The Business Cycle Fluctuation of Mexico: Based on the RBC Model

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Executive Summary

This study examines the business cycle fluctuations in Mexico's economy from 1993 to 2023. Our approach includes constructing two Real Business Cycle (RBC) models: one excluding and one including government expenditure. By focusing on key macroeconomic variables and the role of government expenditure, the analysis aims to provide insights into the cyclical dynamics of Mexico's economy. Calibration results indicate that while output, investment, TFP, and wages match the volatility observed in the data, consumption, working hours, and interest rates are less volatile than expected. The impulse response analysis reveals that a positive government expenditure shock initially reduces consumption and increases labor supply, leading to a temporary boost in output. Overall, this study enhances the understanding of Mexico's economic cycles and evaluates the RBC model's applicability in capturing the country's economic activity.

Keywords: Real Business Cycle, Mexico, Economic Fluctuation

1 Introduction

The analysis of business cycle fluctuations in national economies is an essential aspect of macroeconomic study, providing insights into the periods of expansion and contraction that characterize economic activity over time. This work focuses on the business cycle fluctuations of Mexico, the fifteenth largest economy globally. Utilizing the Real Business Cycle framework, this study aims to provide a detailed examination of the Mexican economy's cyclical dynamics, with a particular emphasis on the roles of government expenditure among other macroeconomic variables.

Mexico's economy, with its diverse sectors including manufacturing, services, and agriculture, presents an intriguing case for examining the implications of the RBC model against actual economic data. These sectors are intricately linked with a large informal economy, encompassing activities that are not regulated by the government and often escape official economic measurement. This sector plays a critical role in the Mexican economy, not only in terms of employment but also in its contribution to GDP. Understanding the influence of this informal sector is essential for a comprehensive analysis of the country's business cycles. Mexico has experienced various economic shocks and consequent macroeconomic policy, examples of these shocks are the peso crisis in 1994, the financial crisis in 2007-2008, and the COVID-19 crisis in 2020.

This study aims to analyse the business cycle fluctuations in Mexico from 1993 to 2023 using a RBC model. Central to our analysis is the construction and comparison of two distinct RBC models, one that excludes government expenditure and one that includes government expenditure. By calibrating these models with macroeconomic data, we seek to determine the accuracy and relevancy of the RBC model in reflecting Mexico's economic activity, providing valuable insights into the dynamics of its business cycles.

# 2   Data and Descriptive Analysis

2.1   Data

The dataset constructed for this project consist out of quarterly data from 1993 to 2023. The source, definition, and period are presented in Table 1.

Table 1: Variables Description

| Variable	Period	Definition	Source
Private Investment	1993-01-01 to 2023-07-01.	National Accounts: GDP by Expenditure: Current Prices: Gross Fixed Capital Formation, in Mexican Peso, Seasonally Adjusted.	FRED
Government Expenditure	1993-01-01 to 2023-07-01.	National Accounts: GDP by Expenditure: Constant Prices: Government Final Consumption Expenditure, in Mexican Peso. Seasonally Adjusted.	FRED
Labour Compensation	1993-01-01 to 2023-07-01	Constructed using average annual wage over hours worked. Monthly data, adjusted for quarter.	OECD & FRED
Hours Worked	2000-01-01 to 2022-10-01	Average Annual Hours Worked by Persons Engaged for Mexico, Annual data, adjusted for quarter. Not seasonally adjusted.	FRED
Private Consumption	1993-01-01 to 2023-07-01	National Accounts: GDP by Expenditure: Current Prices: Private Final Consumption Expenditure, in Mexican Peso, Seasonally Adjusted.	FRED
Short-term Interest Rate	1993-01-01 to 2023-07-01	Component series: Short-term interest rate: Original series. Monthly data, considered the quarter value. Percent, Not Seasonally Adjusted.	FRED
Unemployment Rate	1993-01-01 to 2023-07-01	Infra-Annual Labor Statistics: Unemployment Rate Total: 15 Years or over. Percent, Seasonally Adjusted.	FRED
Consumer Price Index (CPI)	1993-01-01 to 2023-07-01	Consumer Price Indices (CPIs), Consumer Price Index: Growth rate same period previous year, Quarterly, Not Seasonally Adjusted.	FRED
GDP	1993-01-01 to 2023-07-01	GDP, in Mexican Peso, Seasonally Adjusted.	FRED

2.2   Descriptive Analysis

To summarize the business cycle statistics, we first took logs of our variables and then computed the HP-filters, while using output per hour as a stand-in for TFP (denoted in figure 1). By taking this approach the absolute values of the macroeconomic variables matter less, and we can focus our comparison solely on the fluctuations of the business cycle. While this approach may not capture the full scope of the informal sector, its utility lies in minimizing the importance of absolute values, thus decreasing the influence of the informal sector in the data.
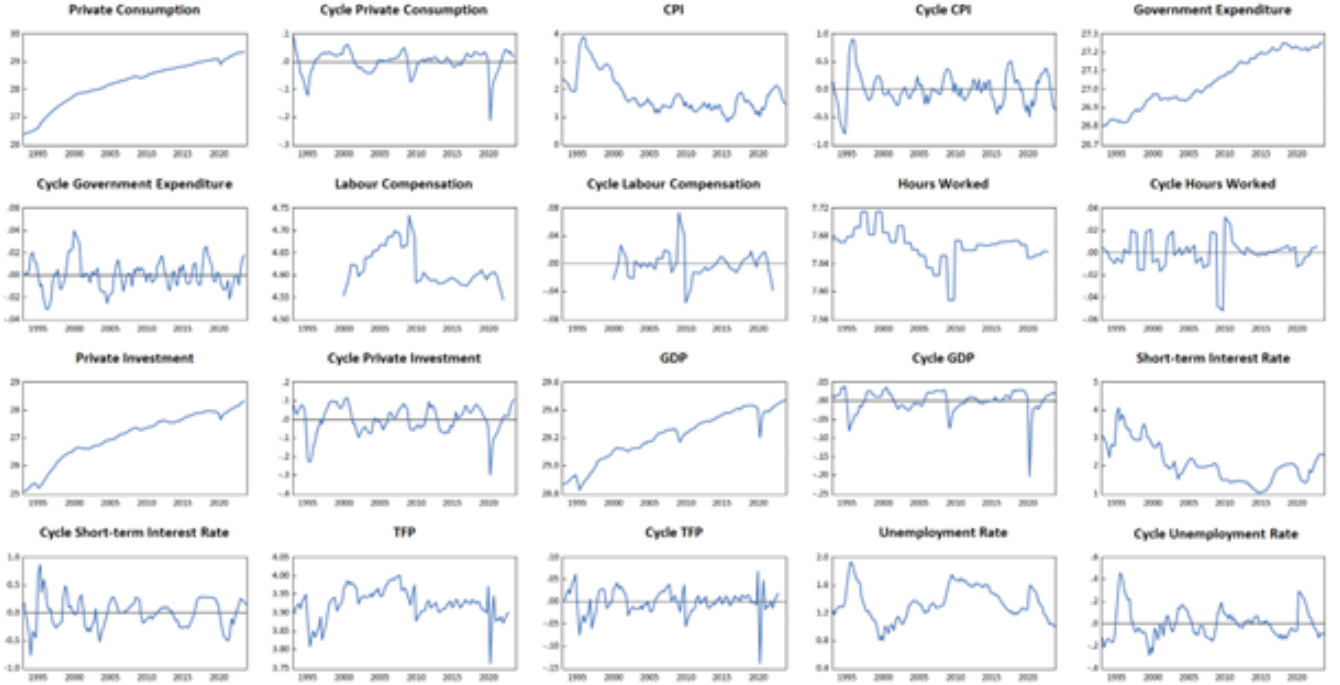
Figure 1: The levels and cycles of the macroeconomic variables in logs

Figure 2 shows that GDP and private consumption almost follow the same cyclical pattern, meaning that private consumption is procyclical. Private investment is also procyclical. Both variables fluctuate more than output, which can be seen during the peso crisis (1994/1995) where both variables are more negatively affected by the crisis than output. Furthermore, investment fluctuates more strongly than consumption especially noticeable between 2002 and 2015. In addition, there is not a clear pattern on which of the variables is leading or lagging. During the peso crisis consumption seems to be leading, while later the variables almost move at the same time. Contrarily, government expenditure does not follow a clear pattern. It would make sense for fiscal policy to be countercyclical to stimulate the economy in economic down turns and vice versa for an economic boom. However, the data does not clearly suggest this, it rather seems that during economic downturns the government expenditure also decreases. It should be noted that by combining various cycles in one graph (figure 2 to 5), the fluctuations of one variable could appear to be less. This is the case due to the difference in scaling between single graphs, because of that it is important while making conclusions to combine the insights from these figures with figure 1.
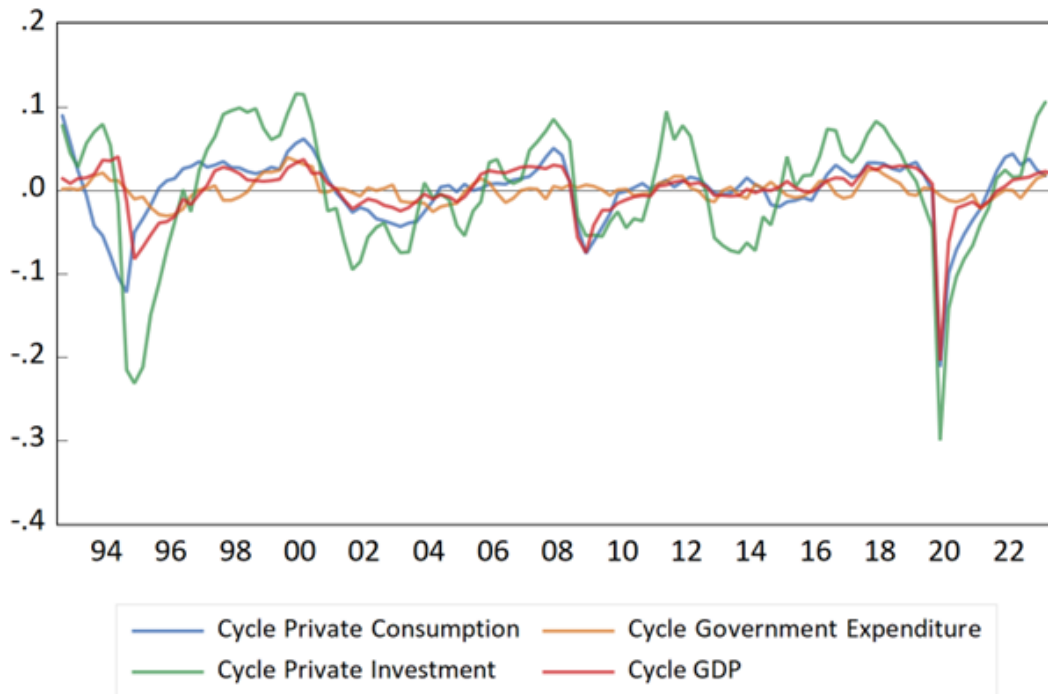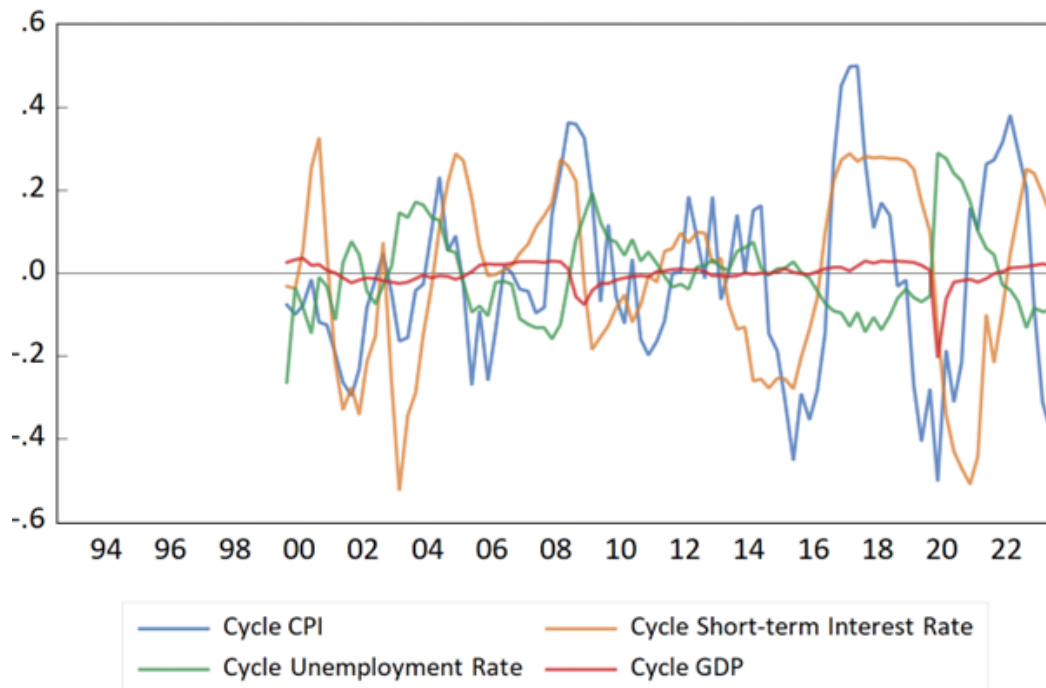
Figure 2: Cycles of the following variables in logs: Private Consumption, Government Expenditure, Private Investment, and GDP

Figure 3 reveals that there is a big outlier following the 1994 peso crisis. The figure could therefore give the wrong conclusions regarding cyclicality, as it seems that the CPI and the short term interest are countercyclical in that period. Because of that figure 4 shows the same cycles but without this outlier. The unemployment rate exhibits a clear countercyclical behaviour compared to GDP. By comparing the cyclicality of the short term interest rate and the CPI with GDP the conclusions are less obvious. It seems that the short term interest rate follows procyclical behaviour, this would make sense following standard central bank policies to raise interest rates to prevent the economy from overheating and lowering interest rates to encourage economic activity during a recession. Similar to the short term interest rates CPI also seems to follow a procyclical pattern. It is unclear which of these two variables is leading or lagging. In the beginnings of the 2000s they move almost at the same time with a slight lead for CPI, while from the financial crisis onwards the short term interest rate is leading until 2017/2018 when CPI starts leading. Both variables have stronger fluctuations than GDP, as they react more to booms and recessions.
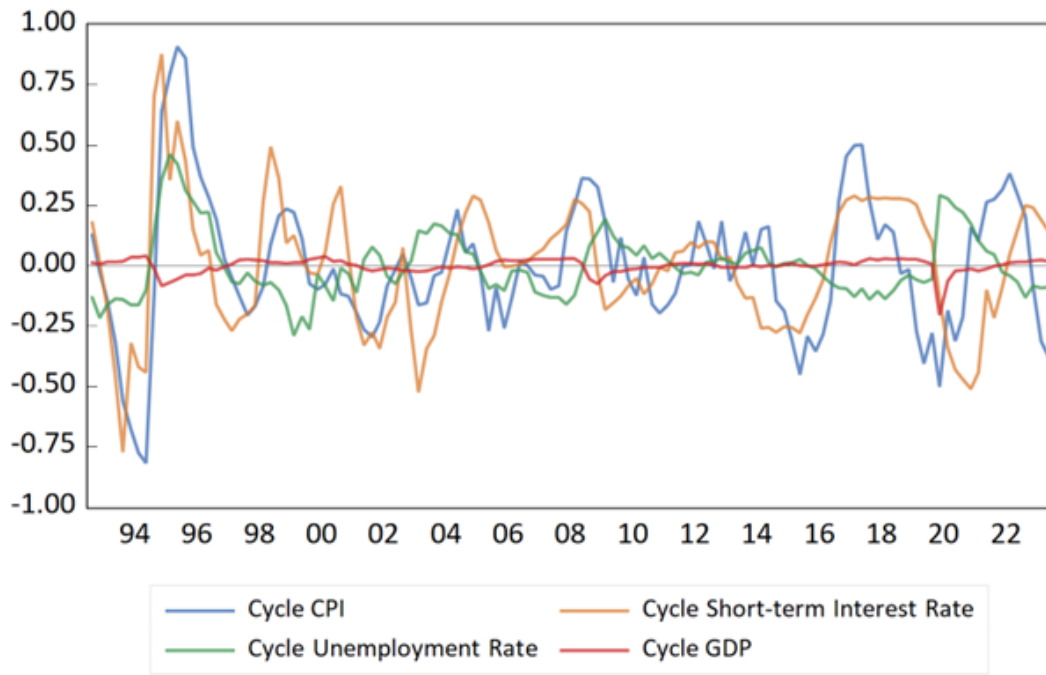
Figure 3: Cycles of the following variables in logs: CPI, the Short-term Interest Rate, the Unemployment Rate, and GDP
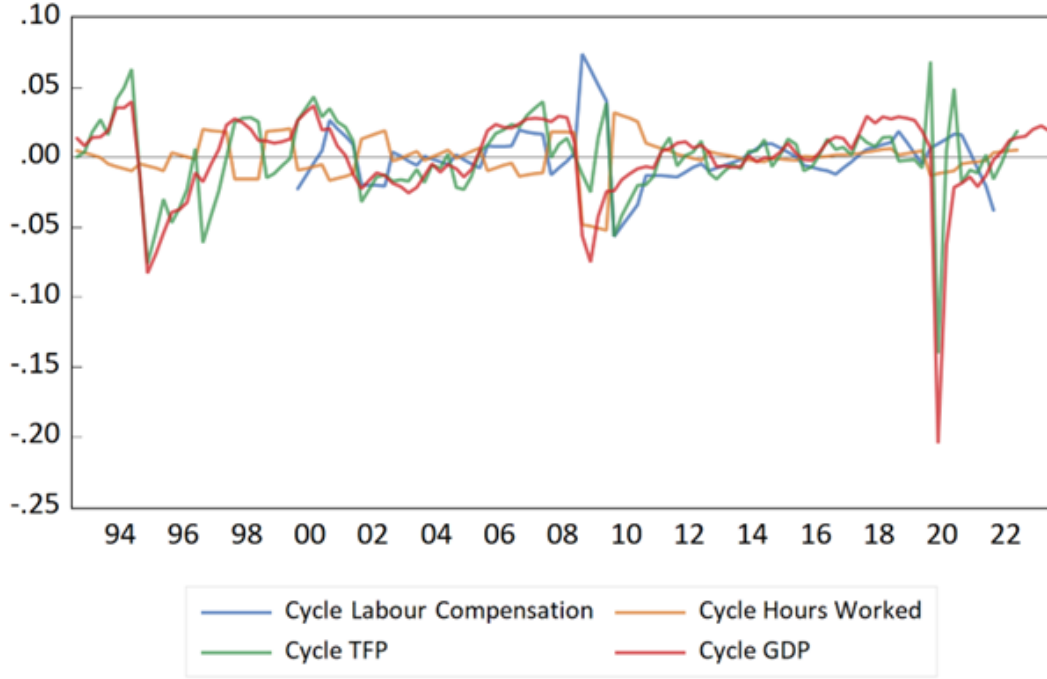

Figure 4: Cycles of the following variables in logs **excluding the pesos crisis**: CPI, the Short-term Interest Rate, the Unemployment Rate, and GDP

Figure 5 shows that both TFP and labour compensation are relatively strongly procyclical

compared to GDP, despite the outlier for the labour compensation during the financial crisis. Hours worked are also procyclical, but it is interesting to note that hours worked strongly reacted to the financial crisis, but less to the pandemic. The outlier of the financial crisis to hours worked and hourly wage suggests that lower skilled workers were laid off while higher paid workers kept their jobs, hence the increase in average hourly wage, but the decrease in hours worked.

Cooley & Prescott (1995) made an analysis for the US economy about standard business cycle statistics and characterized the results in some stylized facts. Following this approach we see that our variables behaved in a similar way:

- Government expenditure does not have a strong correlation with output.

- Private consumption and investment fluctuate more than output.

- Short term interest rates and the CPI slightly follow procyclical behavior.

- TFP (Total Factor Productivity) is procyclical.

- The unemployment rate is strongly countercyclical, while the average hours worked fluctuates less. Meaning that most fluctuations in total hours worked come from movements in and out of the workforce rather than adjustments in hours worked.

- Wages vary less than productivity.

Figure 5: Cycles of the following variables in logs: Labour Compensation, Hours Worked, TFP, and GDP

3 Model Framework

3.1 RBC model without government expenditure

In the decentralized RBC model, the representative household seeks to maximize expected utility over consumption and leisure. The utility function is given by:

$$U(C_t, H_t) = \frac{C_t^{1-\gamma}}{1-\gamma} - \phi\frac{H_t^{1+\eta}}{1+\eta} \tag{1}$$

where C_t represents consumption at time t, H_t denotes hours worked (or labor supply) at time t, γ is the coefficient of relative risk aversion, η is the Frisch elasticity of labor supply, and ϕ is a scale parameter that adjusts the disutility of labor.

The household's intertemporal optimization problem can thus be written as:

$$\max_{\{C_t, K_{t+1}, H_t\}} \mathbb{E}_0\left\{\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} - \phi\frac{H_t^{1+\eta}}{1+\eta}\right)\right\} \tag{2}$$

where β is the subjective discount factor, indicating the household's time preference.

The representative firm employs capital K_t and labor H_t in production, which is described by a Cobb-Douglas production function:

$$Y_t = K_t^\alpha (A_t H_t)^{1-\alpha} \tag{3}$$

where Y_t is the total output, A_t is a technology shock, and α represents the output elasticity of capital.

Firms aim to maximize profits given by the difference between total revenue and costs of production:

$$\Pi_t = Y_t - W_t H_t - R_t K_t \tag{4}$$

where W_t is the wage rate and R_t is the rental rate of capital.

In equilibrium, the markets for goods, labor, and capital clear. The clearings imply that all produced goods are either consumed or invested, all laborers looking for work at the prevailing wage are employed, and all capital available is rented out to firms. Equilibrium conditions also ensure that households and firms optimize given their budget and technological constraints, respectively.

3.2 RBC model with government expenditure

government expenditure introduces an additional layer of complexity to the Real Business Cycle (RBC) model. The representative household maximizes utility, which is a function of consumption, labor, and government expenditure:

$$\max_{\{C_t, K_{t+1}, H_t\}} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\gamma}}{1-\gamma} - \phi \frac{H_t^{1+\eta}}{1+\eta} + h(G_t) \right) \right\} \tag{5}$$

where $h(G_t)$ is a function that captures the utility from government expenditure G_t.

The government budget constraint and the goods market clearing condition in this extended model are given by:

$$C_t + K_{t+1} + T_t = W_t H_t + R_t K_t + \Pi_t + (1-\delta)K_t, \tag{6}$$

$$G_t = T_t, \tag{7}$$

where T_t represents taxes or transfers from the government, W_t is the wage rate, R_t is the rental rate of capital, Π_t denotes profits, and δ is the depreciation rate of capital. The government's spending G_t is financed through T_t, the taxes collected.

The evolution of government expenditure over time is described by the following $AR(1)$ stochastic process:

$$\ln G_t = (1 - \rho_g) \ln(\bar{g} Y^{ss}) + \rho_g \ln G_{t-1} + \epsilon_t^G, \tag{8}$$

where ρ_g is the autoregressive coefficient, $\bar{g}$ is the steady-state ratio of government expenditure to output, Y^{ss} is the steady-state output, and ϵ_t^G is the stochastic shock to government expenditure.

The Lagrangian is:

$$\Lambda_t = \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{C_t^{1-\gamma}}{1-\gamma} - \phi \frac{H_t^{1+\eta}}{1+\eta} + h(G_t) \right) - \lambda_t [C_t + K_{t+1} + G_t - W_t H_t - R_t K_t - \Pi_t - (1-\delta) K_t] \right] \right\} \tag{9}$$

$$\frac{\partial \Lambda_t}{\partial C_t} : C_t^{-\gamma} = \lambda_t \tag{10}$$

$$\frac{\partial \Lambda_t}{\partial K_{t+1}} : \beta^t \lambda_t = \mathbb{E}_t \left\{ \beta^{t+1} \lambda_{t+1} (R_{t+1} + (1-\delta)) \right\} \tag{11}$$

$$\frac{\partial \Lambda_t}{\partial H_t} : \phi H_t^{\eta} = \lambda_t W_t \tag{12}$$

The Euler equation holds:

$$C_t^{-\gamma} = \mathbb{E}_t \left\{ \beta C_{t+1}^{-\gamma} (R_{t+1} + (1-\delta)) \right\} \tag{13}$$

The optimal labor supply:

$$\phi H_t^{\eta} = C_t^{-\gamma} W_t \tag{14}$$

The other parts of this problem are the same as the RBC model without government expenditure. Therefore we can write the solution to the model as follows:

$$C_t^{-\gamma} = \mathbb{E}_t \left\{ \beta C_{t+1}^{-\gamma} \left(\alpha K_{t+1}^{\alpha-1} (A_{t+1} H_{t+1})^{1-\alpha} + (1-\delta) \right) \right\} \tag{15}$$

$$\phi H_t^{\eta} = C_t^{-\gamma} (1-\alpha) K_t^{\alpha} A_t^{1-\alpha} H_t^{-\alpha} \tag{16}$$

$$C_t + K_{t+1} + T_t = Y_t + (1-\delta) K_t \tag{17}$$

$$G_t = T_t \tag{18}$$

$$Y_t = (A_t H_t)^{1-\alpha} K_t^{\alpha} \tag{19}$$

$$I_t = K_{t+1} - (1-\delta) K_t \tag{20}$$

$$\ln A_{t+1} = (1-\rho)\mu + \rho \ln A_t + \epsilon_{t+1} \tag{21}$$

$$\ln G_t = (1 - \rho_g) \ln(\bar{g} Y^{ss}) + \rho_g \ln G_{t-1} + \epsilon_t^G, \tag{22}$$

$$R_t = \alpha K_t^{\alpha-1} (A_t H_t)^{1-\alpha} \tag{23}$$

$$W_t = (1 - \alpha) K_t^{\alpha} A_t^{1-\alpha} H_t^{-\alpha} \tag{24}$$

4 Calibration

4.1 RBC model without government expenditure

In this part, we calibrate the RBC model without government expenditure to the data. We calibrate $\sigma_a = 0.0185$ to fit the standard deviation of TFP in the data. The ACR(1) in the data is very low, to match this we should set ρ to a very low value. However, if we follow this approach private investment and hours worked will see a significant decrease in their ACR(1) values, which consequently results in large deviations from the data. Because of that we sacrificed not being able to match the ACR(1) of TFP with that of the data. The results of calibration are shown in Table 2. Table 3 and Table 4 show the results of the comparison in standard deviation in percentage, auto-regressive conditional root (lags 1) and correlation, respectively.

Table 2: Calibrated Model Parameters

Parameters	Values	Description
β	0.99	discount factor
α	0.33	curvature of production function
δ	0.074	depreciation rate
ρ	0.8	persistence parameter on shocks for TFP
γ	2	coefficient of risk aversion
σ_a	0.0185	standard deviation of shocks for TFP
ϕ	30	scaling parameter of labor supply
η	0.5	inverse elasticity of labor supply

Table 3: Std.% and ACR(1)

	Y	C	I	H	TFP	w	r
				Data			
Std. %	2.89	3.35	5.81	1.45	2.41	1.00	1.46
ACR(1)	0.47	0.63	0.74	0.59	0.03	0.92	0.81
				Model			
Std. %	2.03	0.60	5.85	0.84	2.24	1.41	0.18
ACR(1)	0.64	0.83	0.61	0.62	0.63	0.74	0.62

Table 4: Correlation Matrix

	Y	C	I	H	TFP	w	r
				Data			
Y	1						
C	0.92	1					
I	0.80	0.79	1				
H	0.27	0.36	0.17	1			
TFP	0.70	0.52	0.53	-0.30	1		
w	0.04	-0.03	-0.04	-0.24	0.20	1	
r	0.35	0.47	0.47	-0.01	0.21	0.20	1
				Model			
Y	1						
C	0.82	1					
I	0.99	0.73	1				
H	0.83	0.36	0.91	1			
TFP	0.99	0.78	0.99	0.86	1		
w	0.94	0.96	0.89	0.61	0.93	1	
r	0.84	0.38	0.91	0.99	0.87	0.62	1

In our model, output, investment, TFP and wage approximately match the level of volatility in the data. However, consumption, working hours and interest rates are not volatile enough. Interestingly consumption is more volatile than output in the data, but our model fails to conclude this. For developed countries, it is rather normal that output is more volatile than consumption. As Mexico is still a developing country, this deviation could be rationalized by financial frictions or shortcomings of the model.

As for correlations between different variables, the model implies a positive co-movement between hours and the other aggregates. The model also indicates a strong co-movement between prices and quantities, which is absent in the data.

4.2   RBC model with government expenditure

In this part, we calibrate the RBC model with government expenditure to the data. We use an inverse Frish-elasticity of labor supply of $\eta = 0.5$. We calibrate $\rho = 0.8$ and $\sigma_a = 0.0185$ to fit the standard deviation of TFP. Again as in the model without government expenditure we did not match the ACR(1) value for TFP with the data. Similarly, we calibrate $\rho_g = 0.81$ and $\sigma_g = 0.00745$ to fit the standard deviation of government expenditure in the data. The whole result of calibration is shown in Table 5. Table 6 and Table 7 show the results of the comparison in standard deviation in percentage, auto-regressive conditional root (lags 1) and correlation, respectively.

Table 5: Calibrated Model Parameters

Parameters	Values	Description
β	0.99	discount factor
α	0.33	curvature of production function
δ	0.074	depreciation rate
ρ	0.8	persistence parameter on shocks for TFP
ρ_g	0.81	persistence parameter on shocks for government expenditure
γ	2	coefficient of risk aversion
σ_a	0.0185	standard deviation of shocks for TFP
σ_g	0.00745	standard deviation of shocks for government expenditure
$\bar{g}$	0.11	steady state government expenditure percentage
ϕ	30	scaling parameter of labor supply
η	0.5	inverse elasticity of labor supply

Table 6: Std.% and ACR(1)

	Y	C	I	H	TFP	w	r	G
				Data				
Std. %	2.89	3.35	5.81	1.45	2.41	1.00	1.46	0.97
ACR(1)	0.47	0.63	0.74	0.59	0.03	0.92	0.81	0.63
				Model				
Std. %	1.98	0.63	5.80	0.80	2.41	1.43	0.18	0.97
ACR(1)	0.64	0.82	0.61	0.63	0.63	0.73	0.61	0.63

Table 7: Correlation Matrix

	Y	C	I	H	TFP	w	r	G
					Data			
Y	1							
C	0.92	1						
I	0.80	0.79	1					
H	0.27	0.36	0.17	1				
TFP	0.70	0.52	0.53	-0.30	1			
w	0.04	-0.03	-0.04	-0.24	0.20	1		
r	0.35	0.47	0.47	-0.01	0.21	0.20	1	
G	0.20	0.15	0.34	-0.04	0.15	0.04	0.24	1
					Model			
Y	1							
C	0.82	1						
I	0.99	0.73	1					
H	0.80	0.30	0.87	1				
TFP	1	0.80	1	0.82	1			
w	0.94	0.96	0.89	0.55	0.93	1		
r	0.84	0.37	0.90	0.99	0.86	0.61	1	
G	0.02	-0.04	-0.02	0.07	0	-0.01	0.02	1

In our model, output, investment, TFP, wage and government expenditure approximately match the level of volatility in the data. However, consumption, working hours and interest rates are not volatile enough. Similarly to the model without government expenditure, output is less volatile than consumption in the data, but in our model this is not the case. The data also shows a very low autocorrelation for TFP, but the autocorrelation for TFP is much higher in the model.

As for correlations between different variables, the model implies a positive co-movement between hours and the other aggregates. The model also indicates a strong co-movement between prices and quantities, which is absent in the data. Furthermore, the correlation between govern-

ment expenditure and TFP is zero, which differs from the data.

4.3   Impulse Response Functions

The impulse response functions presented in Figures 6 and 7 provide a comprehensive overview of the simultaneous reactions of the macroeconomic variables following a positive government expenditure shock. The RBC model with government expenditure follows the Ricardian Equivalence theory of government expenditure. The theory suggests that whether a government finances its spending with debt or taxes, the effect on the overall economy is the same. This is because consumers anticipate that government debt will need to be repaid with future taxes. This suggests that through higher taxes private consumption is crowded out. As consumption decreases initially, hours worked increases. Consequently, the interest rate increases by less. Due to the increase in labour supply (hours worked), the wage rate goes down initially. After the initial drop hours worked start to go down back to its steady state, hence the wage rate starts to adjust upwards to its steady state. After the shock, output spikes upwards, meaning that government expenditure has a positive effect on production. This effect diminishes over time in a similar fashion as government expenditure. The sharp fall in investment suggests that government expenditure crowds out private investment, possibly because of higher interest rates or because the firms expect less profitable investment opportunities after the shock. Because of less investment, capital will also go down over time. However, when investment is almost back to its steady state value, there is a shift and capital will start to increase again.
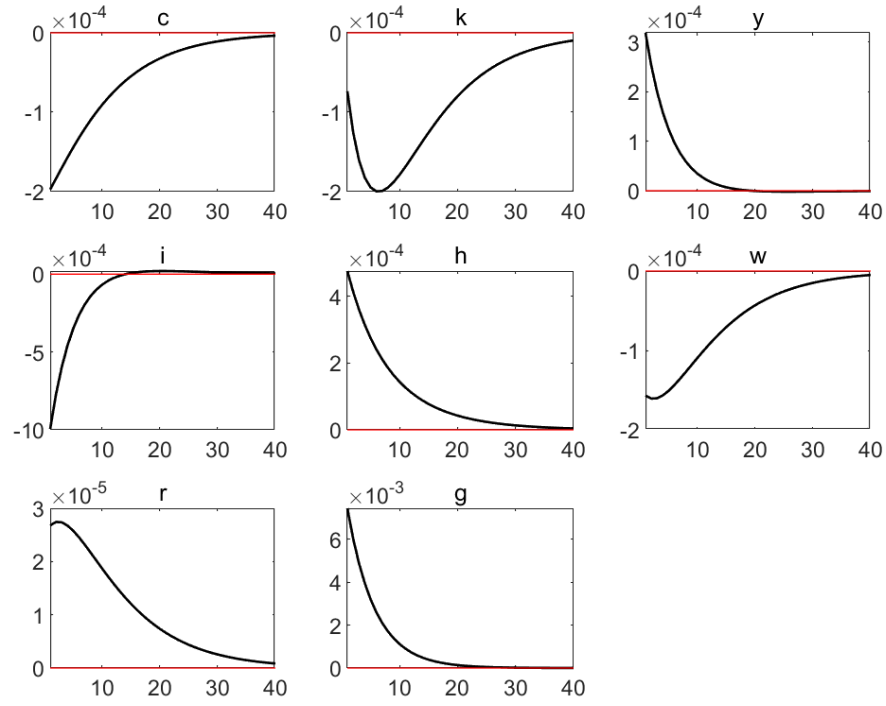
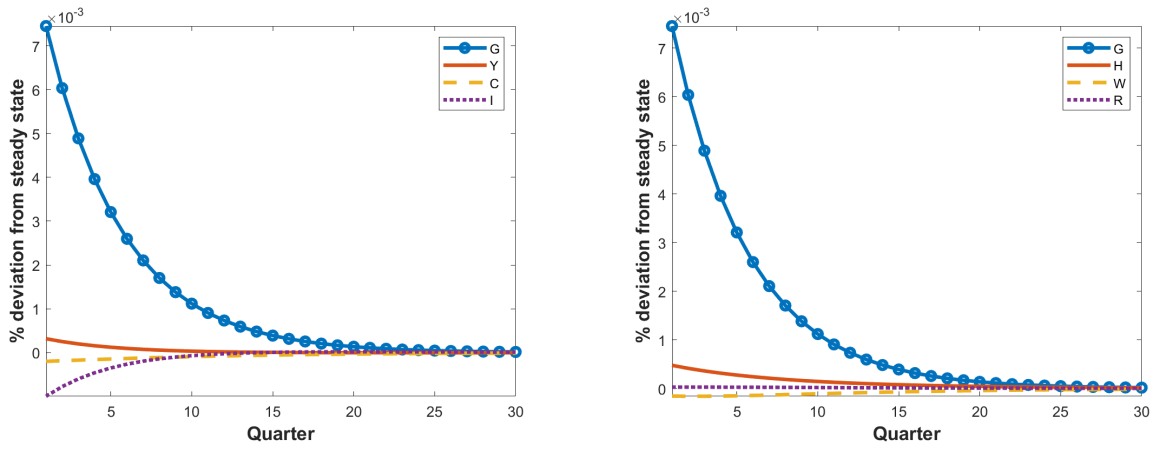Figure 6: Impulse response diagrams for government expenditure

Figure 7: Impulse response diagrams for G

5 Conclusion

In this study, we analyzed the business cycle fluctuations of Mexico's economy from 1993 to 2023 using the Real Business Cycle (RBC) framework. To summarise the business cycle statistics, we utilized logs and HP filters to reduce the influence of absolute values effectively, and consequently the informal sector. We observed that private consumption and investment are notably procyclical, experiencing larger fluctuations compared to overall output. Interestingly, government expenditure does not exhibit a clear cyclical pattern.

In our calibration analysis of the RBC models, both with and without government expenditure, we adjusted the standard deviations in shocks from Total Factor Productivity (TFP) and government expenditure to align with their respective standard deviation values. This calibration showed that variables such as output, investment, TFP, wages, and government expenditure closely matched the volatility observed in the data. However, we also identified mismatches between the observed data and model predictions for consumption, working hours, and interest rates. Our model especially found it hard to explain that consumption is more volatile than output in the data. These discrepancies underscore the need for further refinement of our models to capture the complexities and interactions of Mexico's economy more precisely.

The impulse response analysis provided additional insights, revealing that shocks in government expenditure initially reduce consumption and increase labour supply. This results in a corresponding increase in output and an initial decrease in the wage rate. Additionally, while government expenditure boosts output temporarily, this effect diminishes as all variables go back to their steady states. Government expenditure also appears to crowd out private investment.

Overall, our study offers a nuanced understanding of Mexico's economic cycles, contributing to the evaluation of the accuracy and relevance of the RBC model in representing Mexico's economic activity. It provides valuable insights into the dynamics of its business cycles and emphasizes the importance of refining economic models and policies to more effectively manage the interplay of various sectors within the economy.

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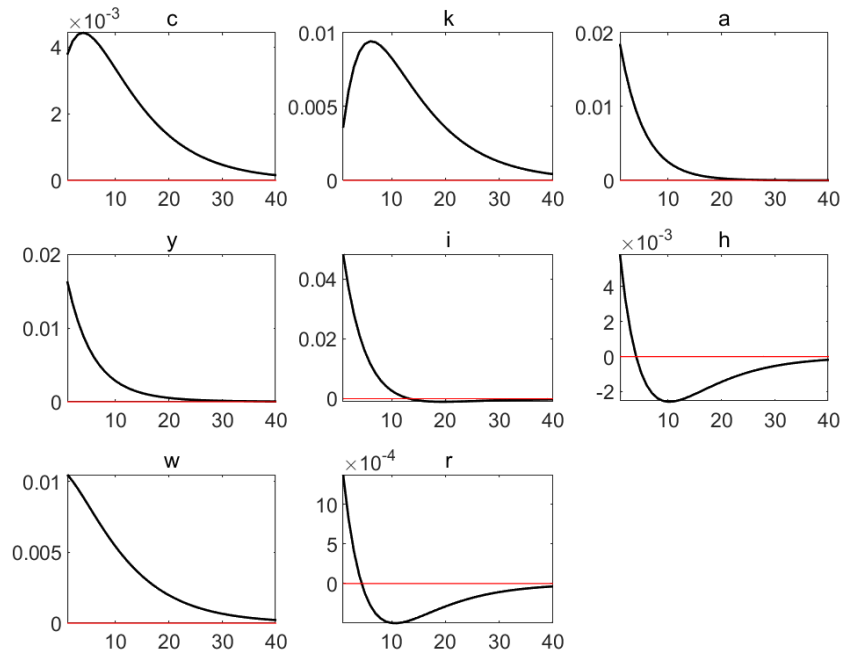
A   Appendix 1

Figure 8: Impulse response diagrams for TFP