The Effect of International Monetary Policy Expansions on Costa Rica

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Abstract

This paper studies if the international monetary policy has a major effect on the Costa Rican economy. The analysis is performed estimating a structural Bayesian vector autoregression (SBVAR) and a dynamic stochastic general equilibrium (DSGE) small open economy model estimated with Bayesian maximum likelihood methods using data from 2000 to 2014. The SBVAR estimation provides evidence that shocks to US interest rates, US inflation and US output in conjunction accounts for the following share of fluctuations: 43.2%, of nominal exchange rates; 52.2% of Costa Rican interest rates; 35.1% of Costa Rican inflation; 51.4% of Costa Rican output; 36.7% of exports; and 39.3% of imports. The DSGE model describes the mechanisms through which the local and foreign disturbances affect Costa Rica. An unexpected increase in the local interest rates means that the holding of local assets by the rest of the world increases; and it also incentives savings, which means postponed consumption. Households substitute deposits, local and foreign currency, with government debt. As expected the substitution of savings by government debt means there is no greater investment in the economy due to an increase in the risk premium. Meanwhile, an unexpected expansion in the US interest rate causes an outflow of resources from the economy, which along with the interest rate increase causes a depreciation of the currency and an increase in the local interest rate. Therefore consumption decreases and exports increase.

Keywords: monetary policy, central banks, general equilibrium.
JEL classification: E52, E58.

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1. INTRODUCTION

The expansive international monetary policy that has been in place since 2009, especially in the United States, has had several effects on the Costa Rican economy. The international financial crisis occurs just in the early stages of structural reforms for the monetary and exchange rate policies. In this context, the authorities have adapted to external conditions while taking advantage of them to finally control inflation and make progress in reforming the exchange rate regime. This paper aims to evaluate the effect of the international monetary policy over the local economic conditions.

The first observable consequence of the international monetary policy is the low interest rates prevalent for several years in the international markets. Given this, domestic economic agents were able to access cheap foreign borrowing. In fact, during the years 2012 to 2016 the Costa Rican government placed the equivalent of 8% of 2014 GDP in new foreign debt. On the domestic side, there was pressure on domestic interest rates originated by the need to finance the government deficit that conducted to a higher interest rate differential. These aspects attracted resources to Costa Rica and generated an appreciation pressure of the *colón* (CRC), which along with low commodity prices have been the main forces to reduce inflation.

Under the circumstances, the net international reserves (NIR) balance significantly increased, explained by the capital inflow into the economy and the obligation to defend the lower limit of the exchange rate band system along with the creation of several reserve accumulation programs established by the authorities of the Central Bank of Costa Rica (Banco Central de Costa Rica, BCCR). The following currency appreciation ended facilitating an important objective of the Central Bank, the reduction and stability of inflation and its convergence to that of the major trading partners.

The document is organized as follows. Section 2 provides a brief characterization of the Costa Rican economy. Section 3 uses a Bayesian vector autoregression estimation to study the magnitude of the effects of the international monetary policy over the local economy, especially the period after the recent financial crisis. Section 4 covers the DSGE model and the results of the impulse response functions that allow us to elaborate on the possible effects of changes in the international and local monetary policies, as well as other important international variables. And finally, Section 5 contains some conclusions and remarks.

2. THE COSTA RICAN ECONOMY AND THE INTERNATIONAL MONETARY POLICY[1]

2.1 Costa Rica in Figures

Costa Rica is a small and open economy; its main commercial partner is the United States of America (USA) that counts for 47% of the international trade (imports and exports). From the stock market point of view, Costa Rica is underdeveloped and it is not internationally integrated.

The GDP is about 53 billion dollars (USD) for 2015; and a GDP per capita for 2015 of 10,947 USD. The average real growth for 1991-2008 was 5.1%; as a result of the international financial crisis, the output decreased in 2009 (−1%) a moderated contraction compared with those of some Latin American economies. Since then the economic activity began a recovery process (4.1% from 2010-2015). According to calculations made by Esquivel and Rojas (2006) and updated by the Central Bank, the potential output in Costa Rica is estimated at 4.3 percent.

The country exhibited a large current account deficit, around 6.2% of the GDP for the period 2005-2008. This disequilibrium experienced a correction due to an improvement in terms of trade, a reduction of the value of its imports and a GDP contraction given the international financial crisis, and by the end of 2009 it was 2% of the GDP. For the period between 2010 and 2015, the current account deficit stands for 4.7% of the GDP and was almost entirely financed by foreign direct investment (Table 1).

From 1980 to 2008 the average inflation annual rate was 18.7%; it declined to 3.9% from 2009 to 2015. The Central Bank faces the challenge of consolidating this process to achieve and maintain similar inflation levels to its main trading partners, in the medium term.

In 2006 the BCCR started a slow transition to inflation targeting by introducing more flexibility in its exchange rate regime.

At that time the assessment of the BCCR was that in Costa Rica the implementation of a variation of fixed exchange rate regime (crawling peg) along with the Central Bank losses were a permanent source of money creation which made impossible to pin down inflation from 1982 to 2005.

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[1] Based on Barquero and Muñoz (2016).

Table 1

COSTA RICA: MACROECONOMIC INDICATORS

Indicator	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Inflation	10.8	13.9	4.0	5.8	4.7	4.6	3.7	5.1	−0.8
Real rate of growth	7.9	2.7	−1.0	5.0	4.5	5.2	3.4	3.5	2.9
Current account deficit (percent of GDP)	6.3	9.3	2.0	3.5	5.4	5.3	5.0	4.8	4.2
Foreign direct investment (percent of GDP)	6.2	6.9	4.6	4.0	5.1	4.2	4.8	4.0	4.2
Net international reserves (percent of GDP)	15.6	12.7	13.8	12.7	11.5	15.1	14.9	14.6	15.2
Global public sector deficit (percent of GDP)[1]	−0.8	0.4	5.0	5.9	5.6	5.1	6.2	5.3	5.8
Financial wealth dollarization	38.0	43.2	42.9	39.8	36.7	32.9	30.8	32.2	30.4
Credit dollarization	42.4	44.6	42.6	38.7	39.4	41.1	42.1	41.0	41.6

[1] Negative value stands for surplus.
Source: Central Bank of Costa Rica.

In other words, the Central Bank did not have control over its monetary base and Costa Rica was a textbook example of the *impossible trinity.*

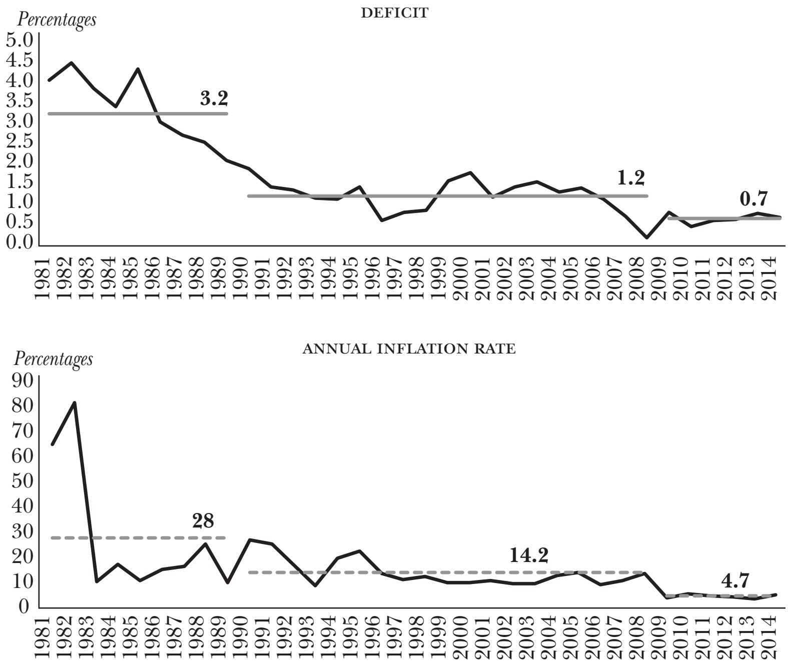
The basic idea was that in the medium and long terms, the inflation was created by the excess of money over its demand. So, by delinking the money creation process from the exchange rate regime that would reduce the sterilization needs of the Central Bank, it will reduce along time the size of the Central Bank deficit (Figure 1 shows this idea). Therefore, the BCCR will gradually take control of its two main sources of monetary expansion (fixed exchange rate regime and losses due to sterilization efforts).

The BCCR purpose was to move gradually from the fixed exchange rate regime to a free float one, in which the market forces are the main determinants of the nominal exchange rate.

Figure 1

BCCR: DEFICIT AND ANNUAL INFLATION RATE

Percentage of GDP



Source: Central Bank of Costa Rica.

During the first 19 months of the new regime the nominal exchange rate appreciated about 6%; however, this was a period in which the Central Bank continued purchasing international reserves and sterilizing the resulting monetary excesses. There was an improvement in its deficit; however, the inflation, in average, during the period 2006-2008 was not different from the previous 23 years, and this could also be partly explained by high inflation expectations generated after almost three decades of double-digit inflation.

2.2 Monetary Policy in Costa Rica

From 1983 to late 2006, the conceptual basis of the BCCR's monetary policy was the monetary approach to the balance of payments, which was run by a financial programming exercise oriented to control monetary aggregates (net domestic assets, M1, M2, total liquidity, total domestic credit), where the monetary policy instruments were basically reserve requirements and open market operations. The monetary approach to the balance of payments operates under a fixed exchange rate system; Costa Rica's exchange rate at the time was a crawling peg which in practice can be considered as fixed.

The fixed exchange rate regime and the opening of the capital account in 1992 actually meant that the BCCR lost monetary control over the economy and thus inflation control. This demonstrated the incompatibility between the monetary system and the exchange rate regime (impossible trinity), that led the country to inflation rates in double digits. Indeed, average inflation for the period 1980-2006 is around 19.3 percent.

In 2005 the Board of Directors of the BCCR decided to gradually advance on the adoption of a monetary policy regime based on inflation targets. As part of this process in October 2006, it decided to leave the exchange rate regime in operation since the early eighties and temporarily moved to a regime of exchange band. This amendment sought not only to provide greater flexibility in determining the nominal exchange rate, but also to strengthen the use of the interest rate transmission mechanism of monetary policy.

In June 2011 the Board redefined the monetary policy rate (*tasa de política monetaria* or TPM, in Spanish) as the reference interest rate used by the BCCR to drive the cost of operations within the integrated liquidity market (MIL). Specifically, the operations are conducted in a corridor formed by the interest rates on its standing facilities of credit and the deposit. Operationally, the Bank implements its monetary policy by influencing the amount of loanable funds and liquidity in the MIL, ensuring that the resulting interest rate approaches the monetary policy.

In February 2015, the Central Bank's Board of Directors makes the decision to migrate to a managed floating exchange rate regime in which the exchange rate is determined by the interaction of supply and demand while the BCCR intervenes to moderate excessive volatility without interfering with the market forces.

The main result of these reforms within an international environment of high liquidity and low interest rates was a sharp decline in the rate of inflation. The rates of inflation, expected inflation, and core inflation decreased from over 12% in 2008 to around 5% by 2010. Since then all these indicators have remained stable and low, allowing the BCCR to achieve a level of inflation that has mostly been within the target announced by the monetary authority and therefore increasing the level of credibility by the economics agents.

However, if the current level of inflation is not sustainable once the international monetary policy changes direction, or at least is not resilient to drastic increases in the exchange rate or the international price of commodities, that should be a source of concern for the Central Bank.

3. STRUCTURED BAYESIAN VECTOR AUTOREGRESSION (VAR) ESTIMATION

In this section, we perform a structured Bayesian vector autoregression (SBVAR)[2] estimation that allows seeing the relation between the main variables in the model. This is performed by checking the effect that the US economy has in the Costa Rican economy estimating a model following Zha (1999), which allows exogenous blocks in the estimation of the VAR in the sense that any variable that is not included in the block does not have an effect (coefficient equal to zero) in the corresponding equations of the exogenous block at time t and in lags. In addition, one can impose some structure in the matrix of contemporaneous coefficients in the left side of the VAR.

Our observable variables vector in this empirical work is given by $Y = [e, r^{CR}, \pi^{CR}, y^{CR}, imp^{CR}, exp^{CR}, r^{US}, \pi^{US}, y^{US}]$, where e is the real exchange rate between Costa Rican currency and US dollar, r is the real interest rate, π is the inflation, Y is the GDP, imp are the imports and exp are the exports. The series contain quarterly data from 2000 first quarter to 2014 third quarter and were transformed by using the Hodrick-Prescott filter.

Partitioning the observables Y_t into Costa Rican nominal, GDP and real variables, and US nominal variables: $Y_t^{e,nom} = [e, r^{CR}, \pi^{CR}]$, $y_t^y = [y^{CR}]$, $Y_t^{CR} = [imp^{CR}, exp^{CR}]$ and $Y_t^{\widetilde{nom}} = [r^{US}, \pi^{US}, y^{US}]$ respectively, the four blocks are given by:

$$\begin{bmatrix} TS_3 & A^{y}_{e,nom} & 0 & A^{\widetilde{nom}}_{e,nom} \\ 0 & I_{1\times1} & A^{CR}_{y} & A^{\widetilde{nom}}_{y} \\ 0 & 0 & I_{2\times2} & 0 \\ 0 & 0 & 0 & TS_3 \end{bmatrix} \begin{pmatrix} Y_t^{e,nom} \\ y_t^y \\ Y_t^{CR} \\ Y_t^{\widetilde{nom}} \end{pmatrix} = \begin{bmatrix} B^{e,nom}_{e,nom} & B^{y}_{e,nom} & B^{CR}_{e,nom} & B^{\widetilde{nom}}_{e,nom} \\ B^{e,nom}_{y} & B^{y}_{y} & B^{CR}_{y} & B^{\widetilde{nom}}_{y} \\ B^{e,nom}_{CR} & B^{y}_{CR} & B^{CR}_{CR} & B^{\widetilde{nom}}_{CR} \\ 0 & 0 & 0 & B^{\widetilde{nom}}_{\widetilde{nom}} \end{bmatrix} \begin{pmatrix} Y_{t-1}^{e,nom} \\ y_{t-1}^y \\ Y_{t-1}^{CR} \\ Y_{t-1}^{\widetilde{nom}} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^{e,nom} \\ \varepsilon_t^{y} \\ \varepsilon_t^{CR} \\ \varepsilon_t^{\widetilde{nom}} \end{pmatrix},$$

where TS_n denotes an upper triangular matrix of dimension $n \, x \, n$. The *structural errors* $\left[\varepsilon_t^{e,nom}, \varepsilon_t^{y}, \varepsilon_t^{CR}, \varepsilon_t^{nom} \right]$ are orthogonal with unit variance.

[2] All the results are reported at the mode of the parameters distribution using maximum likelihood.

The contemporaneous matrix (left) can be seen as an upper triangular matrix of dimension 9x9 and this means that the variable which is on the top e is affected by the greatest number of variables (9), the one below r^{CR} does not receive effect from the first ordered variable e contemporaneously but from the others does it and so on, until the last ordered variable y^{US} is the most exogenous one. In this case, we also impose additional restrictions (zeros) in the model, in the first row the zero means that imports and exports of Costa Rica do not have an impact at time t in $Y_t^{e,nom}$. The other zero (third row) and the use of an identity matrix ($I_{\{2x2\}}$) imply no effect of any variable at time t in Y_t^{CR}.

In the matrix of lags (right), the restrictions are set by the method of estimation and as a consequence, the block of US variables is not affected (not at time t nor in lags) by the domestic variables. We must mention that this method is not equivalent to make two regressions: one with the domestic variables as dependents and all the variables as regressors, and the other with just the US variables as dependents and regressors as well, because this does not take into account the relationship between blocks when, for example, one computes the second moments and the variance decomposition as the other method does.

In the estimation we chose two lags because it gave us the best model fit when we compare the second moments of data and the model (standard deviations and correlations), we report only two tables, one with standard deviations and the correlations of all variables with y^{US} to save space.

As we see the most notable differences come from the correlation table, the first three variables e, r^{CR}, π^{CR} are the ones with more deviations in proportion; however, the signs do not change and the differences are not significant.

Table 1

STANDARD DEVIATIONS

	e	r^{CR}	π^{CR}	y^{CR}	imp^{CR}	exp^{CR}	r^{US}	π^{US}	y^{US}
Data	4.59	0.38	1.49	2.88	3.51	5.56	2.00	0.01	1.17
Model	4.52	0.47	1.49	2.85	4.26	5.14	1.58	0.01	1.05

Table 2

CORRELATIONS WITH y^{US}

	e	r^{CR}	π^{CR}	y^{CR}	imp^{CR}	exp^{CR}	r^{US}	π^{US}	y^{US}
Data	0.02	−0.20	0.44	−0.34	0.50	0.29	0.44	0.52	1.00
Model	0.13	−0.31	0.24	−0.34	0.32	0.21	0.36	0.43	1.00

Our main result in this estimation is the variance decomposition which shows a really big impact from the foreign shocks ξ^r, ξ^π and ξ^y to the domestic and bilateral variables e, r^{CR}, π^{CR}, y^{CR}, imp^{CR} and exp^{CR} with a cumulate effect of 43.2, 52.2, 35.1, 51.4, 36.7 and 39.3 respectively.

Table 3

VARIANCE DECOMPOSITION

	Bilateral	*Costa Rica*					*United States*		
	e	r^{CR}	π^{CR}	y^{CR}	imp^{CR}	exp^{CR}	r^{US}	π^{US}	y^{US}
ξ^e	33.6	7.0	9.1	5.0	7.9	5.7	0.0	0.0	0.0
$\xi^{\tilde{r}}$	7.7	10.5	4.4	2.7	4.8	3.5	0.0	0.0	0.0
$\xi^{\tilde{\pi}}$	4.6	11.6	26.3	4.1	5.3	10.6	0.0	0.0	0.0
$\xi^{\tilde{y}}$	1.9	6.0	10.1	16.4	5.4	4.4	0.0	0.0	0.0
$\xi^{\widetilde{imp}}$	2.7	4.4	11.0	1.8	14.9	3.8	0.0	0.0	0.0
$\xi^{\widetilde{exp}}$	6.4	8.2	3.9	18.8	25.0	32.5	0.0	0.0	0.0
ξ^r	4.5	23.4	7.8	10.4	6.8	9.1	77.1	19.1	23.7
ξ^π	19.6	3.3	14.8	7.0	2.7	6.7	11.4	79.9	2.6
ξ^y	19.1	25.5	12.5	34.0	27.2	23.5	11.6	1.0	73.7

The volatility of the real exchange rate is more affected by the inflation and product from USA and in almost the same quantity, while the domestic monetary policy gets the biggest effect from the interest rate and product, the domestic GDP gets the greatest impact of all the shocks precisely from the foreign GDP, and imports and exports are more influenced by the foreign product. The block of zeroes is brought because USA is the exogenous block, so nondomestic variable has an effect on its variables. To further investigate the mechanisms through which domestic and international shocks affect the Costa Rican economy, we then develop and estimate a DSGE model that characterizes the main elements of that economy.

4. THE EFFECT OF LOCAL AND INTERNATIONAL MONETARY POLICY ON COSTA RICA

4.1 DSGE Model

The DSGE model[3] for Costa Rica used in this paper is a new Keynesian model with price and wage frictions that includes a wide set of economic agents, among them households that receive income from their holdings of financial assets and also wages from labor. Additionally, they receive the profits from the firms that produce intermediate goods and direct transfers from the government. This income is used to buy consumption goods, pay taxes and buy financial assets for the next period.

The model also includes entrepreneurs that produce a homogeneous good using as inputs capital and labor. The production process requires the entrepreneur to buy capital at the beginning of the period. However its net wealth is not enough to buy the amount of capital required, thus it asks the financial sector for loans. These loans are funded with deposits from the households and foreign debt contracted by the banks.

The entrepreneurs sell their homogeneous good to firms that produce intermediate goods, which differentiate the homogeneous good at a zero cost. These firms pick a price that maximizes their profits even though they face a quadratic cost adjustment in price changes following Rotemberg (1982), creating this way price rigidity in the model.

[3] Based on Alfaro et al. (2015).

The firms that produce intermediate goods sell them to the firms that produce final goods, which used the intermediate goods as inputs and then sell the aggregate product to the households as a consumption good, to the foreign sector as exports and to the firms that are capital producers as investment goods or capital input.

Finally, there is a monetary authority that sets the nominal interest rate according to a Taylor rule, and a government that issues debt, charges taxes on capital rents, wages, and consumption, and expends in investment and operating costs using a fiscal rule. A more detailed explanation of the model follows next.

4.1.1 Households

There is a number of identical households and a continuum of household members, where $z \in (0,1)$ represents the labor type offered by each household member, and $S \in (0,1)$ is the disutility of labor for each member (S) that represents the aversion to labor. Labor is indivisible, which means that the market labor adjustment takes place through the number of household members working and not through the amount of hours supplied.

Each employed household member utility is represented as

$$U = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(c_{t+i})^{1-\sigma_r}}{1-\sigma_r} - \chi s^{\eta} \right].$$

And the utility of unemployed members is

$$U = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(c_{t+i})^{1-\sigma_r}}{1-\sigma_r} \right].$$

The aggregate utility function for the household looks like:

$$U = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(c_{t+i})^{1-\sigma_r}}{1-\sigma_r} - \chi \int_0^1 \int_0^{n^d_{z,t+i}} s^{\eta} \, ds dz \right].$$

Or,

$$U = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{(c_{t+i})^{1-\sigma_r}}{1-\sigma_r} - \chi \int_0^1 \frac{\left(n^d_{z,t+i}\right)^{1+\eta}}{1+\eta} dz \right].$$

Integrating among all kind of labor the household disutility of labor is found $\int_0^1 \frac{\left(n_{z,t+i}^d\right)^{1+\eta}}{1+\eta} dz$.

The household problem can be divided into two parts, the first chooses the consumption path $\left\{c_{t+i}\right\}_{i=0}^{\infty}$, real stocks of government bonds $\left\{b_{t+i}\right\}_{i=0}^{\infty}$, and deposits in local and foreign currency at the financial system $\left\{d_{t+i}, d_{t+i}^*\right\}_{i=0}^{\infty}$ in order to maximize the utility subject to the income constraint. In the second stage, the labor wage $w_{z,t}$ is determined by the labor kind z.

Utility Maximization Problem

The first optimization problem would be

$$\max_{\left\{c_{t+i}, b_{t+i}, d_{t+i}, d_{t+i}^{\dot{a}}\right\}_{i=0}^{\infty}} U = E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{\left(c_{t+i}\right)^{1-\sigma_r}}{1-\sigma_r} - \chi \int_0^1 \frac{\left(n_{z,t+i}^d\right)^{1+\eta}}{1+\eta} dz \right],$$

subject to

1 $$\left(1+\tau_{t+i}^c\right) c_{t+i} + b_{t+i} + d_{t+i} + \frac{s_{t+i} p_{t+i}^*}{p_{t+i}^c} d_{t+i}^* = \left(1-\tau_{t+i}^L\right) \int_0^1 w_{z,t+i} n_{z,t+i}^d dz + \frac{i_{t+i-1}}{\pi_{t+i}^c} b_{t+i-1} + $$
$$+ \frac{i_{t+i-1}^d}{\pi_{t+i}^c} d_{t+i-1} + \frac{i_{t+i-1}^{d^*}}{\pi_{t+i}^*} \frac{s_{t+i} p_{t+i}^*}{p_{t+i}^c} d_{t+i-1}^* + $$
$$+ \xi_{t+i} + \xi_{t+i}^b - tr_{t+i}^G .$$

The household receives income from the wages of all the employed members $\int_0^1 w_{z,t} n_{z,t}^d dz$, it also receives the returns and the face value of the holdings of financial assets, for government bonds receives, i_{t-1} for deposits in local and foreign currency receives i_{t-1}^d and i_{t-1}^{d*}. Additionally, receives profits from the firms ξ_t and from the banks ξ_t^b. The household then buys consumption goods c_t, financial assets in local currency b_t, d_t and foreign currency d_t^* (valued using the real exchange rate $s_t p_t^* / p_t^c$). Finally, it pays taxes over consumption τ_t^c and labor τ_t^L and receives transfers for tr_t^G. Local inflation is π_t and foreign inflation π_t^*.

Optimality conditions are:

2 $$\lambda_t = \beta E_t \left(\lambda_{t+1} \frac{i_t}{\pi_{t+1}^c} \right)$$

3 $$\lambda_t = \beta E_t\left(\lambda_{t+1}\frac{i_t^d}{\pi_{t+1}^c}\right)$$

4 $$\lambda_t = \beta E_t\left(\lambda_{t+1}\frac{s_t p_{t+1}^*}{p_t^c}\frac{i_t^{d^*}}{\pi_{t+1}^*}\right)$$

5 $$\left(1+\tau_t^c\right)\lambda_t = c_t^{\left(-\sigma_r\right)}$$

Simultaneously the consumption basket composition between local and imported goods is determined to minimize its costs.

$$\min_{c_t^h, c_t^f} G = \frac{p_t^h}{p_t^c}c_t^h + \frac{p_t^f}{p_t^c}c_t^f ,$$

subject to

6 $$c_t = \left(\left(1-\alpha_c\right)^{\frac{1}{\eta_c}}\left(c_t^h\right)^{\frac{\eta_c-1}{\eta_c}} + \left(\alpha_c\right)^{\frac{1}{\eta_c}}\left(c_t^f\right)^{\frac{\eta_c-1}{\eta_c}}\right)^{\frac{\eta_c}{\eta_c-1}}$$

7 $$c_t^h = \left(1-\alpha_c\right)\left(\frac{p_t^h}{p_t^c}\right)^{-\eta_c} c_t$$

8 $$c_t^h = \left(1-\alpha_c\right)\left(\frac{p_t^h}{p_t^c}\right)^{-\eta_c} c_t$$

Optimal Wage and Labor Supply

The wage from labor z is $w_{z,t}$ and total labor supply $n_{z.t}^d$ is determined by the labor demanding aggregator firms.

Labor aggregator: The labor aggregator firm solves

$$\min_{n_{z,t}^d}\int_0^1 w_{z,t}n_{z,t}^d dz$$

$$s.t\, n_t^d \leq \int_0^1\left[\left(n_{z,t}^d\right)^{\frac{\theta^w-1}{\theta^w}} dz\right]^{\frac{\theta^w}{\theta^w-1}}$$

From which the labor demand can be derived

$$n_{z,t}^{d}=\left(\frac{w_{z,t}}{w_{t}}\right)^{-\theta^{w}}n_{t}^{d},$$

where the aggregate wage is

$$w_{t}=\left(\int_{0}^{1}w_{z,t}^{1-\theta^{w}}dz\right)^{\frac{1}{1-\theta^{w}}}.$$

Given the labor demand, household members determine the wage that maximizes the household utility taking into account there is a chance ε^{w} of not adjusting their wages in the next period.

$$\max_{w_{z,t}}E_{t}\sum_{i=0}^{\infty}\left(\beta\varepsilon^{w}\right)^{i}\left(\frac{\left(c_{t+i}\right)^{1-\sigma_{r}}}{1-\sigma_{r}}-\chi\int_{0}^{1}\frac{\left(n_{z,t+i}^{d}\right)^{1+\eta}}{1+\eta}dz\right),$$

subject to:

$$\left(1-\tau_{t+i}^{L}\right)\int_{0}^{1}w_{z,t+i}n_{z,t+i}^{d}dz+\frac{i_{t+i-1}}{\pi_{t+i}^{c}}b_{t+i-1}+\frac{i_{t+i-1}^{d}}{\pi_{t+i}^{c}}d_{t+i-1}+\frac{s_{t+i}p_{t+i}^{*}}{p_{t+i}^{c}}d_{t+i-1}^{*}\frac{i_{t+i-1}^{d^{*}}}{\pi_{t+i}^{*}}+\xi_{t+i}+\xi_{t+i}^{b}-tr_{t+i}^{G}=$$

$$\left(1+\tau_{t+i}^{c}\right)c_{t+i}+b_{t+i}+d_{t+i}+\frac{s_{t+i}p_{t+i}^{*}}{p_{t+i}^{c}}d_{t+i}^{*}$$

$$n_{z,t+i}^{d}=\left(\frac{w_{z,t+i}}{w_{t+i}}\right)^{-\theta^{w}}n_{t+i}^{d}$$

$$w_{z,t+i}=w_{z,t}$$

The FOC for optimal wage:

9 $$\left(1-\tau_{t}^{L}\right)w_{t}^{opt}=\frac{\theta_{w}}{\theta_{w}-1}\frac{Num_{w_{t}}}{Den_{w_{t}}}$$

10 $$Num_{w_{t}}=\chi_{r}\left(n_{t}^{d}\left(\frac{w_{t}^{opt}}{w_{t}}\right)^{\left(-\theta_{w}\right)}\right)^{1+\gamma_{r}}+\beta\varepsilon_{w}\left(\left(\frac{w_{t}^{opt}}{w_{t+1}^{opt}}\right)^{\left(-\theta_{w}\right)}\right)^{1+\gamma_{r}}Num_{w_{t+1}}$$

11 $$Den_{w_{t}}=\lambda_{t}n_{t}^{d}\left(\frac{w_{t}^{opt}}{w_{t}}\right)^{\left(-\theta_{w}\right)}+\beta\varepsilon_{w}\left(\frac{w_{t}^{opt}}{w_{t+1}^{opt}}\right)^{\left(-\theta_{w}\right)}Den_{w_{t+1}}$$

Aggregate wage is defined by

12 $$\left(w_t\right)^{1-\theta_w} = \varepsilon_w \left(w_{t-1}\right)^{1-\theta_w} + \left(1-\varepsilon_w\right)\left(w_t^{opt}\right)^{1-\theta_w} .$$

Unemployment: Labor participation by each household member is

$$\left(1-\tau_t^L\right) w_{z,t} \geq \frac{\chi s^\eta}{\lambda_t}$$

And the unemployment rate is

14 $$ur_t = \frac{l_t - n_t^d}{l_t} ,$$

which means that

$$\int_0^1 w_{z,t} n_{z,t}^d dz = w_t n_t^d .$$

4.1.2 Capital Goods Producers

These firms operate under perfect competition and each period buy capital and new investment goods in order to produce capital goods that are sold to entrepreneurs.

$$\max_{\{k_{t+i}, x_{t+i}\}_{i=0}^\infty} \xi_t^{CP} = E_t \sum_{i=0}^\infty \left(\beta \frac{\lambda_{t+i}}{\lambda_t}\right)^i \left(\mu_{t+i}^K k_{t+i} - \frac{p_{t+i}^x}{p_{t+i}^c} x_{t+i} - (1-\delta)\mu_{t+i}^K k_{t+i-1}\right),$$

subject to:

15 $$k_{t+i} = x_{t+i}\left(1 - s\left(\frac{x_{t+i}}{x_{t+i-1}}\right)\right) + (1-\delta) k_{t+i-1} ,$$

The optimality condition is

16 $$\frac{p_t^x}{p_t^c} = \mu_t^K \left(1 - s\left(\frac{x_t}{x_{t-1}}\right) - \frac{x_t}{x_{t-1}} s'\left(\frac{x_t}{x_{t-1}}\right)\right) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \mu_{t+1}^K s'\left(\frac{x_{t+1}}{x_t}\right)\left(\frac{x_{t+1}}{x_t}\right)^2\right),$$

where μ_t^k is the price of capital and $\frac{p_t^x}{p_t^c}$ is the price of investment goods. Production technology has adjustment costs a la Christiano et al. (2011), where

$$s\left(\frac{x_t}{x_{t-1}}\right)=\frac{1}{2}\left(e^{\sqrt{a}\left(\frac{x_t}{x_{t-1}}-1\right)}+e^{\left(-\sqrt{a}\right)\left(\frac{x_t}{x_{t-1}}-1\right)}-2\right)$$

$$s'\left(\frac{x_t}{x_{t-1}}\right)=\frac{\sqrt{a}}{2}\left(e^{\sqrt{a}\left(\frac{x_t}{x_{t-1}}-1\right)}-e^{\left(-\sqrt{a}\left(\frac{x_t}{x_{t-1}}-1\right)\right)}\right)$$

$$s'\left(\frac{x_{t+1}}{x_t}\right)=\frac{\sqrt{a}}{2}\left(e^{\sqrt{a}\left(\frac{x_{t+1}}{x_t}-1\right)}-e^{\left(-\sqrt{a}\left(\frac{x_{t+1}}{x_t}-1\right)\right)}\right)$$

The aggregate investment good is obtained as a combination of goods produced locally and imported,

17 $$x_t=\left(\left(1-\alpha_x\right)^{\frac{1}{\eta_x}}\left(x_t^h\right)^{\frac{\eta_x-1}{\eta_x}}+\left(\alpha_x\right)^{\frac{1}{\eta_x}}\left(x_t^f\right)^{\frac{\eta_x-1}{\eta_x}}\right)^{\frac{\eta_x}{\eta_x-1}}.$$

Then the optimal demand for investment goods is

18 $$x_t^h=\left(1-\alpha_x\right)\left(\frac{p_t^h}{p_t^x}\right)^{-\eta_x}x_t$$

19 $$x_t^f=\alpha_x\left(\frac{p_t^f}{p_t^x}\right)^{-\eta_x}x_t$$

where

20 $$\frac{p_t^h}{p_t^x}=\frac{p_t^h}{p_t^c}\Big/\frac{p_t^x}{p_t^c}$$

21 $$\frac{p^f}{p_t^x}=\frac{p_t^f}{p_t^c}\Big/\frac{p_t^x}{p_t^c}.$$

4.1.3 Entrepreneurs

Demand labor $\left(n_t^d\right)$ and supply labor $\left(n_t^e\right)$ acquire capital from the firm's producers of capital and for this use their resources $\left(nw_t\right)$ and acquire debt from the financial system for $\left(cr_t^{tot}\right)$.

22 $$cr_t^{tot}=\mu_t^K k_t-nw_t.$$

Finalized the productive process they sell the homogeneous good $y_t^{h^s}$ to the firms producers of intermediate goods. During the production process these firms face idiosyncratic shocks (z_t) that affect their productivity and that might make that the entrepreneur cannot be able to pay its debts. In this case the banks obtain a fraction of the capital owned by the entrepreneur:

23 $$y_t^{h^s} = z_t\left(\left(n_t^d\right)^{\Omega_n}\left(n_t^e\right)^{(1-\Omega_n)}\right)^{(1-\alpha)}\left(k_{t-1}\right)^{\alpha}\left(k_{t-1}^G\right)^{\alpha^G}.$$

The demand for household labor is determined by

24 $$w_t = \frac{p_t^w}{p_t^c}\Omega_n(1-\alpha)\frac{y_t^{h^s}}{n_t^d}.$$

Remuneration is

25 $$w_t^e = \frac{p_t^w}{p_t^c}(1-\Omega_n)(1-\alpha)\frac{y_t^{h^s}}{n_t^e}.$$

The demand for capital depends on the expected return

26 $$E_t\left(R_{t+1}^K\right) = E_t\left(\frac{r_{t+1}^k\left(1-\tau_{t+1}^K\right)+\mu_{t+1}^K(1-\delta)}{\mu_t^K}\right),$$

where the marginal product of capital is:

27 $$r_t^k = \frac{p_t^w}{p_t^c}\alpha\frac{y_t^{h^s}}{k_{t-1}}$$

and the entrepreneur's wealth then evolves according to

28 $$nw_t = \phi V_t + n_t^e w_t^e,$$

where

29 $$V_t = R_t^K\mu_{t-1}^K k_{t-1} - E_{t-1}\left(R_t^K\right)cr_{t-1}^{tot}$$

are the net returns for unit of capital. Finally, the entrepreneurs consume

30 $$\frac{p_t^h}{p_t^c}c_t^e = (1-\phi)V_t.$$

4.1.4 Intermediate Goods Producers

The firms buy the good produced by the entrepreneur at price p_t^w, it is differentiated at zero cost, and it is sold to the final good producers at price $p^h_{j,t}$. They face imperfect competition with quadratic adjustment costs.

$$\max_{p^h_{j,t}}\left(\xi^{nom}_{j,t}\right)=E_t\sum_{i=0}^{\infty}\left(\beta\frac{\lambda_{t+i}}{\lambda_t}\right)^i\left(\left(p^h_{j,t+i}-p^w_{t+i}\right)y^{h^d}_{j,t+i}-p^h_{t+i}\frac{\Psi}{2}\left(\frac{p^h_{j,t+i}}{p^h_{j,t+i-1}\left(\pi^h_{t-1}\right)^{\iota_n}\left(\bar{\pi}\right)^{1-\iota_n}}-1\right)^2\right)$$

subject to:

$$y^{h^d}_{j,t+i}=\left(\frac{p^h_{j,t+i}}{p^h_{t+i}}\right)^{-\theta}y^{h^d}_{t+i}.$$

The optimal price condition is:

$$\begin{aligned}0={}&y^{h^d}_t\frac{p^h_t}{p^c_t}(1-\theta)+y^{h^d}_t\frac{p^w_t}{p^c_t}\theta-\tilde{c}\left(\frac{\pi^h_t}{\pi^h_{t-1}}\right)\Psi\left(\tilde{c}\left(\frac{\pi^h_t}{\pi^h_{t-1}}\right)-1\right)\frac{p^h_t}{p^c_t}\\&+\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\tilde{c}\left(\frac{\pi^h_{t+1}}{\pi^h_t}\right)\left(\tilde{c}\left(\frac{\pi^h_{t+1}}{\pi^h_t}\right)-1\right)\frac{p^h_t}{p^c_t}\pi^h_{t+1}\right)\end{aligned}$$

$$\xi_t=\left(\frac{p^h_t}{p^c_t}-\frac{p^w_t}{p^c_t}\right)y^{h^d}_t-\frac{p^h_t}{p^c_t}\Psi\left(c\left(\frac{\pi^h_t}{\pi^h_{t-1}}\right)\right)^2,$$

where

$$c\left(\frac{\pi^h_t}{\pi^h_{t-1}}\right)=\frac{\pi^h_t}{\left(\pi^h_{t-1}\right)^{\iota_n}\left(\bar{\pi}\right)^{1-\iota_n}}-1$$

$$\tilde{c}\left(\frac{\pi^h_t}{\pi^h_{t-1}}\right)=\frac{\pi^h_t}{\left(\pi^h_{t-1}\right)^{\iota_n}\left(\bar{\pi}\right)^{1-\iota_n}}$$

$$\tilde{c}\left(\frac{\pi^h_{t+1}}{\pi^h_t}\right)=\frac{\pi^h_{t+1}}{\left(\pi^h_t\right)^{\iota_n}\left(\bar{\pi}\right)^{1-\iota_n}}.$$

Finally, it is possible to find the relationship between the Rotemberg (1982) adjustment cost and the Calvo (1983) price adjusting probability, following $\Psi=\dfrac{\varepsilon\left(\theta-1\right)}{\left(1-\varepsilon\right)\left(1-\beta\varepsilon\right)}$.

4.1.5 Final Good Producers

This firm maximizes its benefit through the determination of the optimal demand for inputs produced by the intermediate goods producers. The firm profit maximization problem is:

$$\max_{y_{j,t}^{h^d}} \xi_t = p_t^h y_t^{h^d} - \int_0^1 p_{j,t}^h y_{j,t}^{h^d} dj ,$$

where y_t^d are total final goods, $p_{j,t}^h$ price of each intermediate good and $y_{j,t}^{h^d}$ is its demand.

The maximization is subject to

$$y_t^{h^d} = \left(\int_0^1 \left(y_{j,t}^{h^d} \right)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}} ,$$

where θ represents the degree of substitutability among the different inputs.

The demand for intermediate goods for final goods is

$$y_{j,t}^{h^d} = \left(\frac{p_{j,t}^h}{p_t^h} \right)^{-\theta} y_t^{h^d} .$$

The local goods price is

$$p_t^h = \left(\int_0^1 \left(p_{j,t}^h \right)^{1-\theta} dj \right)^{\frac{1}{1-\theta}} .$$

In equilibrium supply and demand of final goods should equal and then follow this condition:

33 $$y_t^{h^s} = y_t^{h^d} .$$

4.1.6 Financial System

The financial system of the economy operates under perfect competition and banks are owned by the households. They make loans to the entrepreneurs by taking deposits from the household and loans from abroad.

34 $$cr_t^{tot} = cr_t + cr_t^* .$$

Loans in local currency come from household deposits

35 $$cr_t = d_t .$$

Loans in foreign currency are funded with deposits in foreign currency from the households and foreign debt (loans).

36 $$cr_t^* = \frac{s_t p_t^*}{p_t^c} d_t^* + \frac{s_t p_t^*}{p_t^c} b_t^* .$$

Total household deposits are

37 $$d_t^{tot} = d_t + \frac{s_t p_t^*}{p_t^c} d_t^* .$$

Deposits in foreign currency are a ratio of total deposits.

38 $$\frac{s_t p_t^*}{p_t^c} d_t^* = \alpha_d \left(d_t^{tot} \right) .$$

Given the banks can observe the idiosyncratic shock suffered by the entrepreneurs only if they incur in monitoring costs, the optimal contract offered by the bank stipulates jointly the amount of the loan and the interest rate to be paid. This friction in the intermediation process implies the loan interest rate includes a margin $\left(sp_t\right)$ that depends on the value of the loan and the net wealth of the entrepreneurs,

39 $$R_{t+1}^K = sp_{t+1} \frac{i_t}{\pi_{t+1}^c}$$

40 $$sp_t = \left(\frac{k_{t-1} \mu_{t-1}^K}{nw_{t-1}} \right)^{\nu} .$$

The cost of funds follows the parity condition given by

41 $$\frac{i_t}{\pi_{t+1}^c} = \left(\frac{s_t p_t^*}{p_t^c} \Big/ \frac{s_{t-1} p_{t-1}^*}{p_{t-1}^c} \right) \frac{i_t^*}{\pi_{t+1}^*} .$$

Bernanke et al, (1999) show that the optimal contract guarantees the zero profit condition for the banks:

42 $$\xi_t^b = R_t^K cr_{t-1}^{tot} - \frac{i_{t-1}^d}{\pi_t^c} d_{t-1} - \frac{s_t p_t^*}{p_t^c} \left(\frac{i_{t-1}^{d^*}}{\pi_t^c} d_{t-1}^* - \frac{i_{t-1}^*}{\pi_t^*} b_{t-1}^* \right) .$$

4.1.7 Central Bank and Government

Central Bank: The Central follows this rule to achieve a the inflation objective

43 $$i_i = \left(i_{t-1}\right)^{\rho_s}\left(\bar{i}\left(\frac{\pi_t^c}{\bar{\pi}}\right)^{\rho_\pi}\right)^{1-\rho_s}\varepsilon_t^i .$$

Total inflation can be derived from relative prices

44 $$\frac{\pi_t^h}{\pi_t^c} = \frac{\frac{p_t^h}{p_t^c}}{\frac{p_{t-1}^h}{p_{t-1}^c}} .$$

Government: The government collects taxes, issues bonds and has expenditures represented by g_t , and makes transfers to the households. Government collects taxes from consumption, income and capital returns and follows a countercyclical fiscal policy with automatic stabilizers, to ensure a stable debt to GDP ratio. The balance is given by:

45 $$b_t + Tax_t = b_{t-1}\frac{i_{t-1}}{\pi_t^c} + \frac{p_t^h}{p_t^c}g_t - tr_t^G .$$

Taxes are

46 $$Tax_t = t_t^K + t_t^C + t_t^L$$

given

47 $$t_t^C = \tau_t^c c_t$$

are consumption taxes,

48 $$t_t^L = \tau_t^L n_t^d w_t$$

labor taxes

49 $$t_t^K = \tau_t^K r_t^k k_{t-1}$$

and capital return taxes. Total expenditure includes operating costs and investment

50 $$g_t = c_t^G + x_t^G .$$

The investment expenditure is transformed into public capital that affects the entrepreneurs' productivity,

51 $$k_t^G = x_t^G + \left(1-\delta^G\right)k_{t-1}^G .$$

Finally, it has a set of instruments (expenditure options and tax rates) that guarantee the fulfillment of $b_t = \overline{b}$. This rule follows Leeper et al. (2010b and 2010a). Additionally, the rule also includes a countercyclical response by the government $pib_t > \overline{pib}$.

52 $$\Theta_{tr_t^G} = \overline{tr}^G \left(\frac{b_t}{b_t^s}\right)^{\gamma^{tr^G}} \varepsilon_t^{tr^G} ,$$

53 $$\Theta_{c_t^G} = \left(\frac{pib_t}{\overline{pib}}\right)^{\left(-\psi^{c^G}\right)} \left(\overline{c}^G\right)^{1-\rho^{c^G}} \left(\frac{b_t}{\overline{b}}\right)^{\left(-\gamma^G\right)} \left(c_{t-1}^{G^s}\right)^{\rho^{c^G}} \varepsilon_t^{c^G} ,$$

54 $$\Theta_{x_t^G} = \left(\frac{pib_t}{\overline{pib}}\right)^{\left(-\psi^{x^G}\right)} \left(\overline{x}^G\right)^{1-\rho^{x^G}} \left(\frac{b_t}{\overline{b}}\right)^{\left(-\gamma^{x^G}\right)} \left(x_{t-1}^{G^s}\right)^{\rho^{x^G}} \varepsilon_t^{x^G} ,$$

55 $$\tau_t^K = \left(\frac{pib_t}{\overline{pib}}\right)^{\psi^K} \left(\overline{\tau}^K\right)^{1-\rho^{z^{tk}}} \left(\frac{b_t}{\overline{b}}\right)^{\gamma^{tk}} \left(\tau_{t-1}^K\right)^{\rho^{z^{tk}}} \varepsilon_t^{z^{tk}} ,$$

56 $$\tau_t^L = \left(\frac{pib_t}{\overline{pib}}\right)^{\psi^L} \left(\overline{\tau}^L\right)^{1-\rho^{z^{tl}}} \left(\frac{b_t}{\overline{b}}\right)^{\gamma^L} \left(\tau_{t-1}^L\right)^{\rho^{z^{tl}}} \varepsilon_t^{z^{tl}} ,$$

57 $$\tau_t^c = \left(\frac{pib_t}{\overline{pib}}\right)^{\psi^c} \left(\overline{\tau}^c\right)^{1-\rho^{z^{tc}}} \left(\frac{b_t}{\overline{b}}\right)^{\gamma^c} \left(\tau_{t-1}^c\right)^{\rho^{z^{tc}}} \varepsilon_t^{z^{tc}} ,$$

where

58 $$pib_t = \frac{p_t^h}{p_t^c} y_t^{h^d} .$$

4.1.8 Rest of the World and Aggregate Restrictions

Price of imported goods follows PPP, where the relative price of an imported good in foreign currency $\frac{p_t^{f^*}}{p_t^*}$ is assumed exogenous

59 $$\frac{p_t^f}{p_t^c} = \frac{s_t p_t^*}{p_t^c} \frac{p_t^{f^*}}{p_t^*} .$$

Exports depend on global consumption

60 $$\exp_t = \left(\frac{\frac{p_t^h}{p_t^c}}{\frac{s_t p_t^*}{p_t^c}} \right)^{(-\mu)} c_t^* \cdot$$

The interest rate charged on foreign debt depends on the risk-free rate $\overline{i}^*$, a risk premium shock $z_t^{i^*}$, through which are transmitted the changes in international monetary policy, and the relative size of the stock of debt with respect to its long-term level $\left(b_t^*\right)$.

61 $$i_t^* = \overline{i}^* z_t^{i^*} + \varphi^b e^{\left(\left(b_t^* - \overline{b}^*\right) - 1\right)}$$

Nominal exchange rate variation is defined by the real exchange rate

62 $$\frac{\frac{s_t p_t^*}{p_t^c}}{\frac{s_{t-1} p_{t-1}^*}{p_{t-1}^c}} = \frac{\pi_t^* dev_t}{\pi_t^c} \cdot$$

Finally, a condition that guarantees the local production demand and supply is imposed.

63 $$y_t^{hd} = c_t^e + g_t + \exp_t + c_t^h + x_t^h \cdot$$

4.1.9 Exogenous Variables

64 $$z_t = \rho_z z_{t-1} + (1 - \rho_z) \log(\overline{z}) + \varepsilon_t^z \cdot$$

65 $$c_t^* = \rho^{c^*} c_{t-1}^* + \left(1 - \rho^{c^*}\right) \log\left(\overline{c}^*\right) + \varepsilon_t^{c^*} \cdot$$

66 $$z_t^{i^*} = \rho^{z^{i^*}} z_{t-1}^{i^*} + \varepsilon_t^{i^*} \cdot$$

67 $$\frac{p_t^{f^*}}{p_t^*} = \rho^{p^{f^*}} \frac{p_{t-1}^{f^*}}{p_{t-1}^*} + \left(1 - \rho^{p^{f^*}}\right) \log\left(\frac{\overline{p^{f^*}}}{p^*}\right) + \varepsilon^{p^{f^*}} \cdot$$

68 $$\pi_t^* = \rho^{\pi^*} \pi_{t-1}^* + \left(1 - \rho^{\pi^*}\right) \log\left(\overline{\pi}^*\right) + \varepsilon_t^{\pi^*} \cdot$$

4.1.10 Product Ratios and Definitions

The following are product ratios.

69 $$\Theta_{tax} = \frac{Tax_t}{pib_t}$$

70 $$\Theta_{tr_t^G} = \frac{tr_t^G}{pib_t}$$

71 $$\Theta_{g_t} = \frac{\frac{p_t^h}{p_t^c} g_t}{pib_t}$$

72 $$\Theta_{c_t^G} = \frac{\frac{p_t^h}{p_t^c} c_t^G}{pib_t}$$

73 $$\Theta_{x_t^G} = \frac{\frac{p_t^h}{p_t^c} x_t^G}{pib_t}$$

74 $$\Theta_{t_t^C} = \bar{\tau}^C \left(\frac{c_t}{pib_t} \right)$$

75 $$\Theta_{t_t^L} = \bar{\tau}^L \left(\frac{w_t n_t^d}{pib_t} \right)$$

76 $$\Theta_{t_t^K} = \bar{\tau}^K \left(\frac{r_t^k k_t}{pib_t} \right)$$

77 $$\Theta_{cr_t^{tot}} = \frac{cr_t^{tot}}{pib_t^{anual}}$$

78 $$\Theta_{d_t^{tot}} = \frac{d_t^{tot}}{pib_t^{anual}}$$

79 $$\Theta_{b_t} = \frac{b_t}{pib_t^{anual}}$$

4.2 Calibration and Estimation

The model calibration was done using historical information from the period 2000-2014, adjusting the parameters associated with the fiscal rule in order to adjust the government expenditure and investment. Also the local goods proportion in consumption and investment were used to adjust the total imports. The capital depreciation and the capital participation in the production function were needed to adjust total consumption and private investment. The amount of exports is an equilibrium outcome coherent with the amount of imports and foreign debt.

In the case of the government income and debt, the values are adjusted using the historical effective tax rates. In order to adjust the credit level and the bank spread, the firms, leverage and spread elasticity are used. The long-term value for the interest rate, inflation and unemployment are adjusted using the Central Bank inflation target, the discount factor and the elasticity of substitution of labor.

A preliminary estimation of the model is performed in order to find the parameters that affect the model dynamics. Among the estimated values are the wage and price rigidities, the persistence and variances to the shocks as well as the adjustment costs. In order to find these parameters the models uses the cyclical component of the logarithm of the quarterly series of output, private, government and total consumption, capital formation, exports, imports, local and foreign inflation, nominal interest rate and finally the world total output from 2000Q1 until 2014Q3. These are affected by a series of possible shocks that include shocks to government consumption, investment, government transfers, government consumption taxes, government capital taxes, government labor taxes, monetary policy, foreign inflation, foreign prices, international interest rate, foreign demand shock, productivity shock. Following we present the priors and posteriors obtained from the estimation process as well as the calibration results.

Table 4

ESTIMATION RESULTS

Parameters

	Prior mean	Pstdev	Post. mean	90% HPD interval		Mode	S.D.
ε_w	0.50	β 0.15	0.9127	0.8650	0.9580	0.9368	0.0234
ε_w	0.50	β 0.15	0.3451	0.2196	0.4519	0.3581	0.0690
ρ_s	0.50	β 0.15	0.4952	0.3787	0.6148	0.5005	0.0676
ρ_z	0.50	β 0.15	0.5531	0.4512	0.6812	0.5880	0.0597
ρ^{c^G}	0.50	β 0.15	0.9273	0.8808	0.9728	0.7566	0.0795
ρ^{c^*}	0.50	β 0.15	0.8290	0.7580	0.9061	0.8358	0.0466
$\rho^{z^{i^*}}$	0.50	β 0.15	0.7486	0.6799	0.8143	0.6771	0.0815
ρ^{π^*}	0.50	β 0.15	0.2821	0.1954	0.3989	0.0266	0.0144
$\rho^{p^{f^*}}$	0.50	β 0.15	0.9467	0.9206	0.9725	0.8833	0.0303
a	1.00	Γ 0.50	0.3311	0.2152	0.4370	0.3258	0.0748

Standard Deviation of the Shocks

Prior mean		Pstdev	Post.mean	90% HPD interval		Mode	S.D.
0.013	Γ^{-1}	Inf	0.0264	0.0207	0.0325	0.0217	0.0058
0.013	Γ^{-1}	Inf	0.0098	0.0066	0.0125	0.0094	0.0017
0.013	Γ^{-1}	Inf	0.0110	0.0080	0.0140	0.0106	0.0017
0.013	Γ^{-1}	Inf	0.0053	0.0045	0.0060	0.0051	0.0005
0.013	Γ^{-1}	Inf	0.0042	0.0031	0.0054	0.0048	0.0011
0.013	ε^{i^*}	Inf	0.0063	0.0029	0.0094	0.0535	0.0084
0.013	Γ^{-1}	Inf	0.0218	0.0166	0.0267	0.0217	0.0036

Table 5

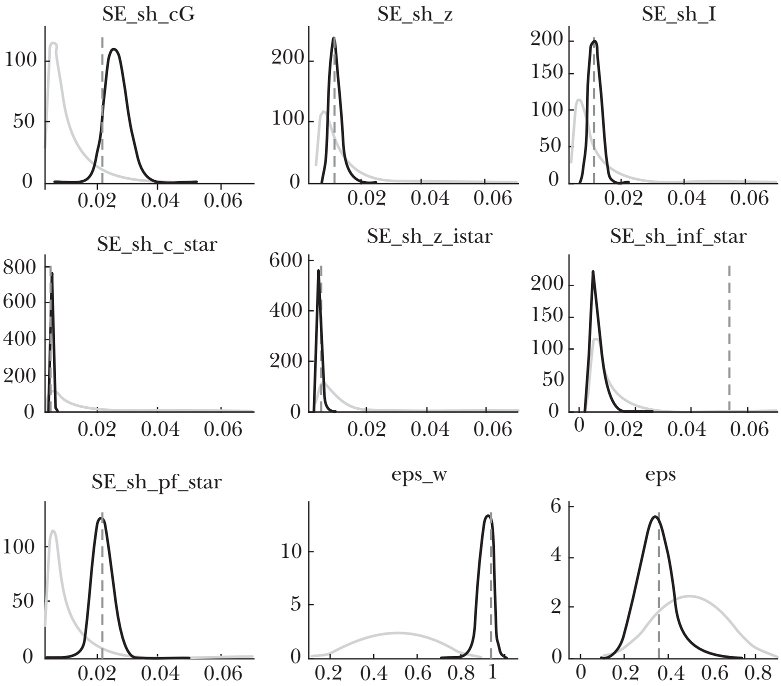
CALIBRATION RESULTS

Percentages

Aggregate demand	*Model*	*Data 2000-2014*
Household Consumption/GDP	58.34	
Entrepreneurs Consumption/GDP	6.52	
Total Consumption/GDP	64.86	66.16
Private Investment/GDP	12.78	15.59
Public Investment/GDP	4.48	4.48
Capital/GDP	7.10	
Ord. Govt. Expenditure/GDP	15.40	15.40
Total Govt. Expenditure/GDP	19.88	19.88
Imports Consumption/GDP	12.57	12.00
Imports Capital Goods/GDP	6.65	7.00
Total Imports	19.22	19.00
Total Exports	19.53	43.06
Trade Balance/GDP	0.31	
Foreign Debt/GDP	16.20	33.60
Government		
Consumption Taxes/GDP	6.46	6.38
Labor Taxes/GDP	3.95	3.95
Capital Taxes/GDP	1.58	1.58
Transfers/GDP	8.58	
Goverment Income/GDP	20.56	14.53
Government Primary Result/GDP	0.68	
Govt. Debt Service/GDP	0.68	
Central Govt. Debt/GDP	35.48	35.48
Financial sector		
Total Credit/GDP	1.80	41.80
Local Currency Credit/GDP	20.16	21.90
Foreign Currency Credit/GDP	21.64	19.90
Local Currency Deposits/GDP	0.16	20.15
Foreign Currency Deposits/GDP	5.44	5.44
Total Deposits/GDP	5.60	25.59
Leverage	1.60	2.11
Loan to Value	7.61	
Spread Loan Interest Rates	10.00	10.04

Figure 2

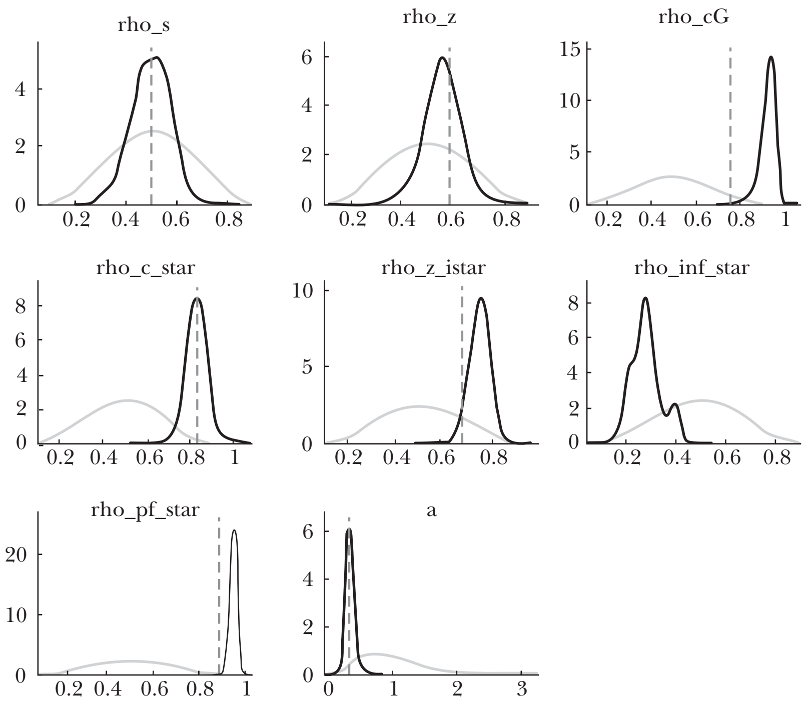
PRIORS AND POSTERIORS GRAPHS[1]



[1] Labels: sh_cG stands for government consumption shock; sh_z for productivity shock; sh_i for monetary policy shock; sh_c_star for foreign demand shock; sh_z_istar for sovereign risk shock; sh_inf_star for foreign inflation shock; sh_pf_star for foreign prices shock; eps_w for concentration coefficient for labor market; and eps for concentration coefficient for goods market.

Figure 2 (cont.)

PRIORS AND POSTERIORS GRAPHS[1]



[1] Labels: sh_cG stands for government consumption shock; sh_z for productivity shock; sh_i for monetary policy shock; sh_c_star for foreign demand shock; sh_z_istar for sovereign risk shock; sh_inf_star for foreign inflation shock; sh_pf_star for foreign prices shock; eps_w for concentration coefficient for labor market; and eps for concentration coefficient for goods market.

4.3 Impulse-response Analysis

This model allows evaluating the impact of unexpected shocks affecting the Costa Rican economy through the use of impulse response analysis. In this case the model shows the reaction over nine selected macroeconomic variables (consumption, GDP, unemployment, wages, investment, real exchange rate, monetary policy rate and inflation) from four different unexpected shocks to local and international interest rate, international inflation and finally international demand. This will allow us to evaluate the relative importance of the local monetary policy over the economy compared to the effect of the international monetary policy.

4.3.1 International Monetary Policy Shock

Figure 3 shows the responses of the variables to an unexpected increase in the international interest rate that a country faces either because of the external interest or the risk premium increase. First, consumption decreases and investment in the local economy too since it is more advantageous to just save in foreign currency. Second, and in contrast, GDP drops and employment grows since the shock leads a capital outflow that produces a depreciation in the real exchange rate (through the uncovered interest rate parity) that pushes exports. In addition, the rise in the depreciation of the currency is balanced with an increase in the domestic interest rate and the foreign debt.

The rise in income derived from the production of more exports does not overtake the reduction derived from consumption and domestic assets. Then, with lower levels of domestic savings and external funds, financing supply contracts while entrepreneurial fundamentals weaken increasing firms financing costs.

4.3.2 Local Monetary Policy Shock

Figure 4 shows the responses of the variables to an unexpected increase in the domestic interest rate, which has a contractive effect. Therefore it reduces consumption and investment. The reduction in consumption can be explained by the substitution effect between current and future consumption. The decrease in investment is due to the fact that now the price of capital is lower and therefore also discourages investing.

The total amount of savings of the economy rises even though there is a net contraction of the domestic assets because this reduction is less than the drop in the GDP.

Figure 3

IMPULSE RESPONSE SHOCK TO THE INTERNATIONAL MONETARY POLICY

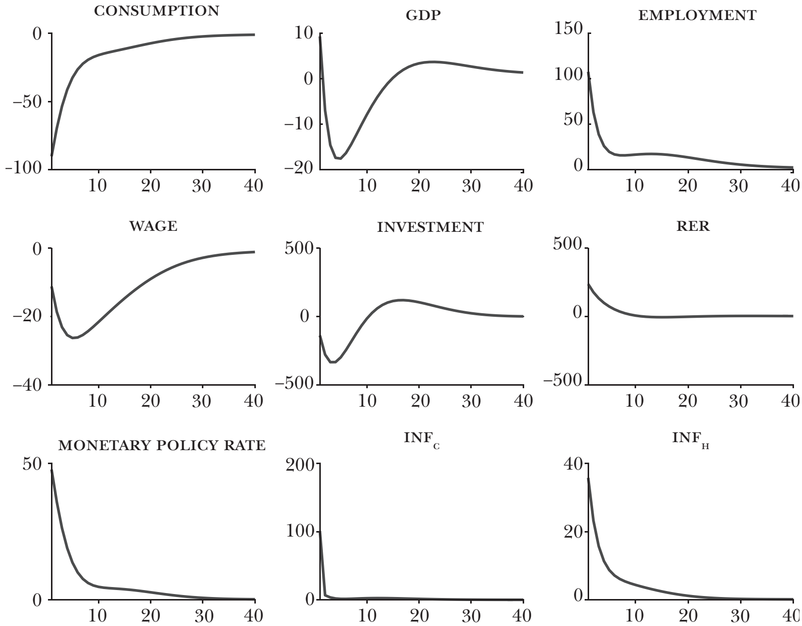
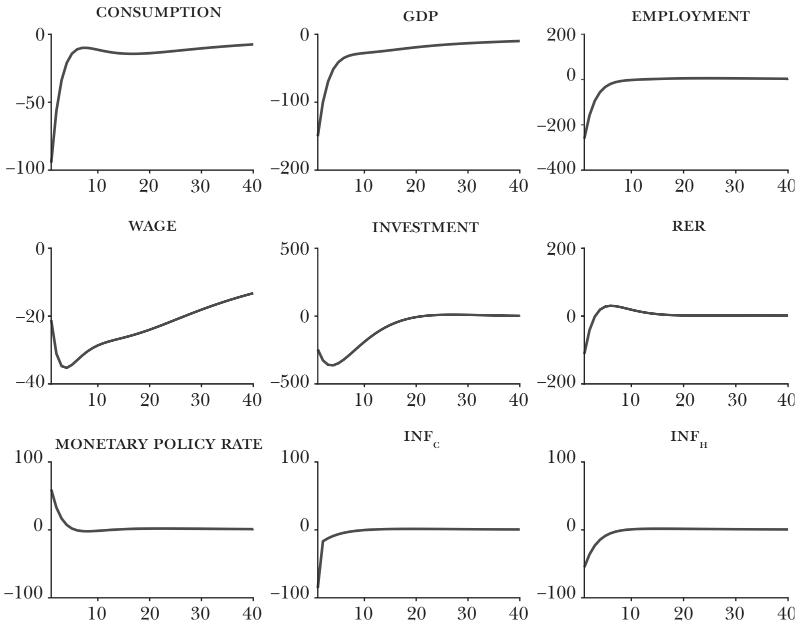


Figure 4

IMPULSE RESPONSE SHOCK TO LOCAL MONETARY POLICY



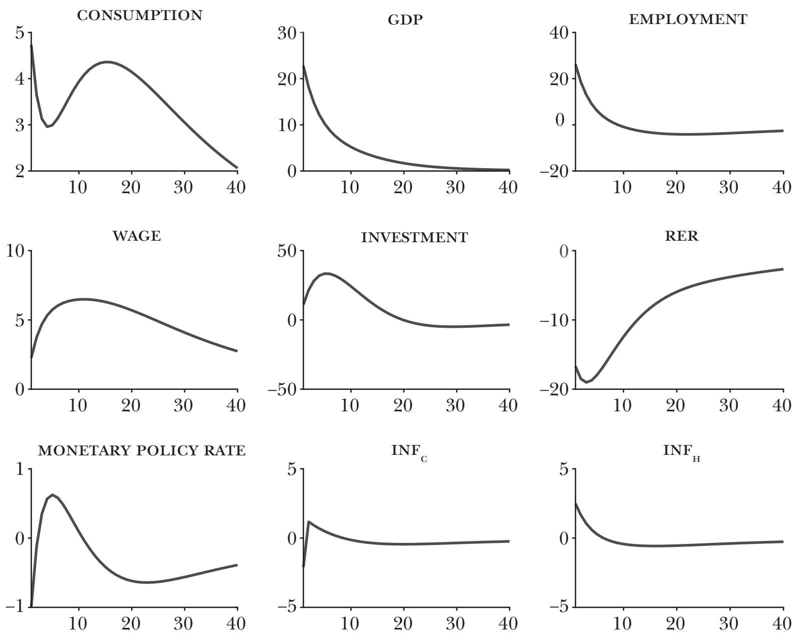
Net exports also suffer a reduction as a result of the real appreciation due to the interest rate differential. Consequently, with all these effects inflation is also lower.

4.3.3 International Demand Shock

Figure 5 shows the responses of the variables to an unexpected increase in the international demand. In this case, first, GDP grows and employment increases since foreign demand is stronger. Second, since the international interest rate has not increased yet, consumption and investment increase in the local economy at the time since it is more advantageous to save in local currency. Additionally, the real exchange rate decrease through the uncovered interest rate parity.

Figure 5

IMPULSE RESPONSE SHOCK TO INTERNATIONAL DEMAND

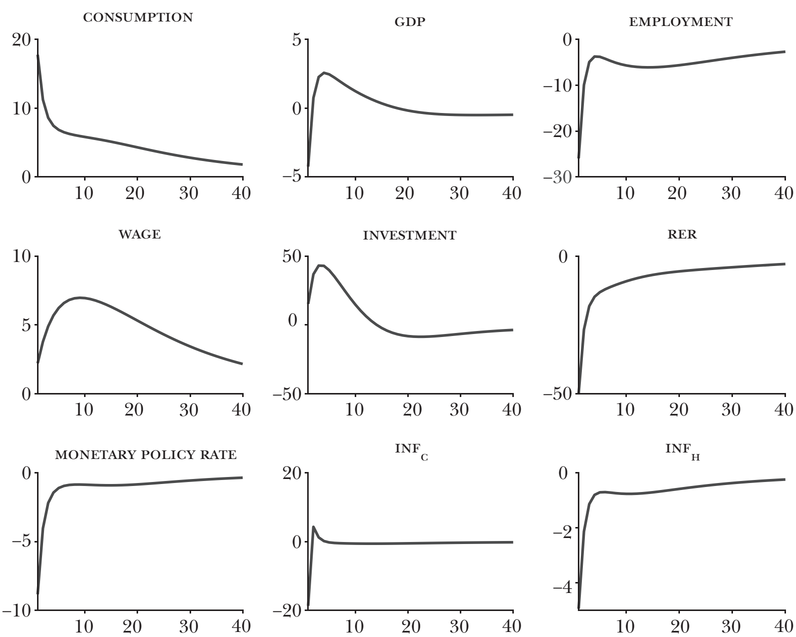


4.3.4 International Inflation Shock

Figure 6 shows the responses of the variables to an unexpected increase in the international inflation. In this case, the rise in the international inflation means that the international monetary policy rate increases and therefore the external demand will decrease so two seemingly contrary effects are observed. First, consumption increases and investment in the local economy too because of advantages to save in local currency. Second, and in contrast, GDP drops and unemployment grows since foreign demand is weaker.

Figure 6

IMPULSE RESPONSE SHOCK TO INTERNATIONAL INFLATION



Finally, it is important to mention that since this is a model that depicts a small open economy it needs to have the best possible integration of the financial system if not the effects from the international policy are just a consequence of the model selected and not of the characteristics of the economy, just like mentioned by Justiniano and Preston (2010). In this regard the model uses the international interest rate as the channel to link the international financial system to the local economy, where the financial system is allowed to take deposits and give loans in foreign currency as well as the households and entrepreneurs are able to take advantage of both choices, and therefore try to reduce the small open economy effect. Given the results from both models are consistent we can assert the actual importance of the international monetary policy over the Costa Rican economy.

5. CONCLUSION

This paper finds that the international monetary policy has a major effect on the Costa Rican economy which is consistent with Costa Rica being is a small open economy. Therefore external shocks play an important part in determining the dynamic of the economy. Given this result, the inflation target regime, as well as the flexible exchange rate provide important flexibility to absorb external shocks. All these was done using first a SBVAR model and then a DSGE formal approach where both allow learning which policies are actually the most important determinants of fluctuations in the Costa Rican economy.

Finally, the authors recognize that the model needs to be improved to integrate more sectors and characteristics of the Costa Rican economy in order to depict a better picture of the reality; however, we believe that the model is complete enough to show a good picture of the effects of the local and international monetary policies which is the objective of this paper.

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