right) - \widehat{\pi}_t + \varepsilon_t^x \tag{99}$$

$$\widehat{n}_t^b = \theta\,x\,\left(\widehat{x}_t + \widehat{n}_{t-1}^b\right) \tag{100}$$

$$\widehat{c}_t^b = \widehat{x}_t + \widehat{n}_{t-1}^b \tag{101}$$

$$(R^l - R)\,(\widehat{r}_t^l - \widehat{r}_t) = R^l\,\widehat{r}_t^l - R\,\widehat{r}_t \tag{102}$$

$$\widehat{R}_t^k = \widehat{\pi}_t + \frac{\widehat{r}_t^k\,r^k + (1-\delta)\ \widehat{q}_t}{R^k} - R^k\,\widehat{q}_{t-1} \tag{103}$$

$$\widehat{\phi}_t^e = \widehat{k}_{t-1} + \widehat{q}_t - \widehat{e}_t \tag{104}$$

$$\widehat{R}_t^k = \widehat{r}_t^b + \chi^{\phi^e}\,\widehat{\phi}_{t-1}^e \tag{105}$$

$$\widehat{m}_t = \widehat{r}_t^l + \frac{1}{\phi^e - 1}\,\widehat{\phi}_t^e \tag{106}$$

$$\widehat{\phi}_t^e\,\frac{R^b}{\phi^e} = \left(-R^k\right)\ E_1\,{\varepsilon^{Rb}}_t + \widehat{R}_{t+1}^k\ \left(R^k\,E_1 - m\,E_2\right) + \widehat{m}_t\,m\,E_2 - \widehat{r}_{t+1}^b\,\frac{R^b\ (\phi^e - 1)}{\phi^e} \tag{107}$$

$$\widehat{e}_t = \frac{\gamma_e\,V^e}{E}\,\widehat{v}_t^e \tag{108}$$

$$\widehat{v}_t^e = \widehat{\phi}_{t-1}^e + \widehat{R}_t^k + \widehat{e}_{t-1} - \widehat{\pi}_t - \frac{\bar{\omega}\,\Gamma'(\bar{\omega})}{1 - \Gamma(\bar{\omega})}\ \left(\widehat{m}_{t-1} - \widehat{R}_t^k\right) + \varepsilon_t^E \tag{109}$$

$$\widehat{l^e}_t = \widehat{e}_t + \widehat{\phi}_t^e\,\frac{\phi^e}{\phi^e - 1} \tag{110}$$

$$\widehat{c}_t^e = \widehat{V}_t^e \tag{111}$$

$$(R^k - R)\,(\widehat{r}_{t+1}^k - \widehat{r}_t) = R^k\,\widehat{R}_{t+1}^k - R\,\widehat{r}_t \tag{112}$$

$$\widehat{y}_t^c = \widehat{a}_t^c + \widehat{h}_t\,\eta_c \tag{113}$$

$$\widehat{w}_t^c + \widehat{r}_t\,\frac{R^d\,\psi_C}{1 + (R^d - 1)\ \psi_C} = \widehat{p}_t^c + \widehat{a}_t^c + \widehat{h}_t\ (\eta_c - 1) \tag{114}$$

$$\widehat{a}_t^c = \alpha_{ac}\,\widehat{a}_{t-1}^c - \varepsilon_t^{Ac} \tag{115}$$

$$\widehat{p}_t^c = (1 - \gamma_o)\ \widehat{p}_{t-1}^c + \gamma_o\,\widehat{o}_t - \varepsilon_t^{Pc} \tag{116}$$

$$\widehat{o}_t = \alpha_o \, \widehat{o}_{t-1} + \varepsilon_t^O \tag{117}$$

$$\widehat{l}_t^c = \widehat{h}_t + \widehat{w}_t^c \tag{118}$$

$$\widehat{q}_t^{ex} = \widehat{y}_t^f - \widehat{p}_t^{ex} \tag{119}$$

$$\widehat{y}_t^f = \rho_{yf} \, \widehat{y}_{t-1}^f + \varepsilon_t^{yf} \tag{120}$$

$$\begin{aligned} \widehat{p}_t^{ex} - \varpi_{ex} \, \widehat{p}_{t-1}^{ex} + \varpi_{ex} \, \widehat{\pi}_t^f = {} & (1-\varpi_{ex}) \, (1-\beta_h \, \varpi_{ex}) \, (\widehat{mc}_t - \widehat{\varrho}_t) \\ & + \beta_h \, \varpi_{ex} \, \left(\widehat{p}_{t+1}^{ex} - \widehat{p}_t^{ex} \, \varpi_{ex} + \widehat{\pi}_{t+1}^f\right) \end{aligned} \tag{121}$$

$$\widehat{\pi}_t^f = \rho_{\pi_f} \, \widehat{\pi}_{t-1}^f + \varepsilon_t^{\pi_f} \tag{122}$$

$$\widehat{p}_t^{im} - \varpi_{im} \, \widehat{p}_{t-1}^{im} + \widehat{\pi}_t \, \varpi_{im} = \widehat{\varrho}_t \, (1-\varpi_{im}) \, (1-\beta_h \, \varpi_{im}) + \beta_h \, \varpi_{im} \, \left(\widehat{\pi}_{t+1} + \widehat{p}_{t+1}^{im} - \widehat{p}_t^{im} \, \varpi_{im}\right) \tag{123}$$

$$\widehat{\pi}_t^d = \widehat{\pi}_t + \widehat{p}_t^d - \widehat{p}_{t-1}^d \tag{124}$$

$$\widehat{r}_t^f = \rho_{Rf} \, \widehat{r}_{t-1}^f + \varepsilon_t^{Rf} \tag{125}$$

$$P^{ex} \, Q^{ex} \, (\widehat{p}_t^{ex} + \widehat{q}_t^{ex}) - P^{im} \, Q^{im} \, \left(\widehat{q}_t^{im} + \widehat{p}_t^{im}\right) = TB \, \widehat{tb}_t \tag{126}$$

$$R^d \, \widehat{r}_t = (1-\rho_{rd}) \, (\widehat{\pi}_t \, \theta_\pi + \widehat{y}_t \, \theta_y) + \widehat{r}_{t-1} \, \rho_{rd} + \varepsilon_t^R \tag{127}$$

$$W \, \tau_w \, H \, \left(\widehat{h}_t + \widehat{w}_t\right) + T \, \widehat{t}_t = G \, \widehat{g}_t \tag{128}$$

$$\widehat{g}_t = \rho_g \, \widehat{g}_{t-1} - \varepsilon_t^G \tag{129}$$

$$\begin{aligned} Y \, \widehat{y}_t = {} & \widehat{f}_t \, F + G \, \widehat{g}_t + Q_{ex} \, \widehat{q}_t^{ex} - \widehat{q}_t^{im} \, Q^{im} \\ & + K \, R^k \, \mu \, G(\bar{\omega}) \, \left(\widehat{k}_{t-1} + \widehat{q}_{t-1} + \widehat{R}_t^k - \widehat{\pi}_t + \left(\widehat{m}_{t-1} - \widehat{R}_t^k\right) \, \frac{\bar{\omega} \, G'(\bar{\omega})}{G(\bar{\omega})}\right) \end{aligned} \tag{130}$$

$$L \, \widehat{l}_t = L^r \, \widehat{l}_t^i + \widehat{l^e}_t \, L^e + \widehat{l}_t^c \, L^c \tag{131}$$

$$C^p \, \widehat{c}_t^p = C \, \widehat{c}_t + C^e \, \widehat{c}_t^e + C^b \, \widehat{c}_t^b \tag{132}$$