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A monetary model for a fully dollarized economy

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ABSTRACT

We develop a small open economy monetary model under a full dollarization regime, compatible with the Ecuadorian economic system and other similar countries. The objective of the research is to mathematically determine some important relationships between monetary aggregates and relevant macroeconomic variables. Moreover, the model developed provides a general equilibrium view for this type of economies. One of our derivations estimates that variations of monetary species in circulation are closely related to the balance of transactions that consumers and the government mantain with the rest of the world. In our economy, both agents are responsible for the amount of inflows and outflows of foreign currency. As a consequence, depending on how the agents decide to transact with the rest of the world, variations of the currency in circulation can be positive, negative or zero.

Keywords: monetary economics, monetary species in circulation, dollarization, Ecuador, mathematical model.

RESUMEN

Desarrollamos un modelo monetario de una pequeña economía abierta bajo un régimen de dolarización completa, compatible con el sistema económico ecuatoriano y otros países similares. El objetivo de la investigación es determinar matemáticamente algunas relaciones importantes entre los agregados monetarios y variables macroeconómicas relevantes. Más aún, el modelo desarrollado provee un panorama de equilibrio general para este tipo de economías. Una de nuestras derivaciones estima que las variaciones de las especies monetarias en circulación están estrechamente relacionadas con el saldo de transacciones que los consumidores y el gobierno mantienen con el resto del mundo. En nuestra economía, ambos agentes son responsables de la cantidad de entradas y salidas de dólares. En consecuencia, dependiendo de cómo los agentes decidan realizar transacciones con el resto del mundo, las variaciones en especies monetarias pueden ser positivas, negativas o nulas.

Palabras Clave: economía monetaria, especies monetarias en circulación, dolarización, Ecuador, modelo matemático.

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2.1 Introduction

Ecuador is one of the countries in the region[1] whose economy operates under a system of complete dollarization. Adopting a foreign currency as an oficial currency has a important impact on how the economic aparatus behaves. Not being able to use monetary policy in its entirety, the system has to adjust the mechanism to control the amount of money of the economy. Therefore, macroeconomic variables like: interest rate, inflation, prices, balance of payments and money supply are determined under a different environment than what is theoretically expected from economies with a completely functional monetary authority. Our main objective in this paper is to build a general equilibrium model of a fully dollarized economy, wherein we will specify how this economy gets its circulating currency. Specifically, the research seeks to understand which transactions determine the flow of foreign currency in the economy. In order to do so, an economic model is developed to derive fundamental relationships between consumers and government variables. Once identified the main equations, a comparative statics analysis is carried on to describe the possible dynamics of the variables. It is important for policy makers to have theoretical models that allow anticipating movements of key economic variables in the face of changes in public policies or external shocks. Similarly, dollarization encourages the use of theoretical and empirical mechanisms that allow quantifying and understanding the movements of foreign currency in the country. In this regard, the model developed can serve as an analytical instrument to describe how variables like money demand and circulating currency are affected depending on public policies, consumers decisions and external shocks. This model is inspired by some stylized facts of the Ecuadorian economy.

From a monetary viewpoint, the model attemps to identify some channels from which foreign currency could enter or leave the economy. Both consumers and the government has access to the international goods and financial markets, they are able to sell or buy goods and debt through these markets. Depending on the balance of the transactions with the rest of the world, the flow of foreign currency change over time. Because money is used for liquidity purposes, the dynamic of the currency variable can be regarded as variations of monetary species in circulation. The theoretical derivation of monetary aggregates as monetary base (M0), money supply (M1) and liquidity (M2) are a key piece for analyzing the behaivor of a fully dollarized economy. Nevertheless, due to the absence of private banks in the model, M0, M1 and M2 cannot be derived. Therefore, the only monetary aggregate calculated in this economy are monetary species in circulation, which is detailed in section 3.2.1.

[1] Other countries include Panama and El Salvador.

Likewise, from a more general perspective, a monetary model provides insight of the relationship between macroeconomic variables and currency depending on the structure of the economy. The overall structure of the model relyes on the assumption of a frictioneless small open economy which produces and consumes tradable and non tradable goods. The inclusion of two different types of goods in the economy provides a broader perspective on how interactions with the external sector can influence the development of the local industry, through the relative price of goods. This variable is connected with the monetary behaivor of consumers because changes in the relative price of goods can affect demand of money. A standard prediction of the monetary models is that money demand depends directly on consumption and inversely on the nominal interest rate. However, we seek to understand how money demand can be altered when consumption is taxed by the government, also when the nominal interest rate contains a risk premium or sovereign risk and in the presence of shifts in the relative price of goods. These assumptions are used in accordance to the actual economic context of the country, where government tax consumption of tradable goods, also sovereign bonds pays yields above the international risk-free interest rate and external shocks affect the relative price of tradable and non tradable goods. The derivation of money demand is described in section 3.1.2, while the respective analysis can be seen in section 3.2.2.

The model developed assumes that interactions between consumers, the central government and the rest of the world are given entirely through a foreign currency, the american dollar. Nevertheless, the economy is not able to emit foreign currency, causing that monetary balances depends on the transactions with the rest of the world. Unlike a fully dollarized scenario, in a non-dollarized economy the monetary authority or Central Bank has the ability to influence the amount of money in the economy depending on it's floating regime. Under a predetermined exchange rate regime, the monetary authority sets the nominal exchange rate and the money supply is determined endogenously. In contrast, under flexible exchange rate regime, the monetary authority sets the money supply and the exchange rate is determined endogenously (Blanchard & Enrri, 2016). Even though a fully dollarized economy can be compared with a fixed exchange rate regime because the money supply is determined endogenously, in a dollarization regime there is not really an exchange rate, given that the domestic currency ceases to exist (Terra, 2015) [2]. Therefore, the monetary authority is not able to control a exchange rate instrument to affect the

[2]Another important difference between dollarization and the fixed exchange rate is that under fixed exchange rates, trade deficits tend to produce a decline in the money supply, as the central bank is forced to sell reserves to maintain the exchange rate. This produces a negative money multiplier effect that can be mitigated by interventions in which the monetary authority buys bonds and sells domestic money. This is not possible in a dollarized economy, because there is not domestic money (Palley, 2003).

endogenous money supply.

Although in a dollarization regime the monetary authority losses most of its power to influence in the supply of money and to act as a lender of last resort for the central government, in some countries like Ecuador it remains as the institution in charge of custodying the international reserves for the public sector. Typically, Central Banks hold financial assets, foreign currency and other forms of valuable assets like gold, in their agreggate of international reserves. For the purpose of the research, we assume that the total international reserves of the economy are divided between public and private holdings. Public international reserves are safeguarded by the monetary authority and are given as foreign bonds holdings, while private international reserves are foreign currency balances in the hand of consumers. This differentiaton can be seen in the balance of payment equation, derived in section 3.1.4.

As stated above, the loss of monetary policy is a central consequence for a dollarized system. This restriction causes fiscal instruments to become more relevant for government interventions in the economy. In the Ecuadorian case, fiscal budget depends, among other variables, on tax revenues, oil rents, public spending and debt. The model attempts to abstract these features in the fiscal restriction and propose a dynamics for public debt depending on the government balances. When the government primary balance is negatively unbalanced, fiscal authority has the option to finance through internal and external debt. On the other hand, when is positively unbalanced, it has the ability to lend the surplus through the financial market, generating future income from interest payments. Using this structure for the public sector, we also are able to propose a equation for the government primary balance, detailed in section 3.1.7.

Regarding the most important findings of the research, a function for the variation of monetary species in circulation is derived. This equation can be regarded as one of the main contributions of the paper because it constitutes a formal expression for variations in the amount of dollars flowing through the economy. Empirically, the Central Bank of Ecuador uses a methodology to measure periodically variations in the circulation of dollars. However, one big assumption that this methodology relyes on, is that the balances of currency deposited in the Central Bank and in the rest of the financial system, largely reflects the variation of the monetary species in circulation (Vera, 2007). Our research can provide a deeper understanding of the origins of those transactions which are reflected in the balance sheet of the financial system and serve as a complement for the monetary studies carried on by the Central Bank. Moreover, the general structure of the model provides interest results for analyzing the interaction between monetary and macroeconomic variables under a full dollarization regime.

The objective of this paper is to develop a monetary general equilibrium model of a fully dollarized economy with characteristics taken from the ecuadorian system. The economy operates entirely with foreign currency, depends on oil revenues, produce local and exportable goods, taxes imports, incurrs in public spending and has access to internal and external debt. The model developed is based mainly on the theoretical work of Vegh (2013). The article is structured as follows, in section 2.2 the literary review is carried out with some of the most relevant works on dollarization. Section 2.3 describes some empirical aspects of dollarization in Ecuador and relates the results to fundamental predictions made by monetary theory. Section 2.4 describes some important features of the Ecuadorian economy, which are used for the assumptions of the model. In section 3.1 the mathematical model is developed. Section 3.2 analyzes the most important results. Finally, in section 3.3 some final thoughts are given.

2.2 Literature Review

Currency substitution or full dollarization has been a highly discussed topic in the monetary economics branch. Our model is related theoretically and mathematically to a series of literature based on dollarized economies. Initially, the dollarization models focused on studying, mainly, the inflationary effects of dollarization and the dynamics of substitution between domestic and foreign currency[3]. With the passage of time, the subject of the investigations has expanded. In recent years, related aspects such as optimal fiscal policy, debt, volatility, welfare, de-dollarization[4] and the role of international reserves in a dollarized system have been developed, as well as deeper relationships found in traditional currency substitution models.

The model developed in this research is largely based on the works of Vegh (2013) and Kiguel and Liviatan (1992). Vegh proposes a basic model to understand the theoretical mechanism of currency substitution. In this model, consumers use domestic and foreign currency for liquidity purposes. The model assumes a small open economy perfectly integrated into world goods and capital market. There exists one tradable and non-durable good. The main objective of the model is to show how the economy trade between foreign and domestic currency. Unlike the former currency substitution basic model, the Liviatan-type model, developed by Kiguel and Liviatan (1992) assumes consumers do not have bonds, that domestic and foreign currency are demanded in equal proportions and adds a non-tradable good. Moreover, what the model tries to answer is whether a monetary expansion affects the real exchange

[3]One of the most influential works in literature is that conducted by Calvo and Vegh (1992), in which they described a series of analytical issues regarding currency substitution in developing countries.

[4]For a deeper understanding of what could be the main drivers for a de-dollarization process to happen, see Uribe (1997).

rate under a flexible exchange rate regime. By using the general framework of Vegh but assuming only foreign currency exists in the economy and adding a non tradable good like in the Liviatan-type model, we are able to propose a monetary model that can be modified in accordance with the objective of the research.

There are several dollarized models in the literature, used to adress specific questions. Schmitt-Grohé and Uribe (2001) developed an optimizing dynamic general equilibrium model of a small open economy with endogenous labor supply and capital accumulation. The research includes a simulation based on the Mexican economy which compares the level of aggregate welfare of a fully dollarized economy with other floating regimes. Similarly, Duncan (2003) proposed a monetary computational model using data from the Peruvian economy. The objective of the research is to compare the volatility of real economic variables between a completely dollarized economy and a partial dollarized under flexible exchange rate regime. By focusing on the debt aspects of dollarization, Arellano and Heathcote (2010) developed a small open economy model comparing the financial consequences of flexible exchange regime and a economy under full dollarization. The objective of the research is to contrast the importance of accessing to the international debt market between the two regimes. Regarding recent work in the topic of financial dollarization, Bocola and Lorenzoni (2020) analyze a four agents scenario: consumers, banks, foreign investors and government, where unofficial dollarization takes place due to crisis expectations. The results show that when governments hold foreign currency reserves, their credibility to response to financial crises increase and financial stability is promoted.

As it can be seen, fully dollarized models are used in a broad sense. However, most of the research is focused on comparing the results of specific economic variables between fully dollarized economies and other floating regimes. This is not what our model seeks to do. Instead of focusing on how differences between monetary regimes affect the behavior of economic variables, our study seeks to understand only the characteristics of a fully dollarized economy, regardless of how the results could vary in other regimes.

Specifically, one of the main objectives of the present model is to derive a formal expression for the variations of monetary species in circulation. Regarding this subject, the only reference in the literature is the work of Vera (2007). This paper constitute the base for the methodology of the Central Bank of Ecuador to measure the amount of monetary species circulating in the economy. The methodology used to calculate variations in the monetary species in circulation is developed using some assumptions. The flow of dollars through the financial system and the Central Bank is quantifiable, however other

origins are difficult to be measured, as in the case of family remittances, tourism, border trade and illegal activities. The relationship that determines the variations in currency considers that the liquidity of the economy is balanced in the Central Bank, through the interaction with the private sector and the banking system. Moreover, it also considers that all sources of dollar income to the economy, which are not realized directly through the Central Bank, converge in the banking system. Therefore, the equation of the variation in currency flow is conformed by remittance received and sent by the Central Bank and variations in the cash holdings from the Central Bank and private banks. In this way, the Central Bank provides an estimation for the amount of dollars circulating in the economy. Nevertheless, this approximation does not offer an approach for the plausible origins from which currency enters or leave the financial system. Exactly, this is one of the main concerns of the model. It attempts to identify the possible transactions of the agentes with the rest of the world, that could determine the flow of monetary species in circulation.

The literature reviewed describes some of the most relevant work regarding theoretical and empirical aspects of dollarized economies. In a general way, the models developed by Duncan (2003), Schmitt-Grohé and Uribe (2001) and Arellano and Heathcote (2010) could be applied to the Ecuadorian economy because they all assume dollarized small open economies with characteristics of Latin American countries. However, the objective of these papers is different of what arises in this research. In that sense, the described literature do not address dollarization in the same direction as the present research intends to. Our work seeks to develop a theoretical monetary model that deals with describing general interactions between monetary and macroeconomic variables of a dollarized economy like Ecuador. Furthermore, the present paper seeks to analyze the flow of foreign currency in a dollarized economy under specific conditions, thus differentiating itself from previous works and contributing to the existing literature in this way.

2.3 Empirical aspects of dollarization in Ecuador

In the year 2000, Ecuador officially adopted a foreign currency (the dollar) as the legal tender for the country. This meant that the dollar started to serve as store of value, unit of account and medium of exchange in the country. The policymakers were forced to do it because of the informal dollarization that was already happening due to the progressive loss of purchasing power of the domestic currency, the Sucre. Despite the criticism that this measure received, dollarization in Ecuador can be classified as satisfactory (Albornoz, 2019; Choudhury, 2018; Espinoza, Toral, & Gordillo, 2018; Lucio-Paredes,

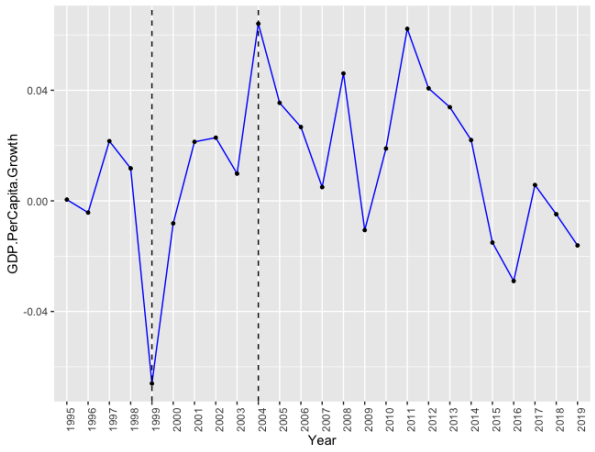


Figure 2.1: GDP per capita growth rate

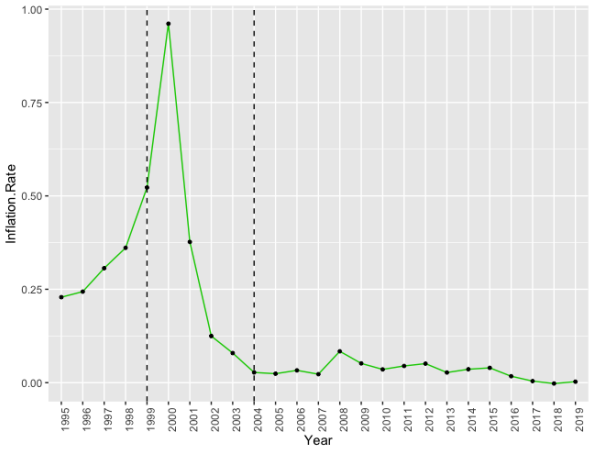


Figure 2.2: Inflation rate

Before dollarization, GDP per capita growth was at its lowest point. Similarly, inflation rate reached the maximum level. On the contrary, after the adoption of dollar as the oficial currency, GDP per capita increased and inflation rate decreased drastically. Figures 2.1 and 2.2 show the evolution of GDP per capita growth rate and inflation rate from 1995 to 2019. Source: BCE (2020).

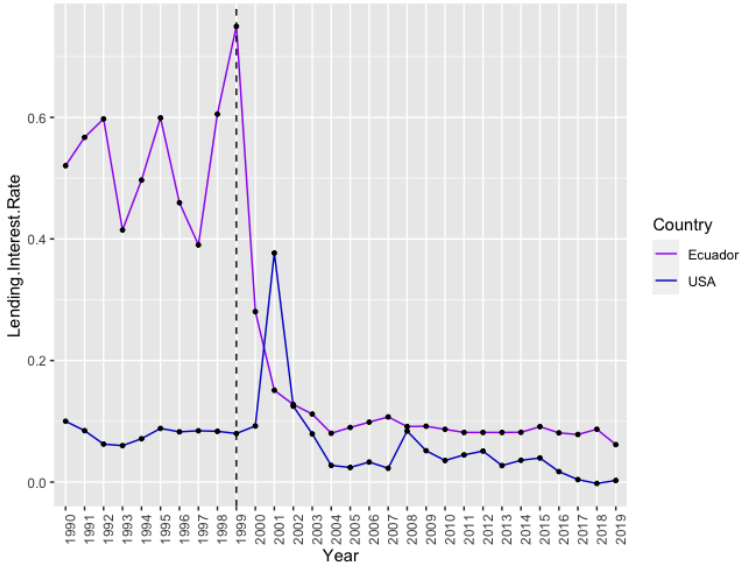
2017).

Few years after the adoption of the dollar as the oficial currency, the inflation rate lowered, GDP growth rose and inflationary uncertainty decreased (Onur & Togay, 2015; Romero & Llerena, 2019) (see figure 2.1 and 2.2). As monetary theory predicted, dollarization resulted in price stabilization and an increase in consumers confidence (Calvo & Vegh, 1992; Hallren, 2014). In the five years following dollarization, GDP per capita growth rate passed from - 0.08 to 0.07, Likewise, the annual inflation rate decreased from 0.95 to 0.04. These behaviors of economic growth and the price level are predicted in currency substitution models. The inflation rate after dollarization is supposed to be inherited by the country from which the currency was adopted. In addition, economic growth can be achieved because price stabilization can lead to an increase in investors confidence, resulting in more investment for the economy.

Another important consequence of dollarization, as pointed out by Berg (2000), is the reduction in the lending interest rate, due to the elimination of the risk of currency crisis, the country risk premia is supposed to drop down, causing lending rate to reduce. As shown in figure 2.3, the year before dollarization, lending interest rate in Ecuador was close to 80 per cent. Inmediately after dollarization, interest rate droped down and it has been stabilized near the interest rate of USA since then.

From what is analyzed in this section, the data shows, at least supperficially, a congruency between what is expected to happen theoretically with the inflation rate, the economic growth and the lending interest rate after dollarization. The effects of dollarization in the interest and inflation rate remains until

Figure 2.3: Evolution of lending interest rate in Ecuador and USA



Before dollarization, banks were lending money at elevated levels because of the lack of liquidity and the high risk of default. In the year when dollarization ocurred, lending interest rate decreased and stabilized close to USA interest rate. Figure 2.3 shows the series of the lending interest rate from 1990 to 2019. Source: WorldBank (2020).

now. However, economic growth is more volatile[5] and it is more difficult to perceive a long run effect caused by the adoption of the dollar as the legal tender of Ecuador.

2.4 Some features of the Ecuadorian economy

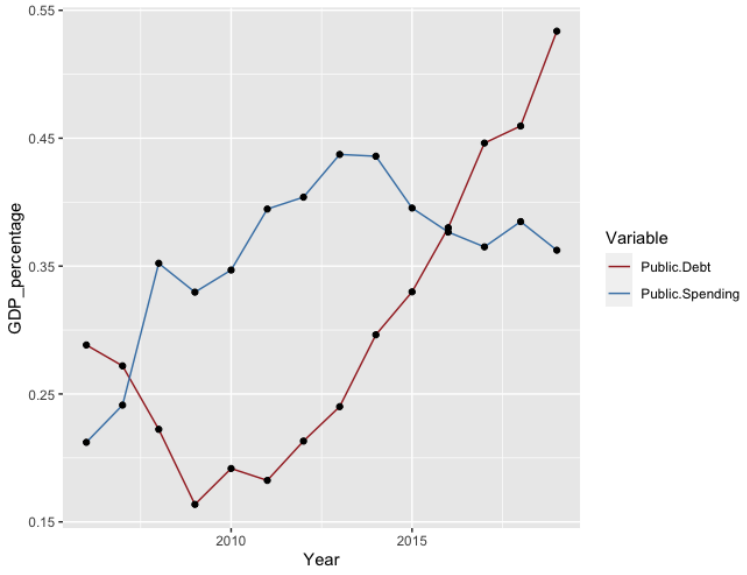
In this section, we justify some of the main assumptions that the model uses, taking into account empirical economic variables which are relevant for the Ecuadorian economy.

Even though the years after dollarization the economy seemed to be re-emerging, it was not long before the problems came again. As pointed out by Anderson (2016) the adoption of the dollar as the official currency generated benefits to the economic well being of Ecuador in the short run. However, after dollarization, the Ecuadorian economy was highly exposed to fiscal policy instruments. In particular, during the last years, public spending has increased, going from representing 23.5 per cent of GDP in 2006 to 36.2 per cent in 2019. Likewise, public debt has rise drastically, passing from representing 28.8 per cent of GDP in 2006 to 53.3 per cent in 2019 (see figure 2.4).

As public debt raises, interest payments also increase, generating pressure to the governments

[5]As Duncan (2003) found out, real economic growth is more volatile in a dollarized economy that in a flexible exchange rate regime.

Figure 2.4: Evolution of public spending and public debt as percentage of GDP



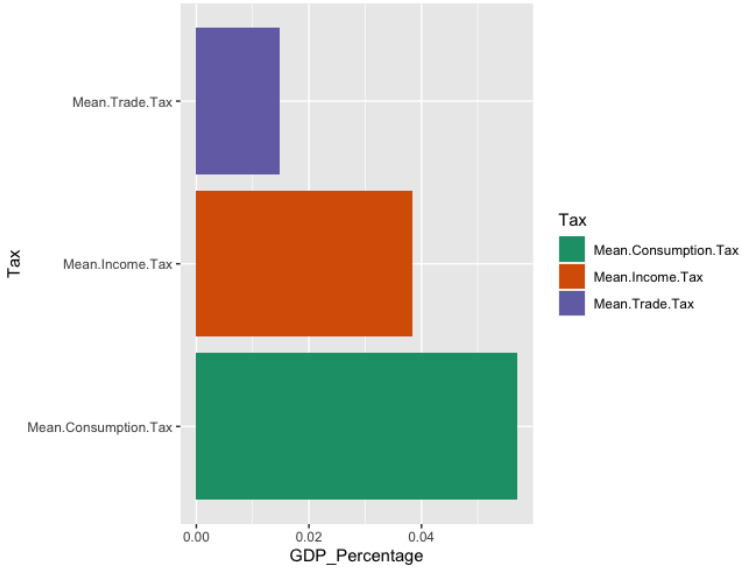
Source: BCE (2020)

budget. As mentioned by Arellano and Heathcote (2010), in a fully dollarized economy, default on debt repayments are extremely costly to the system. Therefore, the best strategy for the government is to repay debt and keep accesing to the international credit market. Similarly, in a budget constraint where public spending weights more than one third of the amount that the economy produces, the dynamic of the variable is decisive for the behaivor of the public budget.

Interest payments and public expenditure must be financied by sources of income from the government. Typically, governments accumulate funds through tax collection. In the case of Ecuador, as shown in figure 2.5, the most important tax revenue for the government is VAT, or consumption tax. In the period from 2006 to 2019, the average annual collection due to consumption tax has been about 6 per cent of GDP. While in the case of income tax has been about 4 per cent and trade tax 1.5 per cent. Nevertheless, import tax has been an important tool for the government regarding of its limited contribution to the fiscal budget. Taxing imports are useful to balance trade deficits and restrict currency outflows to the exterior.

Another way for the ecuadorian government to attract income is through oil exports and sale of oil derivatives. When refering to oil revenues, exports of the commodity has been specially important during the "boom" periods. As shown in Figure 2.6, from 2008 to 2014, oil income was relative high, reaching a peak in 2011 where oil revenues represented more than 16 per cent of GDP. Even though

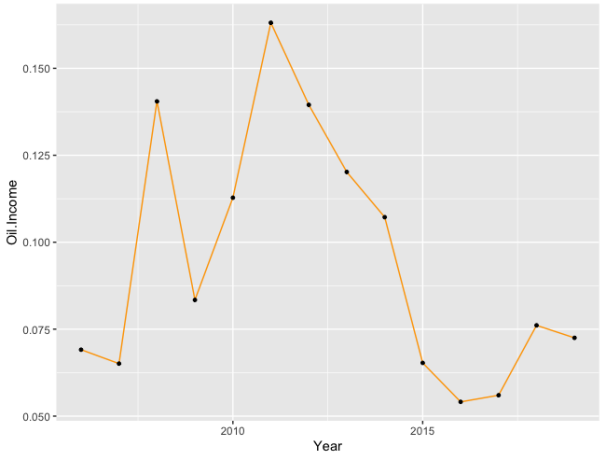
Figure 2.5: Average collection by type of tax as percentage of GDP



Source: BCE (2020)

oil revenues had decreased during the last years, funding through oil exports has been strategic for the government.

Figure 2.6: Evolution of oil income as percentage of GDP



Source: BCE (2020)

In an economic system with almost no monetary policy tools, the importance of fiscal variables; such as government spending and public debt, income from taxes and oil revenues; are determinant for economic policy. Furthermore, fiscal instruments may affect the amount of dollars in the economy via

public saving, and the real exchange rate.

Analysis and Results

3.1 The model

3.1.1 Initial assumptions

We develop a small open economy model that consists in two agents: consumers and government, with participation of the rest of the world. Furthermore, there are two type of goods, a tradable good which can be imported from the rest of the world and a non tradable good produced exclusively for local consumption. The former assumption implies different prices for the two goods. For convention, we assume the price of the tradable good as the numeraire for the economy, meaning that the price level for the economy is going to be expresed in terms of the price of the tradable good $P_t^T = P_t$, except in the case of consumption and production of non tradable goods P_t^N, we express this relative price between these goods as e_t and this also plays the role of real exchange rate in our model.

Moreover, we assume that in the economy there exists only one currency which are dollars (foreign currency). Both the country and the rest of the world trade only in dollars, meaning that exchange rate is constant and equal to one $E_t = 1$. From the law of one price $P_t = E_t P_t^*$, and because $E_t = 1$, $\forall t \in [0, \infty)$, it follows that $P_t = P_t^*$. In other words, the domestic price P_t is equal to the foreign price P_t^*. Because of it, the domestic inflation rate is equal to the foreign inflation rate $\pi_t = \pi_t^*$. Therefore, the dollarized country inherits the inflation rate of the rest of the world.

The treatment is different for the nominal interest rate. It is assumed that local interest rate i_t is greater than foreign rate i_t^* due to a risk premium or sovereign risk[1] ϕ. Mathematically, it can be expressed as $i_t = i_t^* + \phi$.

Regarding general public aspects, government functions are divided between a monetary and a fiscal entity. Monetary authority or Central Bank, is in charge, mainly, of the custody of international reserves and conceding loans to the fiscal authority[2]. While the fiscal authority manages public resources. Government tax (θ) international trade through imports and receive loans from the monetary authority and the rest of the world. It uses the income for public spending and debt interest payments.

[1] In this model, sovereign risk does not arise from the possibility of a sovereign default. It can simply be understood as the risk premium that ensures that the local interest rate is higher than the risk-free international interest rate (Uribe & Schmitt-Grohé, 2017)

[2] The assumption that monetary authority can provide loans to the fiscal authority is standard on the models used for reference. However, it is important to clarify that according to the current legislation in Ecuador, the central bank cannot lend money directly to the fiscal authority due to the possible existence of conflicts of interest, and to preserve his autonomy.

Finally, we use a framework of perfect foresight equilibrium, which implies that in this economy there are no stochastic variables because agents know all relevant information and can predict events without uncertainty. Because of it, the expectation value and the true value are the same, converting the probability that an event occurs equal to one. In an economy where long run steady state variables exist, a perfect foresigh equilibrium is possible (Eatwell, Milgate, & Newman, 1990).

3.1.2 Consumers

The economy is populated by identical, infinitely lived consumers with perfect foresight. Consumers are endowed with two goods: one tradable, non-durable and constant good y^T, which they use to trade with the rest of the world and consume what they are able to import c_t^T while paying a government tax θ_t; and one non tradable good y^N which they also consume c_t^N. Consumers have access to the international financial market, therefore their financial assets (A_t) are compound by foreign currency balances or dollars (F_t) and foreign bonds (B_t), it can be expressed as $A_t = F_t + B_t$. Consumers accumulate financial assets by balancing between revenues from international interest payments ($i_t^* B_t$) and endowments and expenses due to consumption of both goods. Finally, preferences are given in a "money in the utility function" type of model. Therefore, consumers gain utility directly from consumption of tradable and non tradable goods and from their foreing currency holdings. In other words, consumers are always going to prefer having positive balances of money to enhance their utility. [3]

Consumers flow budget constraint in nominal terms is given by:

$$\dot{A}_t = i_t^* B_t + P_t y^T + P_t^N y_t^N - P_t(1+\theta_t)c_t^T - P_t^N c_t^N \tag{3.1}$$

To find consumers flow constraint in real terms we divide by the general level of prices of the economy P_t (we use the relative price of goods as $e_t = \frac{P_t}{P_t^N}$).

$$\frac{\dot{A}_t}{P_t} = i_t^* b_t + y^T + \frac{y^N}{e_t} - (1+\theta_t)c_t^T - \frac{c_t^N}{e_t}$$

From the fact that real financial assets are calculated using $a_t = \frac{A_t}{P_t}$, we obtain its time derivative:

$$\dot{a_t} = \frac{\dot{A}_t P_t - A_t \dot{P}_t}{(P_t)^2}$$

Setting an inflation rate equal to $\pi_t = \frac{\dot{P}_t}{P_t}$:

[3] For further information about money in the utility function models see Walsh (2017).

$$\dot{a}_t = \frac{\dot{A}_t}{P_t} - \pi_t a_t \tag{3.2}$$

Substituting (3.2), and using Fisher equation $i_t^* = r + \pi_t$ we find consumers real flow budget constraint in terms of foreign money balances:

$$\dot{a}_t = ra_t + y^T + \frac{y_t^N}{e_t} - (1+\theta_t)c_t^T - \frac{c_t^N}{e_t} - i_t^* f_t \tag{3.3}$$

Consumers real flow budget constraint explain that the change in foreign assets depends positively on the endowment of both goods and real interest rate payments over financial assets ra_t. On the other hand, it depends negatively on the consumption of the goods, taxes and the opportunity cost of holding money $i_t^* f_t$ [4].

To capture the entire consumers constraint through the infinite periods of time we integrate equation (3.3). Grouping and integrating over $t \in [0; \infty)$:

$$\int_0^\infty (\dot{a}_t - ra_t) exp^{-rt} dt = \int_0^\infty (y_t^T + \frac{y^N}{e_t}) exp^{-rt} dt - \int_0^\infty (c_t^T + \frac{c_t^N}{e_t} + i_t^* f_t) exp^{-rt} dt$$

Solving $\int_0^\infty (\dot{a}_t - ra_t) exp^{-rt} dt$ and imposing the traversality condition $\lim_{t\to+\infty} a_t exp^{-rt} = 0$::

$$\int_0^\infty (\dot{a}_t - ra_t) exp^{-rt} dt = \int_0^\infty \frac{d(a_t exp^{-rt})}{dt} dt = -a_0$$

Replacing $\int_0^\infty (y) exp^{-rt} dt = \frac{y}{r}$ in above equation we find the intertemporal consumer flow constraint:

$$a_0 + \frac{y^T}{r} + \int_0^\infty \frac{y_t^N}{e_t} exp^{-rt} dt = \int_0^\infty [(1+\theta_t)c_t^T + \frac{c_t^N}{e_t} + i_t^* f_t] exp^{-rt} dt \tag{3.4}$$

We assume preferences of consumers are given by:

$$U = \int_0^\infty [(1-\alpha) log(c_t^N) + \alpha log(c_t^T) + \gamma log(f_t)] exp^{-\beta t} dt \tag{3.5}$$

Where $\gamma \in (0, 1]$ is the liquidity factor, $\beta \in [0, 1]$ the subjective discount rate and $\alpha \in (0, 1)$ represents the preferences parameter between non tradable and tradable goods.

Using (3.5) and (3.4) we define the consumer maximization problem:

$$\max_{c_t^N, c_t^T, f_t} \int_0^\infty [(1-\alpha) log(c_t^N) + \alpha log(c_t^T) + \gamma log(f_t)] exp^{-\beta t} dt$$

[4] Because money can also be used to buy bonds, the opportunity cost of money is equal to the interest revenues that consumers loss when they dont invest.

subject to

$$a_0 + \frac{y^T}{r} + \int_0^\infty \frac{y_t^N}{e_t} exp^{-rt} dt = \int_0^\infty [(1+\theta_t)c_t^T + \frac{c_t^N}{e_t} + i_t^* f_t] exp^{-rt} dt$$

Expressing in terms of Lagrange:

$$\mathcal{L} = \int_0^\infty [(1-\alpha)log(c_t^N) + \alpha log(c_t^T) + \gamma log(f_t)] exp^{-\beta t} dt + \lambda [a_0 + \frac{y^T}{r} + \int_0^\infty [\frac{y_t^N}{e_t} - (1+\theta_t)c_t^T - \frac{c_t^N}{e_t} - i_t^* f_t] exp^{-rt} dt]$$

We will assume as in Vegh (2013) that $\beta = r$, then consumption of goods is constant over time. Applying first order conditions:

$$\frac{\partial \mathcal{L}}{\partial c_t^N} = \frac{(1-\alpha)e_t}{c_t^N} = \lambda \tag{3.6}$$

$$\frac{\partial \mathcal{L}}{\partial c_t^T} = \frac{\alpha}{(1+\theta_t)c_t^T} = \lambda \tag{3.7}$$

$$\frac{\partial \mathcal{L}}{\partial f_t} = \frac{\gamma}{i_t^* f_t} = \lambda \tag{3.8}$$

By matching (3.6) = (3.7) we find the optimal relative price of goods:

$$e_t = \frac{\alpha c_t^N}{(1-\alpha)(1+\theta_t)c_t^T} \tag{3.9}$$

In the optimal, the relative price of the goods must be equal to the relation between their consumption, taking into account the preferences for each good and the tax rate.

When (3.6) = (3.8) the demand for dollars in term of the non tradable good can be found:

$$f_t^N = \frac{\gamma c_t^N}{(1-\alpha)i_t^* e_t} \tag{3.10}$$

Demand for dollars increase depending on the liquidity factor and the consumption of non tradable goods. On the contrary decreases according to the nominal interest rate of bonds, the relative price of goods and the preferences parameter.

Likewise, when matching (3.7) with (3.8) the demand of dollar in terms of the tradable good appears:

$$f_t^T = \frac{\gamma(1+\theta_t)c_t^T}{\alpha i_t^*} \tag{3.11}$$

As in the previous case, demand for dollars in terms of the tradable good depend directly on its consumption, the liquidity factor and tax rate. Similarly, it depends negatively on nominal interest rate and the preferences parameter.

3.1.3 Government

In order to derive the government flow constraint we first have to divide it according to the monetary and fiscal authority it represents.

- Monetary authority

We assume that the monetary authority hold international reserves H_t in terms of foreign bonds which pays an interest rate $i_t^* H_t$. Also, the monetary authority give loans to the fiscal authority $\dot{D}_t$. Because of this, monetary authority generates income from the interest payments of the loans it gives to the fiscal authority $i_t D_t$. Finally, any revenue generated by the monetary authority is transfered to the fiscal authority $P_t \tau_t^g$.

The nominal flow constraint of the monetary authority is given by:

$$\dot{H}_t = i_t^* H_t + i_t D_t - \dot{D}_t - P_t \tau_t^g \tag{3.12}$$

Dividing by P_t:

$$\frac{\dot{H}_t}{P_t} = i_t^* h_t + i_t d_t - \frac{\dot{D}_t}{P_t} - \tau_t^g$$

Replacing $\frac{\dot{H}_t}{P_t} = \dot{h}_t + \pi_t h_t$ and $\frac{\dot{D}_t}{P_t} = \dot{d}_t + \pi_t d_t$

$$\dot{h}_t + \pi_t h_t = i_t^* h_t + i_t d_t - \dot{d}_t - \pi_t d_t - \tau_t^g$$

Replacing Fisher $r = i_t^* - \pi_t$ we find the real flow budget constraint for the monetary authority:

$$\dot{h}_t = r h_t + (r + \phi) d_t - \dot{d}_t - \tau_t^g \tag{3.13}$$

Equation (3.13) determines that the change in international reserves from the monetary authority ($\dot{h}_t$) increases according to the payments received from the fiscal authority and the rest of the world due to interests ($r d_t, r h_t$). However it decreases when the monetary authority lends money ($\dot{d}_t$) and transfer revenues (τ_t^g) to the fiscal authority.

- Fiscal authority

The fiscal authority borrows from the monetary authority $\dot{D}_t$ and pays interests for the loans $i_t D_t$. It receives transfers from the monetary authority $P_t\tau_t^g$. Moreover, the fiscal authority can also borrow or give credit to the international market $E\dot{D}_t$ with an international interest rate for the loans $i_t^* ED_t$. The total government debt is composed by the sum of both the internal and the external debt $GD = D_t + ED_t$. Only if the fiscal budget is unbalanced the fiscal debt increases. The fiscal expenses are pulic consumption of both goods G_t^N and G_t^T. Finally, the fiscal authority generates income by taxing imports θc_t^T and from selling oil to the rest of the world. The net oil goverment income is represented by R_t. With these modifications, the nominal flow constraint of the fiscal authority is set by:

$$\dot{D}_t = i_t D_t + E\dot{D}_t - i_t^* ED_t + P_t G_t^T + P_t^N G_t^N - P_t\tau_t^g - P_t R_t - \theta_t P_t c_t^T \tag{3.14}$$

Dividing the expresion by P_t

$$\frac{\dot{D}_t}{P_t} = i_t d_t + \frac{E\dot{D}_t}{P_t} - i_t^* e d_t + G_t^T + \frac{G_t^N}{e_t} - \tau_t^g - R_t - \theta_t c_t^T$$

Solving $\frac{\dot{D}_t}{P_t} = \dot{d}_t + \pi_t d_t$, $\frac{E\dot{D}_t}{P_t} = e\dot{d}_t + \pi_t e d_t$, $i_t^* = r + \pi_t$ and replacing in the previous equation:

$$\dot{d}_t + \pi_t d_t = i_t d_t + e\dot{d}_t + \pi_t e d_t - i_t^* e d_t + G_t^T + \frac{G_t^N}{e_t} - \tau_t^g - R_t - \theta_t c_t^T$$

In this way we find the fiscal authority real flow constraint:

$$\dot{d}_t = (r + \phi) d_t + e\dot{d}_t - r e d_t + G^T + \frac{G^N}{e_t} - \tau_t^g - R_t - \theta_t c_t^T \tag{3.15}$$

Internal debt of the fiscal authority change in function of the balance of external debt (it can be positive, negative or zero depending if the country borrow or lend money from the rest of the world). Fiscal income is given by transfers from the monetary authority (τ_t^g), oil revenues (R_t), interest payments (if the country lend to the rest of the world) and tax revenues. On the other hand, the expenses of the fiscal authority are the interest payments (if the country borrows from the rest of the world) and public consumption of tradable and non tradable goods.

- Consolidated Government

Replacing (3.15) in the monetary real constraint we find the government real flow constraint:

$$\dot{h}_t = r h_t + r e d_t + R_t + \theta_t c_t^T - e\dot{d}_t - G_t^T - \frac{G_t^N}{e_t} \tag{3.16}$$

The government flow constraint in real terms states that the change in international reserves ($\dot{h}_t$), depends positively on the interests generated by international reserves rh_t, oil revenues (R_t) and tax collection, but lowers depending on public consumption of tradable and non tradable goods. Moreover, international reserves varies depending on the balance of external debt, when the country lends to the rest of the world we expect a minus sign on $e\dot{d}_t$ and a positive sign in interest payments red_t. Evidently, when the country borrows from the rest of the world the sign of the variables are the opposite.

As for the consumers, the government restriction can take into account the future values through all the periods of time. For it to happen, we need to group and integrate over the entire time horizon. Furthermore, we need to impose transversality conditions for h_t and ed_t to avoid possible Ponzi schemes. Solving in the same way as for the consumers we find the intertemporal government constraint:

$$h_0 + ed_0 + \int_0^\infty (R_t + \theta_t c_t^T) exp^{-rt} dt = \int_0^\infty (G_t^T + \frac{G_t^N}{e_t}) exp^{-rt} dt \tag{3.17}$$

3.1.4 Balance of Payments

The balance of payments of a dollarized country is a key ingredient to understand how international trade is being done. This macroeconomic indicator allows to know all the income that a country receives from the rest of the world and the payments that such country makes to the rest of the world due to imports and exports of goods, services, capital or transfers in a period of time. Given that a monetary of a fully dollarized economy cannot control the amount of foreign money in the country, the balance of payments can be used to analyze foreign currency balances and its evolution[5].

Replacing θc_t^T from consumers flow constraint into government constraint, assuming that in equilibrium $y^N = c_t^N + G_t^N$ and replacing $\dot{a}_t = \dot{f}_t + \dot{b}_t$ we find the balance of payments equation:

$$\dot{h}_t + \dot{f}_t = -\dot{b}_t - e\dot{d}_t + r(b_t + f_t + h_t + ed_t) + y^T + R_t - c_t^T - G_t^T - i_t^* f_t \tag{3.18}$$

This result shows that in a dollarized economy the so called international reserves are not just in the central bank's vault. These are hold by the public and the private sector. In this sense, a dollarized regime is distinct from a currency board or fixed exchange regime. The change in international reserves is equal to the capital account plus the current account. Here the mechanism of the monetary approach to the balance of payments works as in other systems. In equation (3.18) the capital account is represented by the terms $-\dot{b}_t - e\dot{d}_t$. Likewise, current account is composed by the income balance $r(b_t + f_t + h_t + ed_t)$

[5]See Krugman (1979)

and trade balance $y^T + R_t - c_t^T - G_t^T$. Finally, the term $i_t^* f_t$ can be understood as inflation tax revenues, or payments that the dollarized country makes the issuing country of the foreign currency for using it.

3.1.5 Economy constraint

The total financial assets in the economy (k_t) is defined by the sum of the private $f_t + b_t$ and public financial assets $h_t + ed_t$:

$$k_t = f_t + h_t + b_t + ed_t \longrightarrow \dot{k}_t = \dot{f}_t + \dot{h}_t + \dot{b}_t + e\dot{d}_t \tag{3.19}$$

Replacing (3.19) in (3.18) we find the economy resource constraint:

$$\dot{k}_t = rk_t + y^T + R_t - c_t^T - G_t^T - i_t^* f_t \tag{3.20}$$

The change in the total amount of financial assets in the economy ($\dot{k}_t$) has a similar analysis than the one exposed for the balance of payments equation. Furthermore, because all the financial assets in the economy are international, the total financial assets can be interpreted as the economy stock of net foreign assets. It implies that if $\dot{k}_t > 0$, the country accumulate foreign assets.

As for the government and consumers, we can define the restriction of the economy for all the periods of time. By integrating and imposing a transversality condition for the stock of net foreign assets, we can find the intertemporal resource constraint of the economy:

$$k_0 + \frac{y^T}{r} + \int_0^\infty R_t exp^{-rt} dt = \int_0^\infty (c_t^T + G_t^T + i_t^* f_t) exp^{-rt} dt \tag{3.21}$$

3.1.6 Consumption Path

To determine the optimal amount of tradable goods consumed in the economy under a perfect foresight equilibrium path frmework, we need to assume a steady state scenario for consumption and therefore, for demand of foreign currency balances. First, we assume that consumption is constant $c_t^T = c^T$, $\forall t \in [0, \infty)$. Similarly, using demand of dollars equation $i_t f^d = \frac{\gamma(1+\theta)c^T}{\alpha}$ and replacing in equation (3.21), we find steady state consumption:

$$c^T = \frac{\alpha[rk_0 + y^T + r[\int_0^\infty (R_t - G_t^T) exp^{-rt} dt]]}{\alpha + \gamma(1+\theta)} \tag{3.22}$$

Steady state consumption is equal to permanent income, defined by $\alpha[rk_0 + y^T + r[\int_0^\infty (R_t - G_t^T)exp^{-rt}dt]]$. Equation (3.22) is also used to derive the optimal tariff for the economy (see appendix 1).

3.1.7 Government Primary Balance

The primary balance of the government is the fiscal balance net of interest payments. We can rewrtite equation (3.16) eliminating debt and interest variables to find the primary balance of the government GPB_t:

$$GPB_t = R_t + \theta_t c_t^T - G_t^T - \frac{G_t^N}{e_t} \tag{3.23}$$

The government primary balance is conformed by fiscal incomes $R_t + \theta_t c_t^T$ minus fiscal expenditures $G_t^T + \frac{G_t^N}{e_t}$. If $GPB_t > 0$ the government mantains a primary superavit. Otherwise, when $GPB_t < 0$ the government has a primary deficit. Evidently, a positive shock in oil income $\dot{R}_t > 0$ or in tax collection $\theta_t \dot{c}_t^T > 0$ would improve the primary balance. If, instead, government expenditure increases $\dot{G}_t^T > 0$ or $\dot{G}_t^N > 0$, then primary balance is negatively affected. The government primary balance is an important indicator for the sustainable administration of the fiscal budget [6].

3.1.8 Monetary Equilibrium

The monetary equilibrium in the economy happens when the money supply equals money demand. The supply of money is going to be defined as $f^s = \frac{F}{P}$, which is the real value of the monetary species existing in the economy. Using money demand for tradable goods, we state the nominal monetary equilibrium as:

$$F^s = F^d$$

$$\longrightarrow F^s = P\frac{\gamma(1+\theta_t)c_t^T}{\alpha(i_t - \phi)}$$

In the same way, we can derive the equilibrium in real terms:

$$f^s = f^d$$

[6] For a better understanding of how solid fiscal policies are important to achieve macroprudential policies in the region see De la Torre, Ize, and Schmukler (2011).

$$\longrightarrow f^s = \frac{\gamma(1+\theta_t)c_t^T}{\alpha(i_t - \phi)}$$

Using previous equations, we can derive the optimal local interest rate for the economy in real and nominal terms, respectively:

$$i_t = \frac{\gamma(1+\theta_t)c_t^T}{\alpha f} + \phi \quad \text{and} \quad i_t = \frac{\gamma(1+\theta_t)Pc_t^T}{\alpha F} + \phi \tag{3.24}$$

The local interest rate of the economy has a direct relationship with consumption of tradable goods and sovereign risk, but an inverse one with the supply of money. It means that consumption pushes up the interest rate because money is used for transactional purposes, therefore causing increments on interest rate to make investments more attractive. Regarding sovereign risk, increments in this indicator may reflect a loss in the capacity to pay the country's obligations, which implies that the interest rate offered is higher to compensate for the additional risk incurred by the investor.

3.2 Results

So far, a theoretical framework has been developed for the Ecuadorian economy, taking into account some important features of it's economic dollarized behaivour. The model developed suggests a close relationship between the amount of foreign money in the economy and transactions with the rest of the world. To delve a little deeper into this topic, the section analyzes the determinants of variations in the monetary species in circulation. Similarly, an comparative statics analysis is carried out for some variables that may be critical for the economic development of the country.

3.2.1 Variation of monetary species in circulation

By rewritting equation (3.18) we can find the change in dollars for the country. Due to the absence of banks in the economy, the only monetary indicator in the economy are monetary species in circulation [7]. Therefore, we are able to define the change in the currency circulation:

$$\dot{MSC} = \dot{f}_t = -\dot{h}_t - \dot{b}_t - e\dot{d}_t + r(b_t + f_t + h_t + ed_t) + y^T + R_t - c_t^T - G_t^T - i_t^* f_t \tag{3.25}$$

[7] To calculate monetary base or M0 the amount of banks reserves are needed. For the M1 or money supply the amount of check accounts plus M0 are needed. Finally, for M2 or total liquidity the amount of saving deposits and quasimoney is added to M1.

As it can be noticed in equation (3.25), variations in MSC are determined by the transactions the country mantain with the rest of the world. There are three possible scenarios under these conditions regarding the sign of the variations of circulating currency. First, we define wheter it exist inflows or outflows of currency depending on the sign of the variables. A positive sign represents currency inflows, while a negative one can be regarded as outflows. From the above equation, only the signs of exports y^T, imports c_t^T, G_t^T and inflation tax $i_t^* f_t$ can be interpreted literally. The rest of the variables can have opposite signs depending if the country lends or borrows from the rest of the world. When Ecuador borrows from the rest of the world, the country receives money as credit $+\dot{ed}_t$ and pays interest $-red_t$. Likewise, oil balance R_t can be positive or negative depending if the country imports oil related products in bigger proportions than oil exports. Under these circunstances, inflows can be bigger than outflows, meaning a positive change of MSC. On the other hand, outflows can be bigger, resulting in a negative change of circulating currency. Finally, inflows and outflows could be equal, resulting in no variations of MSC.

3.2.2 Comparative statics

To understand how relative price of goods, consumption and demand of dollars varies we use a comparative statics analysis. Relative price of tradable and non tradable goods are important to estimate how some industries can develop over time. A positive value of e_t could result in a strong incentive for the international trade. On the contrary, the local production industry could be affected because of the bigger resource allocation for the international industry. Equation (3.9) can be stated as $e_t = \frac{\alpha(y^N - G_t^N)}{(1-\alpha)(1+\theta_t)c_t^T}$. By derivating with respect of public consumption $\frac{\partial e_t}{\partial G_t^N} = -\frac{\alpha}{(1-\alpha)(1+\theta_t)c_t^T} < 0$, we find that increases in public consumption of non tradable goods, decreases relative price or generates a real appreciation. It is important to note that when we take into account the real money demand expressed in non tradable goods, the effect of a real appreciation increases the real money demand. The same negative relation can be found for the tax rate $\frac{\partial e_t}{\partial \theta_t} = -\frac{\alpha(y^N - G_t^N)}{(1-\alpha)(1+\theta_t)^2 c_t^T} < 0$. On the contrary, increments in the preferences parameter and in endowment of non tradable goods increases the relative price or generates a real depreciation $\frac{\partial e_t}{\partial \alpha} = \frac{\alpha(y^N - G_t^N)}{(1-\alpha)^2(1+\theta_t)c_t^T} > 0$ and $\frac{\partial e_t}{\partial y^N} = \frac{\alpha}{(1-\alpha)(1+\theta_t)c_t^T} > 0$.

Regarding consumption of tradable goods, the amount of imports are strategic for the trade balance. Using equation (3.22) we find that increments in the tariff contracts consumption of tradable goods $\frac{\partial c^T}{\partial \theta_t} = -\frac{\alpha[rk_0 + y^T + r[\int_0^\infty (R_t - G_t^T) exp^{-rt} dt]]}{\gamma[\alpha + \gamma(1+\theta)]^2} < 0$. The same contraction in consumption can be seen when

increments in the liquidity factor happens, $\frac{\partial c^T}{\partial \gamma} = -\frac{\alpha[rk_0+y^T+r[\int_0^\infty (R_t-G_t^T)exp^{-rt}dt]]}{(1+\theta)[\alpha+\gamma(1+\theta)]^2} < 0$. On the contrary, $\frac{\partial c^T}{\partial r} = \frac{\alpha[k_0+\int_0^\infty (R_t-G_t^T)exp^{-rt}dt}{\alpha+\gamma(1+\theta)} > 0$ and $\frac{\partial c^T}{\partial k_0} = \frac{\alpha r}{\alpha+\gamma(1+\theta)} > 0$, meaning that increasing real interest rate and the amount of financial assets enhance consumption of tradable goods.

Demand for money implies that consumers prefer to use cash as a mean of payment for their consumption, instead of investing in foreign bonds. This idea can be clarified because $\frac{\partial f^T}{\partial c^T} = \frac{\gamma(1+\theta_t)}{\alpha i_t^*} > 0$ and $\frac{\partial f^N}{\partial c^N} = \frac{\gamma}{(1-\alpha)i_t^* e_t} > 0$. When consumption increases, demand for money is also boosted. In order to adjust to a new level of consumption, consumers need to use more (or less) cash for liquidity transactions. The same is true to finance variations in the tariff and for the liquidity factor $\frac{\partial f^T}{\partial \theta_t} = \frac{\gamma c_t^T}{\alpha i_t^*} > 0$ and $\frac{\partial f^T}{\partial \gamma} = \frac{(1+\theta_t)c_t^T}{\alpha i_t^*} > 0$.

Furthermore, by replacing $i_t^* = i_t - \phi$, we observe that sovereign risk also has a direct relationship with money demand $\frac{\partial f^T}{\partial \phi} = \frac{\gamma(1+\theta_t)c_t^T}{\alpha(i_t-\phi)^2} > 0$. The sovereign risk decreases the foreign nominal interest rate, making foreign investment less profitable and therefore, lowering the opportunity cost of holding cash. On the other hand, we can see an inverse relationship between money demand and the local interest rate $\frac{\partial f^T}{\partial i_t} = -\frac{\gamma(1+\theta_t)c_t^T}{\alpha(i_t-\phi)^2} < 0$, meaning that increments in nominal rate decreases demand for money. Because interest rate is associated with the opportunity cost of holding cash, increments in nominal rate becomes cash holding more costly. The same negative relationship can be found between money demand and relative price, $\frac{\partial f_t^N}{\partial e_t} = -\frac{\gamma c_t^N}{(1-\alpha)i_t^* e_t^2} < 0$. In other words, when consumption of non tradable goods becomes cheaper in relation with tradable goods, the amount of money needed to consume non tradable goods lowers.

3.3 Final remarks

From an empirical point of view, it is difficult to measure the amount of money that flows through a economy. But in a fully dollarized economy it is even harder due to the lack of precise information for monetary aggregates calculated by the monetary authority. The research conducted proposed a theoretical model to describe the Ecuadorian economy under a monetary framework. The results indicate that variations of currency circulation of the economy is determined by the balance of transactions the country mantains with the rest of the world.

Moreover, the model constructed is a simplification of the Ecuadorian economy and aims to detail

some important general aspects of its dollarized system. The inclusion of variables like oil balance, trade tax, relative price of goods, external debt and sovereign risk, under a monetary framework where only foreign currency operates in the economy, provides an approximation to analyze the economic behavior of the country. Furthermore, the assumptions used can be applied to other dollarized economies in the region.

For further research, the model could be parametrized using a computational method. A computational analysis would deepen the anaysis carried out in this research. Moreover, the computational model would be useful to predict numerically the effects of modifying fiscal instruments. Similarly, including banks in the model would expand the analysis, enabling for the derivation of the rest of monetary aggregates: M0, M1 and M2.

ADDITIONAL FEAUTURES

Appendix 1

Calculating the optimal tax in the economy

To find the optimal tariff we express equation (3.22) differently:

$$c^T = \frac{\alpha r}{\alpha + \gamma(1+\theta_t)}[J]$$

Where $J = k_0 + \frac{y^T}{r} + \int_0^\infty (R_t - G_t^T) exp^{-rt} dt$

Replacing steady state consumption c^T and money demand f^d in consumers utility and maximizing using government intertemporal constraint we find optimal tax policy:

$$\mathcal{L} = \int_0^\infty [(1-\alpha) log(c_t^N) + \alpha log[\frac{\alpha r}{\alpha + \gamma(1+\theta_t)}(J)] + \gamma log[\frac{\gamma(1+\theta_t)c^T}{\alpha i_t}]] exp^{-\beta t} dt$$

$$+\lambda[z_0 + \int_0^\infty (R_t + \theta_t c^T - G_t^T - \frac{G_t^N}{e_t}) exp^{-rt} dt]$$

Assuming $\beta = r$ and applying First Order Conditions:

$$\frac{\alpha}{c^t}\frac{\partial c^T}{\partial \theta_t} + \frac{\gamma}{f^d}\frac{\partial f^d}{\partial \theta_t} + \lambda(c^T + \theta_t \frac{\partial c^T}{\partial \theta_t}) = 0$$

Using $\lambda = \frac{\alpha}{(1+\theta_t)c^T}$ ando solving for θ_t

$$\theta_t^* = \frac{\gamma^2 + \alpha(\alpha+\gamma)}{\gamma(\alpha-\gamma)} \quad \text{with} \quad \alpha > \gamma$$

The optimal tax θ_t^* maximizes consumers utility while assuring that it's value is high enough for the government to meet their financial needs. We find a direct relationship between the optimal tax rate and the liquidity factor $\frac{\partial \theta_t^*}{\partial \gamma} > 0$. Increasing the liquidity factor augments the consumption of tradable goods, resulting in an increase in the tariff. On the other hand, there is an inverse relationship between optimal tax and preferences for tradable goods $\frac{\partial \theta_t^*}{\partial \alpha} < 0$. Because the parameter α shows the preferences of consumers for tradable goods, increasing the parameter results that consumers utility becomes more sensitive to consumption of this type. Therefore, increasing the tariff lowers consumers utility.

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