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THE RIGHT FIT FOR THE WRONG REASONS: REAL BUSINESS CYCLE IN AN OIL-DEPENDENT ECONOMY*

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Venezuela has an oil-dependent economy subject to large exogenous shocks and a rigid labor market. These features go straight to the heart of two weaknesses of real business cycle (RBC) theory widely reported in the literature: neither shocks are volatile enough nor real salaries sufficiently flexible as required by the RBC framework to replicate the behavior of the economy. We calibrate a basic RBC model and compare a set of relevant statistics from RBC-simulated time series with actual data for Venezuela and the benchmark case of the United States (1950–2008). Despite Venezuela being a heavily regulated economy, RBC-simulated series provide a good fit, in particular with regard to labor markets.

JEL classifications: E10, E32, O47, O54, Q32

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1. Introduction

The theory of business cycles studies the causes leading to and consequences resulting from recurrent expansions and contractions in aggregate economic activity. The idea that a few equations can have the power to replicate means, volatilities, relative volatilities, auto-correlations, and cross-correlations observed in time series of real macroeconomic data is highly appealing and has motivated a significant number of authors since the seminal contributions of Kydland and Prescott (1982) and Long and Plosser (1983). Real business cycle (RBC) theory assumes that these periodic fluctuations are caused primarily by real factors. It has become ever less ambitious and nowadays does not aspire to explain why business cycles exist, but rather to assess and interpret the movements and co-movements of real variables along the cycle.

Most of the empirical evidence in support or denial of RBC models is focused on OECD countries, which are supposed to be fully functioning

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market economies with appropriate institutional and policy settings. Our purpose here is somewhat the opposite: we set ourselves to study how an RBC model would fare in explaining historical data moments for Venezuela, which throughout most of the sample period (1950–2008) has been a highly regulated economy, with strong government intervention, stiff labor markets, and unsteady political and institutional framework.[1] There have been many papers using RBC models to assess the impacts of oil shocks in oil-importing countries (Kose *et al.*, 2003; Benczur and Ratfai, 2005; Kilian, 2006), but to our knowledge, this is the first attempt at using the basic RBC framework to understand the cycles in an oil-exporting country. Our interest has been spurred by a number of economic reasons.

The use of Solow residuals as a proxy for exogenous technology shocks has been a permanent source of criticism for RBC models. In order to approximate movements and co-movements of historical data, the RBC needs to be fed with large, persistent, and volatile technological shocks. This solution is unappealing, as Summers (1986) emphasized, since to simulate a recession you would need an implausible degree and frequency of technological regress (negative exogenous technology shocks).

As it turns out, the Venezuelan economy is indeed affected by large, frequent, volatile, and exogenous shocks: oil prices. The oil sector of the economy is an enclave that represents an average of 30 of gross domestic product (GDP)[2] and 1.2 of employment, while providing 85 of exports.[3] As the country does not have a stabilization fund and fiscal policy is highly pro-cyclical, oil shocks are transmitted and even amplified to the rest of the economy (see Hausmann *et al.*, 1996; Erbil, 2011), becoming the driving force behind the business cycle (Korhonen and Mehrotra, 2009). As exogenous oil shocks are normally not matched by corresponding variations in capital or labor, they tend to be gathered in the Solow residuals (Finn, 1995).

A second critique made of RBC models has to do with simulated real wages being far too pro-cyclical relative to those observed in real data. King and Rebelo (2000), using quarterly data for the United States for the period 1947–1996, reported that simulated standard deviation

1. Within our 57-year sample, there are two distinct periods: one going from 1950 to the early 1970s, where free-market policies and relatively low state intervention prevailed; and a longer period from then onwards characterized by state-driven interventionism and stiff regulations.

2. Measured at 2007 constant prices.

3. All these figures correspond to averages over the simple period (1950–2008).

of employment relative to output is half the observed values (0.99 as compared to simulated 0.48).[4] On the other hand, simulated standard deviation of real wages relative to output is substantially larger than the observed one (0.38 in real data as compared to simulated 0.54). That is to say that, in contrast to observed time series, the RBC model has an internal mechanism of adjustment for labor markets that relies less on quantities (workers) and more on prices (real wages).

The Venezuelan labor market has particular features that make it appealing from a RBC perspective. As reported by the World Bank[5] and a number of studies (see, for instance, Alayon *et al.*, 2002), for the previous 40 years Venezuela has had one of the most rigid and distorted labor regulations in the world, with high relative firing costs, widespread minimum salary, and more recently, forbidden dismissal below certain salary thresholds.[6] Within that framework, the market response to shocks in demand has been adjusting real salaries by means of large swings in inflation. As a result, the cyclical component of wages is much more volatile and (positively) correlated with output than in the United States. The flip side of that coin is that as quantitative labor restrictions prevent a number of workers from adjusting to shocks, employment tends to be much less volatile and correlated with output (less pro-cyclical). As both features (high real wage volatility and low employment volatility) run along the patterns of RBC-simulated time series, the model is able to provide a better match of real observed labor market data.

There are two significant implications of these results in terms of the model and policy. With regard to the former, the extreme conditions that facilitate an unlikely good fit for Venezuela question the validity of the standard RBC framework in more parsimonious economies. Total factor productivity does not suffer frequent exogenous shocks of the oil-price type, nor do real wages exhibit cyclical volatilities as high as that of GDP. From a policy standpoint, our results are a warning against the effectiveness of job-protection policies. High dismissal costs, widespread minimum salary, and outright restrictions to outplacements might end up leading to highly volatile real wages. In developing countries with widespread financial constraints and few

4. Sims (2012) has also stressed this point.

5. See www.doingbusness.org.

6. See Presidential Decree 639, published in Official Gazette 40.310, extending the labor immobility law proclaimed in 2003, yet for another year (2014).

other means to smooth consumption, the net welfare effects of such policies are questionable, at the very least.

The paper is organized as follows. Section two derives total factor productivity from a growth accounting exercise for Venezuela and the benchmark case of the United States for the period 1950–2008. Section three provides some stylized facts and actual statistics of real business cycle for both countries. Section four introduces the standard RBC model and derives its equilibrium conditions. Section five is devoted to calibration. In section six, relevant statistics coming out of the simulation for both countries are presented and contrasted with observed data. Here, we also provide some conjectures on the potential sources of differences in the performance of the RBC model for both economies. Conclusions, implications, and policy recommendations are presented in section seven.

2. Growth accounting

In order to identify the productivity shocks that will be later input into the RBC model, we calculated Solow residuals from a growth accounting exercise. We depart from a Cobb-Douglas aggregate production function:

$$y_t = a_t k_t^{\alpha} n_t^{(1-\alpha)}, \tag{1}$$

where y_t stands for aggregate output, k_t for net non-residential capital stock, n_t for labor input, and α is the capital share of output. Taking logs on both sides and clearing out technology leads to:

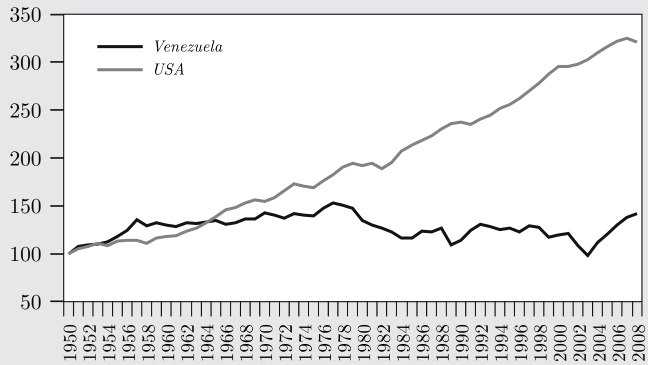
$$\ln a_t = \ln y_t - \alpha \ln k_t - (1 - \alpha) \ln n_t \tag{2}$$

All the data for Venezuela has been taken from the Venezuelan Central Bank and Baptista (2011). Capital stocks have been built using the perpetual inventory method. The average capital share of output used is 43.2 (average 1950–2008), which is not far from the 40 that Gollin (2002) estimated for Venezuela in his seminal paper on income shares for Latin America. In the case of the United States, data for gross domestic product (GDP) and non-residential capital stock were obtained from the Bureau of Economic Analysis (BEA), whereas data for the labor input comes from the Federal Reserve Bank of St. Louis. The capital share of output used was 0.33, as elsewhere in the literature (Gertler and Karadi, 2011; Sims, 2012; Gertler and Kyiotaki, 2012).

Over the sample period (1950–2008), the income gap between Venezuela and United States widened considerably. Assuming that both countries started at the same place (1950 = 100), by 2008 Venezuela income per capita would have been just 44.1 of that of the United States, as reported in Figure 1.[7]

Figure 1. GDP per capita: Venezuela and USA

(1950 = 100)



Sources: Venezuela Central Bank, Baptista (2011), Bureau of Economic Analysis, author's own calculations.

We can differentiate two distinct periods in the evolution of Venezuelan GDP. While GDP per capita expanded 1.1 per year (34.5 in total) in the 27 years between 1950–1977, it collapsed by -0.2 per year (7.2 in total) on the following 31 years (1977–2008). One of the most spectacular cases of economic growth turned into a colossal growth failure.

A growth accounting exercise helps in identifying the sources behind the dismal differences in growth performance in these periods. We have

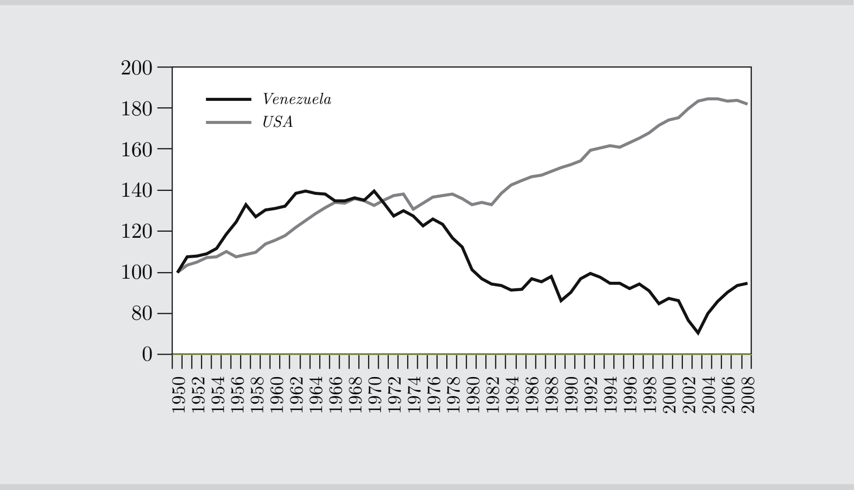
7. The Venezuelan income per capita by 1950 was estimated by Bello, Blyde, and Restuccia (2011) to be 66 that of the United States. Taking into account that it widened 55.9 over the next 58 years, the resulting Venezuelan income per capita would be 29 of that of the United States by 2008. This figure is consistent with the one reported by Penn World Tables (26) and the World Bank (28) for that year.

done this exercise using workers, total hours, and hours per worker as a proxy for the labor input.[8] While these methods portray growth evolution from different perspectives, they yield very similar average total factor productivity and almost identical total factor productivity shocks.

As we can see from Figure 2, total factor productivity accounts for most of the income gap between the United States and Venezuela. Assuming again that both countries started at the same level, by 2008 the difference in income based solely on differential total factor productivity would have been 48. These results are in line with those reported for both countries by Cole *et al.* (2005) in their study of Latin America and also with those estimated by Calcavanti *et al.* (2012) for Venezuela.

Figure 2. Total factor productivity: Venezuela and USA

(1950 = 100)



Sources: Venezuela Central Bank, Baptista (2011), Bureau of Economic Analysis, author's own calculations.

Table 1 below contains growth accounting results in total GDP and contribution to GDP per hour worked, for both countries and divided into the sub-periods mentioned above. We can see that from 1950 to 1977, the contribution of total factor productivity in Venezuela was lower than in the United States (0.84 vs. 1.21).

8. Data for average hours per worker has been obtained from the University of Groningen, Growth and Development Center Conference Board, Total Economy Database at http://ggdc.net.

Table 1. Growth accounting: Venezuela and USA, 1950–2008

(average percentage change year on year)

	Venezuela 1950-2008		USA 1950-2008	
	Growth rate/hour	Contribution to growth/hour	Growth rate/hour	Contribution to growth/hour
Gross domestic product per hour	0.43	0.43	1.62	1.62
Non-res capital stock per hour	0.96	0.42	1.72	0.57
Total factor productivity		0.02		1.05
	1950-1977		1950-1977	
	Growth rate/hour	Contribution to growth/hour	Growth rate/hour	Contribution to growth/hour
Gross domestic product per hour	1.99	1.99	1.92	1.92
Non-res capital stock per hour	2.67	1.16	2.14	0.71
Total factor productivity		0.84		1.21
	1977-2008		1977-2008	
	Growth rate/hour	Contribution to growth/hour	Growth rate/hour	Contribution to growth/hour
Gross domestic product per hour	-0.92	-0.92	1.37	1.37
Non-res capital stock per hour	-0.53	-0.23	1.36	0.45
Total factor productivity		-0.69		0.92

Sources: Venezuela Central Bank, Baptista (2011), Bureau of Economic Analysis, University of Groningen Total Economy Database, and author's own calculations.

For the second sub-period (1977–2008), the contribution of total factor productivity per hour was not only lower than that of the United States, but highly negative (-0.69). This loss, coupled with a fall in the stock of non-residential capital per hour worked (-0.23), led to a compounded annual rate of growth of -0.92. In these 31 years, Venezuela lost 24.9 of its income per unit of labor. Table 1 also provides conclusive evidence indicating that poor total factor productivity was the driving force behind the income gap reported in Figure 1.[9] These results are consistent with those of Bosworth and Collins (2008) and Loayza *et al.* (2005).

3. Stylized facts of the Venezuelan business cycle

We have calculated a number of relevant business cycle statistics for Venezuela and the benchmark case of the United States using HP-filtered annual series for the period 1950–2008.[10, 11] All series are expressed in logs, with the exception of the rental rate, and in real terms. The purpose is to get acquainted with the particularities of the business cycle in Venezuela, while providing a benchmark to gauge the effectiveness of the RBC model in replicating actual data. The calibration for the latter follows the same guidelines and yields similar results obtained by King and Rebelo (2000) for 1948–1997 using quarterly data.

3.1 Venezuela

Most of the data used come from the national accounts of the Venezuelan Central Bank and Baptista (2011). The only statistic from a different source is average hours per worker, which was taken from the Total Economy Database of the University of Groningen. As Venezuela lacks a fully functioning and representative stock market, estimates for the annual rental rate have been obtained by dividing the share of output going to capital into the stock of non-residential capital. This ex-post

9. Appendix I contains a growth accounting exercise for the oil and non-oil sectors of the Venezuelan economy. The results suggest that the massive decrease in total factor productivity was most prominent in the oil sector, presumably driven by declining yields within oil fields forcing the investment of more capital to maintain production.

10. We stick to the convention of using parameter $\lambda = 100$ for annual data.

11. We have used the Baxter-King filter as an alternative. The results do not differ significantly from those reported here using the Hodrick-Prescott filter. Results are available from the author upon request.

indicator has at least two shortcomings that have been pointed out in the literature. First, given that the rental rate is determined *ex-ante*, this approach does not incorporate the effects of expectations (Stock and Watson, 1998). Second, using the capital share of output results in implausibly high returns on physical capital (Bergoing *et al.*, 2002). We may neglect the latter, since our interest here does not involve levels but rather cyclical variations. As for the former, it is not so much a matter of convenience, but rather one of availability. Results are reported in Table 2.

Table 2. Real business cycle statistics for the Venezuelan economy

1950-2008

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	5.08	1.00	0.53	1.00
Consumption	5.88	1.16	0.66	0.76
Investment	18.73	3.69	0.59	0.82
Employment	1.98	0.39	0.50	0.44
Labor productivity	4.57	0.90	0.57	0.92
Real wages	5.91	1.16	0.58	0.69
Real rental rate	1.32	0.26	0.44	0.50
TFP	4.36	0.86	0.53	0.93

Source: Author's own calculations based on data published by the Venezuelan Central Bank.

The first and second columns contain absolute and relative volatilities, with the volatility of the cyclical component of output being the reference variable. The volatility of TFP shocks (standard deviation 4.36) is amplified at the level of investment (18.73), real wages (5.91), consumption (5.88), output (5.08), and labor productivity (4.57). In contrast, cyclical variations on the rental rate (1.32) and most notably employment (1.98) are significantly lower and do not amplify TFP shocks.

Most of the remaining figures in Table 2 are reasonable (i.e., investment much more volatile than output, rental rates much less), so we will focus on two noteworthy and exceptional facts. Having consumption more volatile than output (relative standard deviation 1.16) goes against all economic rationale. One would expect that had consumers decided not to smooth consumption at all (either for undesirability, lack of financial depth, or a combination), the worst scenario possible would be having consumption as equally volatile as output. But it is hard to imagine why rational agents would have their consumption fluctuating more than output.[12]

The second interesting feature lies in labor markets. The rigidities that prevent the market from adjusting to shocks via quantities (high relative firing costs, widespread minimum salary, and forbidden dismissal below certain salary levels) have driven employment volatility well below that of output (0.39); while real salaries display a high relative volatility (1.16). That is to say that extreme restrictions within the labor market have put the burden of adjustment on real salaries, as opposed to quantities, a feature that mirrors well the internal adjustment dynamics of RBC models.

Annual time series do not display a high degree of persistence, as measured by first-order autocorrelations (third column). TFP shocks (0.53) do propagate at the consumption (0.66), investment (0.59), real wages (0.58), and labor productivity (0.57) levels, but not when it comes to output (0.53), employment (0.50), or rental rate (0.44).

Finally, most of the time series analyzed tend to move together with the cyclical component of output, as portrayed by the cross-correlations in column four. All variables exhibit pro-cyclical behavior, as they all tend to correlate positively with output, although at different levels of intensity. Labor productivity seems to move together with TFP shocks, both being highly correlated with output (0.92 and 0.93 respectively). This is also the case of investment (0.82), consumption (0.76), and real wages (0.69). The variables with lower correlation to output are the rental rate of capital (0.50) and employment (0.44).

3.2 United States

We have calculated a similar set of real business cycle statistics for the benchmark case of the United States. As in the case of Venezuela, all series are expressed in logs, with the exception of the rental rate, and in real terms. All time series have been obtained from the Federal Reserve Bank of Saint Louis and expressed either

12. Appendix B aims to replicate Table 2 for the non-oil sector. The resulting volatility of the cyclical component of consumption is slightly lower than that of output (0.99), suggesting that the 1.16 reported here might be distorted by the existence of oil. One possible explanation is that total GDP is a composite of a highly volatile non-oil output and a relatively steady oil production. Such an economy is subject to shocks coming from large swings in oil prices, which impact the demand-side of the non-oil economy but are squeezed out of the system without exerting much of a multiplying effect (i.e., via capital flight).

in constant 2009 US$ (output, consumption, investment) or in 2009-based real indexes (total hours, wages). Total hours and wages have been approximated by total hours in the non-farm business sector, as reported also by the Federal Reserve Bank of Saint Louis. We have run the calculations using different index years for the same labor aggregates calculated by the Bureau of Labor Statistics and found no significant difference in the set of selected second moments. The rental rate comes from the annual deflated return of the S&P 500 Index. Summary statistics for the selected real business cycle variables are reported in Table 3.

Table 3. Real business cycle statistics for the United States

(Cyclical variations in real returns using S&P 500 as a proxy for rental rate)

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	2.04	1.00	0.48	1.00
Consumption	1.74	0.86	0.58	0.82
Investment	6.21	3.05	0.55	0.77
Employment	2.28	1.12	0.50	0.86
Labor productivity	1.18	0.58	0.59	0.07
Real wages	1.24	0.61	0.57	0.25
Real rental rate	16.52	8.12	-0.16	-0.25
TFP	1.57	0.77	0.54	0.57

Source: Author's own calculations based on data published by the Federal Reserve Bank of Saint Louis and Reuters.

A comparison between standard deviation statistics provides some preliminary insights. Output, consumption, investment, labor productivity, and TFPs, unsurprisingly, display a much lower volatility that ranges between a third and a half of that registered in Venezuela for the same aggregates. In the labor market, however, the differences are striking. Average volatility of employment in the United States is 1.2 times that of Venezuela (2.28 vs. 1.98), while volatility of real wages is just 0.2 (1.24 vs. 5.91). The high volatility displayed by the rental rate can be attributed to the indicator used (cyclical component of real S&P 500 returns).[13] We will return to this point later. By comparing standard deviations on column one of Table 3 we can also verify

13. King and Rebelo (2000) used the rental rate provided by Stock and Watson (1998), who created a real rental rate based on vector auto-regressive (VAR) inflation expectations.

that TFP shocks (1.57) amplify output (2.04), consumption (1.74), investment (6.21), employment (2.28), and rental rate (16.52), but not labor productivity (1.18) or real wages (1.24).

All relative volatilities, autocorrelations, and cross-correlations are aligned with those obtained by King and Rebelo (2000) using quarterly data for the period 1947–1996. The cyclical component of consumption is less volatile than output (0.86), while investment turns out to be three times as volatile as output (3.05). Employment results more volatile than output (1.12), as opposed to labor productivity (0.58) and wages (0.41).

All auto-correlations are in the order of 0.45–0.60, with the sole exception of rental rate, whose cyclical component displays negative auto-correlation (-0.16).[14] TFP shock propagation is weak, with all the correlations in the vicinity of the one registered by TFP shocks (0.54). Most of the variables are pro-cyclical, with employment (0.86), consumption (0.82), investment (0.77), and TFP shocks (0.57) being those most correlated with output. Real wages (0.25) and labor productivity (0.08) display low correlations to output, with the latter being very close to acyclic.

The counter-cyclicality of the rental rate of capital (-0.25) in the United States has already been mentioned in the literature and remains a puzzle today, despite numerous efforts to reconcile it with the theory of business cycles (see Kydland and Prescott, 1990; Cooley, 1995; Mertens, 2005; Di Cecio, 2005; and Mertens, 2010). Using the cyclical component of S&P 500 returns as a proxy results in a highly volatile and negatively auto-correlated rental rate, two unlikely features of the marginal product of capital. In order to ease the comparisons between cycle moments in these two countries, we have re-estimated Table 3 using a proxy for the rental rate obtained in a similar way to the case of Venezuela: capital share of output divided into the stock of non-residential capital. As can be seen in Table 4, such a procedure results in rental rates that co-move along with output, similar to Venezuela, although the correlation is lower (0.25 vs. 0.70).

14. As expected, the autocorrelation orders are lower than those reported by King and Rebelo (2000) using quarterly data.

Table 4. Real business cycle statistics for the United States

(Rental rate as capital share of output into stock of non-residential capital)

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	2.04	1.00	0.48	1.00
Consumption	1.74	0.86	0.58	0.82
Investment	6.21	3.05	0.55	0.77
Employment	2.28	1.12	0.50	0.86
Labor productivity	1.18	0.58	0.59	0.07
Real wages	1.24	0.41	0.57	0.25
Real rental rate	0.48	0.24	0.54	0.67
TFP	1.57	0.77	0.54	0.57

Source: Author's own calculations based on data published by the Federal Reserve Bank of Saint Louis.

4. Standard RBC model

In this section, we outline the formulation and equilibrium conditions of a standard frictionless RBC model.

4.1 Preferences

There are only two representative agents: households and firms. Households consume, save (by investing in capital and renting it to firms), and supply labor. Firms produce only one good by combining capital and labor.

The economy is populated by a large number of identical and infinitely lived agents who maximize expected utility given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t), \tag{3}$$

where β denotes the discount factor, c_t is consumption, and l_t represents leisure. We assume the standard properties of the utility function hold: utility is increasing in both arguments, jointly concave in consumption and leisure, and satisfies the Inada conditions.

4.2 Endowments

Individuals' main endowment is time, which can be split into hours of work (n_t) and leisure (l_t). For simplicity, the total amount of time is normalized to one, which yields the following time constraint:

$$l_t = 1 - n_t \tag{4}$$

All output must be either consumed or invested domestically, as formalized by the aggregate resource constraint:

$$y_t = c_t + i_t \tag{5}$$

4.3 Technology

The standard unit of output is produced by a large number of identical firms. The representative firm combines capital and labor inputs with constant returns to scale (CRS), according to a standard Cobb-Douglas function:

$$y_t = a_t k_t^{\alpha} n_t^{(1-\alpha)}, \tag{6}$$

where a_t is a random total factor productivity shock whose law of motion follows a mean-zero AR(1) process, in logs:

$$\ln a_t = \rho \ln a_{t-1} + \varepsilon_t , \tag{7}$$

for $\varepsilon_t \sim i.i.d.\ N\,(0,\sigma_\varepsilon^2)$. Also, we assume the standard properties of the production function, i.e., production is increasing and concave on both factors. The law of motion of capital stock is then:

$$k_{t+1} = (1 - \delta)\ k_t + i_t , \tag{8}$$

where δ denotes the annual depreciation rate.

Based on this formulation, general equilibrium conditions can be computed. The representative household maximizes utility over consumption and leisure subject to its budget constraints, and the representative firm maximizes profits. By equalizing supply and demand for capital and labor, we obtain our market-clearing prices w_t (real wages) and R_t (real rental rate of capital). A representative firm decides how much capital and labor to employ by solving:

$$\max_{k_t n_t} \; a_t k_t^{\alpha} n_t^{1-\alpha} - R_t k_t - w_t n_t \tag{9}$$

This optimization problem yields real wage and rental rate equations:

$$w_t = (1-\alpha) a_t k_t^{\alpha} n_t^{-\alpha}, \tag{10}$$

and

$$R_t = \alpha \; a_t k_t^{\alpha-1} n_t^{1-\alpha} \tag{11}$$

Given the functional form $u(c_t, n_t) = ln\ c_t + \theta ln\ (1 - n_t)$, the representative household decides how much to consume and supply labor by solving

$$\max_{\{C_t, n_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln c_t + \theta \ln(1-n_t)\right], \tag{12}$$

subject to

$$k_{t+1} = (1-\delta)k_t + w_t n_t + R_t k_t - c_t \tag{13}$$

Equilibrium in this model can be described by a system of non-linear stochastic differencial equations and some auxiliary equations:

$$\frac{1}{c_t} = \beta^t E_t \left\{ \frac{1}{c_{t+1}} \left[\alpha \cdot a_{t+1} k_{t+1}^{\alpha-1} n_{t+1}^{1-\alpha} + (1-\delta)\right]\right\} \tag{14}$$

$$\frac{\theta}{1-n_t} = \frac{1}{c_t}(1-\alpha)a_t k_t^{\alpha} n_t^{-\alpha} \tag{15}$$

$$k_{t+1} = a_t k_t^{\alpha} n_t^{1-\alpha} - c_t + (1-\delta)k_t \tag{16}$$

$$\ln a_t = \rho \ln a_{t-1} + \varepsilon_t \tag{17}$$

$$y_t = a_t k_t^{\alpha} n_t^{1-\alpha} \tag{18}$$

$$y_t = c_t + i_t \tag{19}$$

$$w_t = (1-\alpha) a_t k_t^{\alpha} n_t^{-\alpha} \tag{20}$$

$$R_t = \alpha a_t k_t^{\alpha-1} n_t^{1-\alpha} \tag{21}$$

5. CALIBRATION

We have calibrated the model's parameters for Venezuela and the United States. In most cases, the proxies for parameters come from observed, long-term features of the time series we are modeling. Only in a couple of cases have we relied on highly conventional parameters widely used in RBC theory for the United States.

The *discount factor* β was calibrated using the Euler equation for a risk-free bond:

$$\frac{1}{c_t} = \beta E_t \frac{1}{c_{t+1}}(1+r_{t+1}),$$

which, when evaluated in steady state,[15] implies:

$$\beta = \frac{1}{1+r} \tag{22}$$

15. Variables without time subscripts denote steady-state levels.

β has been calibrated so that the steady-state interest rate coincides with average return to capital. In the case of Venezuela, we have used average real returns on capital for the economy as a whole ($r = 13.98$ per year) as reported in Baptista (2011), which results in $\beta = 0.8773$. For the United States, following the convention of the literature (see Lucas, 1980; Kydland and Prescott, 1982; Long and Plosser, 1983; King and Rebelo, 2000), we computed average real returns on the Standard and Poor 500 Equity Index over the analyzed period (1950–2008), which resulted in $r = 6.27/year$, and $\beta = 0.9401$.

Average depreciation rate was derived from historical time series data on depreciation expense and capital stock provided by Baptista (2011), resulting in 4.61 per year. For the United States, we have performed a similar calculation using the data provided by the Federal Reserve Bank of Saint Louis, resulting in yearly depreciation of 5.67. The latter figure is close to that used by Levy (1995, $\delta = 5.2$), Stokey and Rebelo (1995, $\delta = 6.0$), and Nadiri and Prucha (1996, $\delta = 5.9$).

We have used the *capital share on total output* for the economy ($\alpha = 0.432$) from our growth accounting exercise. For the United States, we relied on a parameter ($\alpha = 0.333$) widely used elsewhere in the literature.

We calibrated the *utility parameter of leisure* (θ) solving the Euler equation for the steady-state capital-labor ratio:

$$\frac{k}{n} = \left(\frac{\alpha}{\frac{1}{\beta} - (1-\delta)} \right)^{\frac{1}{(1-\alpha)}}, \tag{23}$$

where we can plug calibrated values for α, β, and δ to calculate the steady-state capital-labor ratios. From here, we just need to solve the law of motion of capital for the steady-state consumption per worker:

$$\frac{c}{n} = \left(\frac{k}{n} \right)^{\alpha} - \delta \frac{k}{n} \tag{24}$$

Then, we solve the first-order condition for labor supply and obtain another expression for consumption per worker:

$$\frac{c}{n} = \frac{1}{\theta}\frac{1-n}{n}(1-\alpha)\left(\frac{k}{n}\right)^{\alpha} \tag{25}$$

Equating (24= to (25) leads to:

$$\left(\frac{k}{n}\right)^{\alpha} - \delta\frac{k}{n} = \frac{1}{\theta}\frac{1-n}{n}(1-\alpha)\left(\frac{k}{n}\right)^{\alpha}, \tag{26}$$

and solving for θ (taking n as given) we obtain:

$$\theta = \frac{\frac{1-n}{n}(1-\alpha)}{1-\delta\left(\frac{k}{n}\right)^{(1-\alpha)}} \tag{27}$$

We have estimated θ so that n matches the long-run average time devoted to work, as reported by the Total Economy Database of the University of Groningen for the United States (21.4) and Venezuela (22.6). This exercise results in $\theta = 2.90$ for the United States and $\theta = 2.68$ for Venezuela. In any case, the results reported below are not contingent on these assumptions, as changes of θ within the [2,4] range do not produce any significant impact on RBC simulations (see King and Rebelo, 2000).

Finally, we calibrated parameters associated to TFP by using evidence from inside the model. We de-trended TFP series by regressing:

$$\ln\widehat{a}_t = \phi_0 + \phi_1 t_t + u_t\,, \tag{28}$$

and then use the estimated residuals $\hat{u}t$ as a measure of de-trended TFP series and estimate an AR(1) process:

$$\hat{u} = \rho\hat{u}_{t-1} + e_t\,, \tag{29}$$

where $\hat{p}$ and $\widehat{\sigma}_e$ may be taken as proxies for the autocorrelation coefficient of technology and standard deviation of the innovations of Solow residuals. This yields a calibration of $\hat{p} = 0.9098$ for Venezuela and $\hat{p} = 0.8966$ for the United States. The associated standard deviations are $\sigma_e = 0.0454$ for Venezuela and $\sigma_e = 0.0161$ for the United States.

According to these estimations, the persistence of TFP shocks is similar in both countries, but Venezuela turns out to be three times as volatile as the United States. That is precisely one of the shortcomings of the RBC models calibrated for the United States: shocks are persistent, but they do not exhibit enough volatility to explain the business cycle (Summers, 1986). And that is where the Venezuelan case, with oil shocks gathered on Solow residuals, may be a better candidate for RBC predicaments. Table 5 summarizes the result from calibration.

Table 5. Calibrated parameters of the baseline model

Parameter	Description	Venezuela	United States
β	Discount factor	0.8773	0.9400
α	Capital share of output	0.4325	0.3333
δ	Annual depreciation rate	0.0761	0.0567
θ	Utility parameter of leisure	2.6784	2.9041
ρ	Autocorrelation Solow residuals	0.9098	0.8966
σ	Standard deviation of innovations of Solow residuals	0.0454	0.0161

6. RBC-simulated business cycle statistics

One way to assess the capacity of RBC time series to mirror the actual behavior of the economy during the business cycle is to contrast relevant second moments for simulated and real data. Table 6 below contains standard deviations (absolute and relative), autocorrelations, and cross-correlations with output for a number of real variables, as derived from a RBC-standard model calibrated for the Venezuelan economy. We can gather successes and failures by comparing these statistics with those reported in Table 2 for actual data.

Although the model's output is more volatile than the actual experience (8.22 vs. 5.08), RBC simulated series do remarkably well in predicting relative volatilities. The model captures the fact that investment is more volatile than output, with simulated relative standard deviation (3.20) coming out relatively close to observed values (3.69). Similar accuracy is registered on relative volatilities of employment (0.34 vs. 0.39), labor productivity (0.77 vs. 0.90), real rental rate (0.19 vs. 0.26), and productivity shocks (0.76 vs. 0.86). As has been anticipated, the model results in smoothed consumption series that are less volatile than output (0.71), a fact that does not match the awkward feature of real data (1.16). Also, real wages are predicted to be less volatile than output (0.76), when in fact, they exhibit a higher relative volatility (1.16). Modeled volatility of TFP shocks (5.87) is amplified by real wages and labor productivity (6.25), output (8.22), and investment (26.32), a fact that matches the actual data well, where they also amplify consumption.

As reported in the literature (see Kydland and Prescott, 1982 and 1990; King *et al.*, 1998; King and Rebelo, 2000), RBC-simulated time series tend to be more persistent than actual values. The order of autocorrelations goes from 0.64–0.87 in the model, in contrast to 0.44–0.66 in real data. As a result, propagation is also weaker, with observed TFP auto-correlation (0.53) being slightly below that of productivity (0.57), real wage (0.58), and investment (0.59), when in the model, it propagates to all real variables with the sole exception of the rental rate.

RBC rightly predicts all real variables to be highly pro-cyclical. The degree of co-movement with output varies, with predicted cross-correlations for investment (0.89 modeled vs. 0.82 observed), labor productivity (0.96 vs. 0.92), and TFP shocks (0.98 vs. 0.92) being more accurate than those obtained for consumption (0.93 vs. 0.76), real wages (0.96 vs. 0.69), employment (0.79 vs. 0.44), and rental rates (0.77 vs. 0.50).

From this battery of RBC-simulated statistics, we can see that the original RBC model, one portraying a closed economy without government, produces a surprisingly good account of Venezuela's cyclical economic activity.

We can contrast the performance of the RBC model in describing the behavior of the Venezuelan economy during the business cycles with the benchmark case of the United States. It is noteworthy that we are opposing a heavily regulated oil-dependent economy with a fully functioning market, the subject of most empirical applications and adaptations of RBC models. To this purpose, we have calibrated a basic RBC model for the United States economy and gathered significant

Table 6. Venezuela: Real business cycle statistics from basic RBC model

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	8.22	1.00	0.76	1.00
Consumption	5.86	0.71	0.87	0.93
Investment	26.32	3.20	0.65	0.89
Employment	2.78	0.34	0.64	0.79
Labor productivity	6.25	0.76	0.85	0.96
Real wages	6.25	0.76	0.85	0.96
Real rental rate	1.60	0.19	0.64	0.77
TFP	5.87	0.71	0.70	0.98

Table 7. United States: Real business cycle statistics from basic RBC model

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	3.03	1.00	0.72	1.00
Consumption	1.76	0.58	0.85	0.90
Investment	11.50	3.80	0.65	0.94
Employment	1.28	0.42	0.64	0.89
Labor productivity	1.99	0.66	0.81	0.95
Real wages	1.99	0.66	0.81	0.95
Real rental rate	0.36	0.12	0.65	0.79
TFP	2.07	0.68	0.69	1.00

statistics in Table 7, which we will compare to the statistics derived from real data as reported in Tables 3 and 4

As in the case of Venezuela, modeled output volatility (3.03) is higher than that observed in real data (2.04). The model captures well the fact that investment tends to be more volatile than output (3.80 modeled vs. 3.05 observed), whereas consumption turns out to be less volatile than output (0.58 modeled vs. 0.86 observed). Persistence and propagation appear stronger in simulated series than in actual data, as well as co-movements with output.

For comparison purposes, given that Venezuela has no representative stock market from which to derive rental rates of capital, we prepared

Table 4 for the United States. There, we used as a proxy the same statistic as in Venezuela, namely a rate derived from the share of capital in GDP divided into the net stock of non-residential capital. The statistics for the latter are closer to the predictions of the model in relative standard deviation (0.12 vs. 0.24), autocorrelation (0.65 vs. 0.54), and cross-correlations with output (0.79 vs. 0.72). More importantly, the rental rate proxy results pro-cyclical, just as predicted by the RBC model. The puzzle remains, however, as to why stock returns (as reported in Table 3) or other expectations-based estimates of the actual rental rate (see Stock and Watson, 1996) result anti-cyclical when the *ex-post* returns on capital as derived from national accounts are consistently pro-cyclical.

The most striking differences are to be found in labor markets. In the case of the United States, the model predicts a relative standard deviation of unemployment (0.42) that is a third of the value observed in real data (1.12). To the contrary, the model predicts a relative volatility of wages (0.66) much higher than the one observed (0.41).[16] One could surmise that as actual real wages are not as flexible as presumed in the RBC model, the bulk of the adjustment to shocks falls upon quantities (workers).

The opposite happens to be true in Venezuela. Given large restrictions to labor mobility in the form of high dismissal costs, widespread (nominal) minimum salary, and outright restrictions of outplacements, the bulk of the adjustment to exogenous shocks falls upon prices (real wages), as opposed to quantities (workers). Simulated relative volatility of employment (0.34) almost matches observed values in either case (0.39). Employers simply do not venture into hiring workers in a boom, because they are aware that it will be either impossible or very expensive to fire them in a recession.

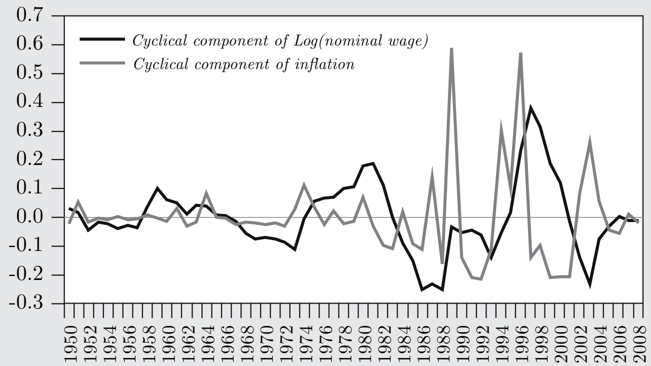
This translates into a highly pro-cyclical real wage, which turns out to be more volatile than predicted in the model, displaying a relative volatility of 1.16, in stark contrast to that registered for simulated time series (0.77). The main factor behind the high volatility displayed by real wages is a highly volatile and unpredictable rate of inflation. Figure 3 below contains the cyclical components of the time series for inflation and the log of average nominal wages. Although the

16. Some authors have noticed this shortcoming and suggested alternative ways to circumvent it by incorporating contracts between firms and workers that allow for wage smoothing (Gomme and Greenwood, 1995).

business cycles have become more pronounced since 1970, the swings in the cyclical component of inflation have not only outscored but also preceded those in the average nominal wage, inducing a high volatility in cyclical real wages.

Figure 3. Venezuela: Cyclical components of CPI variation and average nominal wage

(1950–2008)

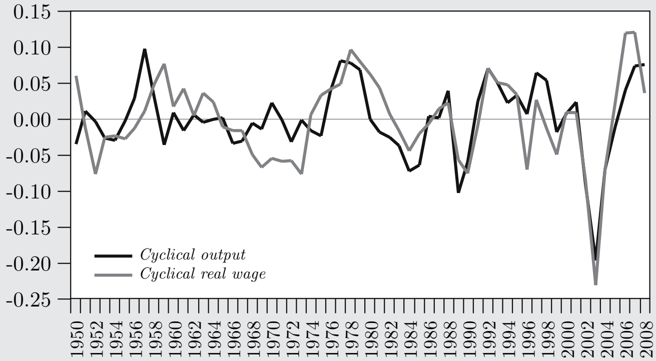


Sources: Venezuela Central Bank, Baptista (2011), author's own calculations.

Large differences in the behavior of real wages registered in Venezuela and the United States do mirror the differences in labor productivity. In Figure 4, we report on actual cyclical behavior of real wages and output over 1950–2008. The correlation in Venezuela is relatively high (69.1), whereas in the United States, observed real wages are much less pro-cyclical, displaying a low correlation with output (24.8). The disparities between both labor markets in terms of labor productivity are even more salient. As reported in Figure 5, labor productivity displays an almost-perfect correlation with cyclical output in Venezuela (92.1), in stark contrast with the United States, where there is barely any correspondence (6.7). Fully flexible real wages and pro-cyclical labor productivity, intrinsic to the mechanics of adjustment of the standard RBC model, more closely resemble the Venezuelan labor market and thereby explain the better fit.

Figure 4. Cyclical output and real wages

A. Venezuela



B. United States of America

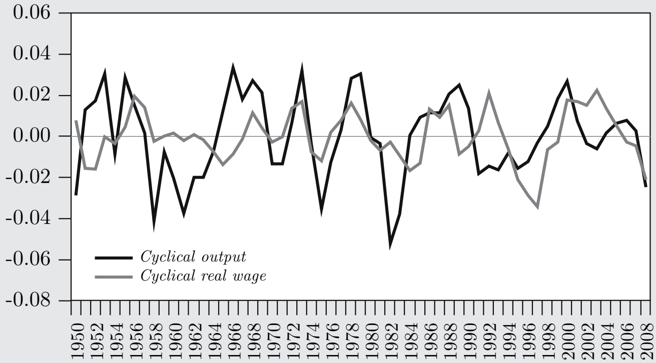


Figure 5. Cyclical output and labor productivity

7. Conclusions

We have calibrated a standard version of the RBC model to Venezuela and contrasted the accuracy of its predictions with those obtained for the benchmark case of the United States. Despite being a heavily regulated economy, Venezuela has some particular features that make it appealing from an RBC standpoint. First, the country is subject to large, frequent, and highly volatile exogenous shocks, in the form of oil prices. Second, Venezuela has a rigid labor legislation, with high dismissal costs, widespread minimum (nominal) salary, and (more recently) an outright labor freeze below certain salary thresholds. All these restrictions place the burden of adjustment to shocks on real wages, which in turn display a very high volatility. This is a rare case in the literature, where the original RBC framework of Kydland and Prescott (1982) provides a surprisingly good fit without any further enhancements.

As it turns out, the very same drivers of this good fit in Venezuela lead us to question the validity of the framework within more parsimonious and less frenzied economies. It has taken not only the volatility of oil prices, but also the large exposure and dependence on oil that Venezuela displays. These shocks, coupled with stiff labor legislation, have resulted in real wages as volatile as GDP itself. From a RBC standpoint, it is surprising that such strong labor market restrictions could result in much more flexible (volatile) real wages, as needed to match the predictions of the model.

From a policy standpoint, the implications for Venezuela are far reaching. Protecting jobs by introducing legislation that hinders adjustment in quantities only translates into highly volatile real wages. The net welfare effect of such a policy choice—protecting jobs at the expense of utterly unpredictable real wages—may end up being negative for workers, in particular as liquidity constrains—the only other mean of smoothing out consumption—are all too pervasive in developing countries.

The empirical findings reported here provide fertile ground for further research. Modeling the net welfare impacts of stiff job regulations—such as the ones prevalent in Venezuela—within a general equilibrium analysis seems fitting, in particular in times when concerns regarding the unequal nature of growth often drive the debate to the labor market arena. Moreover, the distortions that—we conjecture—underlie the goodness of fit, can be formally incorporated into the RBC framework through a search model with a Nash bargaining mechanism (as in Andolfatto, 1996) within the context of a small open economy. As economists usually do, now that we have seen things working in practice, we might start wondering if they would work in theory.

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APPENDIX A

Growth Accounting in Venezuela: Oil vs. Non-oil Sector

Using Venezuelan Central Bank statistics and the revised dataset provided by Baptista (2011), we have tried to disentangle the differences in factor contribution and total factor productivity between the oil and non-oil sectors. The share of capital for the non-oil sector is 33.9 (similar to the one used in the literature for the United States (Gertler and Karadi, 2011; Sims, 2012; Gertler and Kyiotaki, 2012). The figure is reported by Baptista (2011) as the rate of return on capital excluding oil rents. Baptista (2011) estimates this time series following a methodology introduced by Baptista and Mommer (1989), consisting in using the rate of return on capital on the non-oil sector of the economy to calculate the rate of return on capital within the oil sector (the difference being oil rents).

The results reported in Table A1 below have been calculated using a slight variation on the accounting methodology as in Hayashi and Prescott (2002): growth per worker has been decomposed into the contribution of non-residential capital per worker and average hours per worker.

The differences are startling. The non-oil sector of the economy exhibits annual average positive total factor productivity of 0.94 throughout the sample, in stark contrast to the loss of 1.50 exhibited by the oil sector.

Within the period of steep decline in Venezuela's income (1977–2008), the non-oil sector experienced a loss in GDP per worker of 0.70 per year (19.6 in total). Over the same period, output per worker in the oil industry has fallen an annual average of 3.19 (a total decline of 63 throughout the period), a likely outcome of investing more money into the same oil developments to fight-off field depletion. Differences in TFPs are presented in Figure A1.

Table A1. Growth accounting per worker: Venezuela oil vs. non-oil sector, 1950–2008

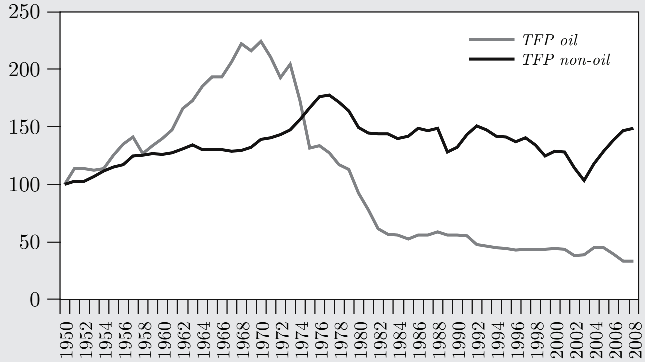
(average percentage change year on year)

	OIL GDP		NON-OIL GDP	
	1950-2008		1950-2008	
	Growth rate	Contribution to growth	Growth rate	Contribution to growth
Gross domestic product per worker	0.17	0.17	1.19	1.19
Non-residential capital stock	1.94	1.70	1.13	0.38
Labor input (hours per worker)	-0.21	-0.03	-0.21	-0.14
Total factor productivity		-1.50		0.94
	1950-1977		1950-1977	
	Growth rate	Contribution to growth	Growth rate	Contribution to growth
Gross domestic product per worker	4.04	4.04	3.36	3.36
Non-residential capital stock	3.20	2.80	3.47	1.17
Labor input (hours per worker)	-0.35	-0.04	-0.35	-0.23
Total factor productivity		1.28		2.41
	1977-2008		1970-2008	
	Growth rate	Contribution to growth	Growth rate	Contribution to growth
Gross domestic product per worker	-3.19	-3.19	-0.70	-0.70
Non-residential capital stock	0.85	0.74	-0.91	-0.31
Labor input (hours per worker)	-0.09	-0.01	-0.09	-0.06
Total factor productivity		-3.92		-0.34

Sources: Venezuela Central Bank, Bureau of Economic Analysis, University of Groningen Total Economy Database, and author's own calculations.

Figure A1. Venezuela total factor productivity: Oil and non-oil sectors

(1950 = 100)



Sources: Venezuela Central Bank, Bureau of Economic Analysis, University of Groningen Total Economy Database, and author's own calculations.

APPENDIX B

Real Business Cycle Statistics for the Venezuelan Non-oil Economy

Table B1. Real business cycle statistics for the Venezuelan non-oil economy

1950-2008

	Standard deviation	Relative standard deviation	Autocorrelations	Cross-correlation with output
Output	5.96	1.00	0.63	1.00
Consumption	5.88	0.99	0.66	0.78
Investment	19.37	3.25	0.51	0.78
Employment	1.99	0.33	0.50	0.36
Labor productivity	5.55	0.93	0.68	0.94
Real wages	6.20	1.04	0.57	0.78
Real rental rate	1.49	0.25	0.47	0.70
TFP	5.29	0.89	0.64	0.96

The standard deviation is higher in the non-oil sector (as compared to the overall economy) for all the variables selected, with the notable exception of employment, which remained unchanged (1.98 for the economy as a whole, 1.99 for the non-oil sector).[17] This finding seems to reinforce the idea that stringent labor legislation affects both sectors alike. Relative volatilities are also quite similar, but a noteworthy feature shows up in the non-oil economy: the cyclical component of consumption is now lower than that of output. Although the figure is still high (0.99) and indicates little or no smoothing consumption within the non-oil sector, the reduction turns out to be significant (down from 1.16 for the whole economy to 0.99 in non-oil sector).

One possible explanation is that total GDP is a composite of a highly volatile non-oil output and a relatively steady oil production. Such an economy is subject to shocks coming from large cyclical swings in oil prices, which impact the demand-side of the non-oil economy (as

17. Standard deviation of consumption is identical to the overall economy reported in Table 2, as we used the same aggregate measure per unit of labor.

gathered by the Solow residuals) but are squeezed out of the system without exerting much of a multiplying effect (i.e., via capital flight).

Looking at auto-correlations (column three in Table B1), we notice that persistence and propagation within the non-oil sector are weaker than in the case for the whole economy. TFP shocks (0.64) only propagate at the level of labor productivity (0.68) and consumption (0.66). All non-oil variables turn out to be pro-cyclical (column four) with coefficients very similar to those reported in Table 2.