Bringing an RBC Model to the Data: The case of Albania

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Abstract— This paper presents an empirical investigation of the basic RBC model. The empirical analysis uses Penn Word Tables data for Albania during 1970-2014. The results omit the calibration of the model. Instead, this work aims to examine whether some of the Kaldor's facts are observable for the Albanian macroeconomic series including output, consumption, investment, capital stock and labor supply. The method used consists in smoothing, detrending, descriptive statistics and impulse response functions (IRF). The results indicate that investment is the most volatile series, and labor supply is the least volatile. The strongest correlation is among output and employment. Regarding the IRFs, the results indicate that the most persistent unexpected shocks are observed in the case of consumption and labor supply. The shocks of investment and capital vanish within 10 periods (years). However, it can be concluded that the Koldor's fact are inconclusive in the case of Albania. That could be partly attributed to the quality of the data.

Index Terms— Cycles, impulse response functions, volatility, output, consumption, employment, capital, investment.

1 Introduction

THIS paper presents an empirical application of the RBC (Real Business Cycles) model using Albanian macroeconomic series. In principle, the RBC model remains an augmented neoclassical growth model that includes labor supply as a variable (Kydland & Prescott, 1982). Barro and Martin-i-Sala (2004) argue that the RBC model introduces the unexpected shock for the first time in growth models. In addition, many authors argue that the RBC model is the baseline model of the class of growth models classified as "DSGE" or *Dynamic Stochastic General Equilibrium Models* (see Gali, 2015). However, considering the mechanism technology is modeled, it remains an exogenous growth model. (Romer, 2012).

This work builds on Gjelaj (2018) that provides the theoretical framework of RBC models. In essence, the main finding of the model is an offsetting effect of technological progress on labor supply, i.e., a positive technological shock has a compensating effect on the average working hours. Nevertheless, Romer (2012) determines that the mechanism of the model does not match facts about fluctuations of the business cycles, i.e., labor supply is not constant but cyclical. Another disadvantage of the model is its simplification and strong assumptions referring the Walsarian features of the economy modeled.

Business cycles represent periodical fluctuations of output and other macroeconomic variables including consumption, capital, investment and labor supply, observable in the economy. In general, the duration of the cycles lies in the interval of 2 quarters up to 8 years. Regarding the stylized or Kaldor's facts, it is generally observed that the components of GDP have strongly correlated cycles. In addition, investment is the most volatile and variability of consumption cycles is lower than that of GDP. Further, consumption of durables has similar dynamics to investment. Lastly, employment is procyclical, i.e., fluctuations of employment have similar amplitudes as GDP.

This paper is organized as follows. Section (2) presents the data investigation and preparation. Section (3) conducts the multivariate analysis, i.e., impulse response functions. Lastly, section (4) concludes.

2 Data Work

The data is retrieved from Penn Word Tables[1]. Based on the theoretical considerations of the RBC model (see Romer, 2012), I have retrieved at least a measure of output (Y), consumption (C), investment (I), capital (K) and labor supply (N) for the period 1970-2014. It is worth noting that these are the longest annual series for Albania. The output is measured as the real GDP at constant 2011 national prices (in mil. 2011US$). The measure of consumption is real consumption at constant 2011 national prices (in mil. 2011US$) which includes both private consumption and government consumption. Unfortunately, there is no data on average working hours. Instead, we use a measure of employment: number of persons engaged in the labor market (in millions). The measure of capital is capital stock at constant 2011 national prices (in mil. 2011US$). Investment is calculated using the law of motion for capital:

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

K_{t+1} is merely the lead value of K_t and the depreciation rate, delta, is provided by the data source. Figure (1) presents the plot of all five series in levels.

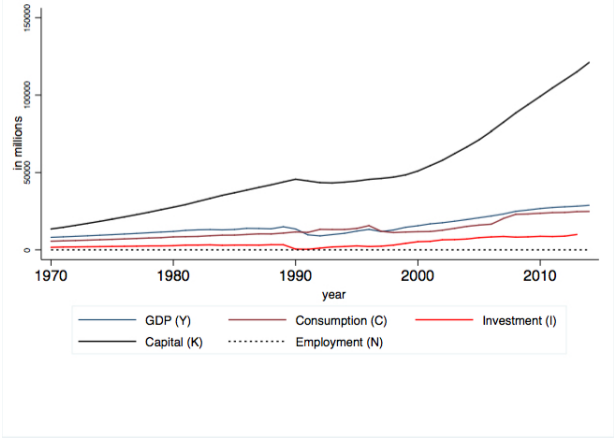

Fig. 1. Output, consumption, capital, investment and employment from 1970 to 2014 (in levels)

[1] Source: https://www.rug.nl/ggdc/productivity/pwt/

While capital follows an upward trend throughout the time interval analyzed, the rest of the series follow a constant trend until the beginning of the 90s. However, as the RBC model predicts, employment remains at at a constant level. Investment experiences growth after 2000. Output and consumption appear to be the most volatile series, and it could be the case that output fluctuations are mostly driven by changes in consumption. Nevertheless, we present the standard deviations for all five series in the next section.

2.1 Data Inspection: Smoothing & Detrending

This section presents the univariate analysis of the series chosen. First, we detrend the data using the Hodrick-Prescot (HP) filter to separate the trend and cyclical component form the series. The mechanism of the HP filter (Ljungqvist & Sargent, 2012) is provided by (2).

$$\min \{\sum_{t=1}^{T}(y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1}[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})]^2\} \quad (2)$$

y is the series at hand and τ represents the trend component. Lastly, λ is the smoothing parameter, which in our case is set to be 100 (see Stock & Watson, 2002 for a parameter setting discussion). Figure (2) presents the output and consumption business cycles. Note that the logarithmic transformation is applied prior to detrending. Hence, the gaps are in percentage. Apparently, the cyclical component of consumption is not moving along the output cycles. Despite the negative correlation, one expectation that we observe in the data is that consumption is less volatile than output.

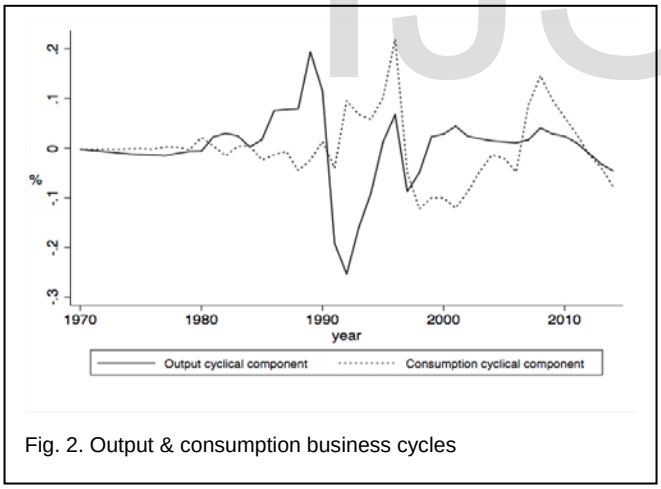

Fig. 2. Output & consumption business cycles

Figure (3) presents the cycles of output and investment. In contrast, investment is more volatile than output. Moreover, the cycles move along, indicating that the correlation is positive. However, the drop in capital is smaller in magnitude compared to the drop in output. From the 2010s onwards, the cycles move along.

Figure (4) plots the cyclical components of output and capital. Again, output is more volatile than capital. Further, it can be concluded that capital is a procyclical variable, i.e., positively correlated with output.

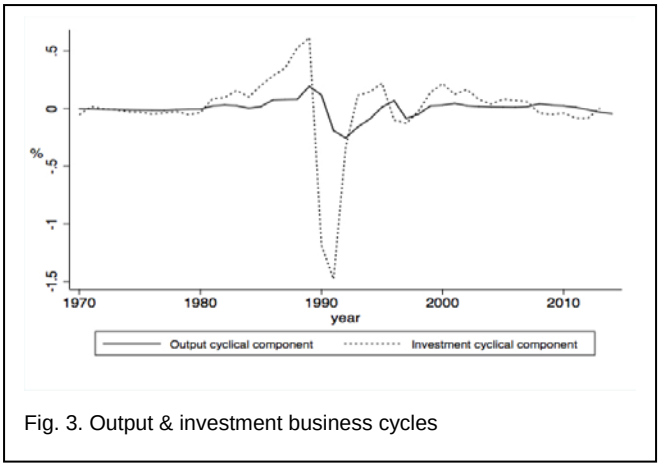

Fig. 3. Output & investment business cycles

Lastly, Figure (5) presents the cyclical component of output and employment. While till the early 90s recession the clycles move in the same direction, we observe that post-90s, with the deindustrialization of Albania, as output rises, employment falls. That could be due to the substitution of the labor force with technology. Nevertheless, from the early to the late 2000s, the cycles fluctuate in the same direction, with output being more volatile than employment.

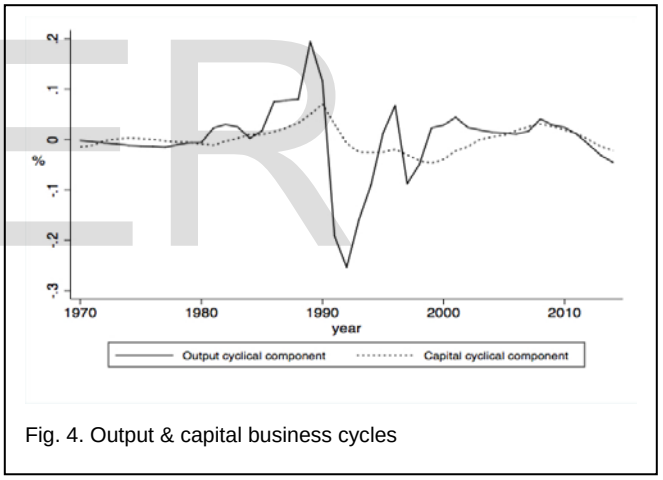

Fig. 4. Output & capital business cycles

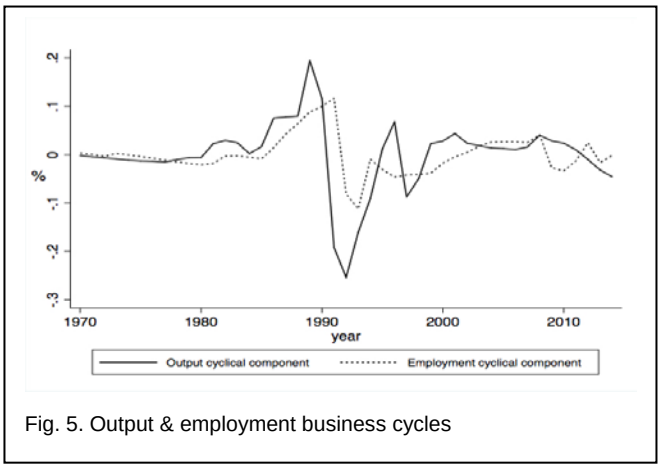

Fig. 5. Output & employment business cycles

For precise correlation and volatility analysis of the series, we refer to descriptive statistics. Table (1) reports the standard deviations of the five detrended series and their correlation with output. While labor supply and capital are the least volatile series, investment is the most volatile among all series. Regarding correlation with output, it is clear that the variation in the labor supply affects mostly the variation in output. Investment and capital are also positively correlated with output. In contrast, consumption is negatively correlated with output. Note, that the cycles are negatively correlated, not the series in levels.

TABLE 1

Variable	Observations	Std. Dev.	Correlation with Y
Output (Y)	45	0.073	1.000
Consumption (C)	45	0.067	-0.060
Employment (N)	45	0.041	0.440
Investment (I)	44	***0.339***	0.399
Capital (K)	45	0.023	0.423

DESCRIPTIVE STATISTICS

3 MULTIVARIATE ANALYSIS: IRF

This section performs the multivariate analysis of the series at hand. In specific, this section borrows from Sims (1980) Vector Autoregressive Models (VAR). In this case we estimate the reduced form VAR (see Enders, 2014; Hamilton, 1994). In particular, we are interested in the impulse response functions (IRF). An IRF describes the reaction of one variable to the impulse of the another variable. Consider two stationary and ergodic series: $\{y_t\}_{t=-\infty}^{+\infty}$ and $\{z_t\}_{t=-\infty}^{+\infty}$. The stationarity property reads as constant variance and ergodicity means the independence of any couple $\{y_t, y_{t-k}\}$ when t goes to infinity. Hence, we can apply the Ergodicity theorem for dependent observations (Hamilton, 1994): under the assumption that $\mathbb{E}[\,|y_t|] < \infty$, the theorem states that when $t \to \infty$ the mean of the series converges (almost sure, a.s) to $\mathbb{E}[\,y_t]$:

$$\frac{1}{T}\sum_{t=1}^{T} y_t \xrightarrow{as} \mathbb{E}[\,y_t] \tag{3}$$

The same applied to the other series. A bivariate VAR model can be written as:

$$y_t = \sum_{i=1}^{n} a_{11}^{(i)} y_{t-i} + \sum_{i=1}^{n} a_{12}^{(i)} z_{t-i} + e_{1t}$$
$$z_t = \sum_{i=1}^{n} a_{21}^{(i)} y_{t-i} + \sum_{i=1}^{n} a_{22}^{(i)} z_{t-i} + e_{2t} \tag{4}$$

Enders (2014) indicates that the impulse response function is obtained using the moving average representation:

$$y_t = \sum_{i=1}^{n} b_{11}^{(i)} e_{1,t-i} + \sum_{i=1}^{n} b_{12}^{(i)} e_{2,t-i} + e_{1t}$$
$$z_t = \sum_{i=1}^{n} b_{21}^{(i)} e_{1,t-i} + \sum_{i=1}^{n} b_{22}^{(i)} e_{2,t-i} + e_{2t} \tag{5}$$

Before applying the model, it is crucial to satisfy the conditions, under which VAR is asymptotically efficient and consistent. Sims, Stock and Watson (1990) argue that the VAR model should estimate parameters of stationary variables. To this extent, we perform the stationarity (unit root) test to all five series (Table 2). If we reject the null under the presence of a unit root, then the series is generated by a stationary process.

TABLE 2
UNIT ROOT TEST

Series	Observations	ADF *p*-value
Output	45	0.0014
Consumption	45	0.0015
Capital	45	0.0562
Investment	45	0.0002
Employment	45	0.0007

ADF-Augmented Dickey Fuller test; p-value: the null hypothesis is rejected if p-value is lower than 1, 5 or 10 percent.

At the common significance levels, we reject the null hypothesis under the presence of a unit root. Further, the VAR models are checked for normality, residual autocorrelation and stability. Hence, it is safe to proceed with the impulse response functions.

Figure (6) presents the response of output as a result of an unexpected shock on consumption. Note that the series are smoothed and detrended. An unexpected consumption shock reduces output by less than 2 percent in the first period (year), and afterwards the effect is positive. It is clear that from the second period onwards, the effect fluctuates around zero, but does not vanish, i.e., the cycles do not lie in the time interval of 2 quarters up to 8 years. This result indicates failure of the RBC model, or low data quality.

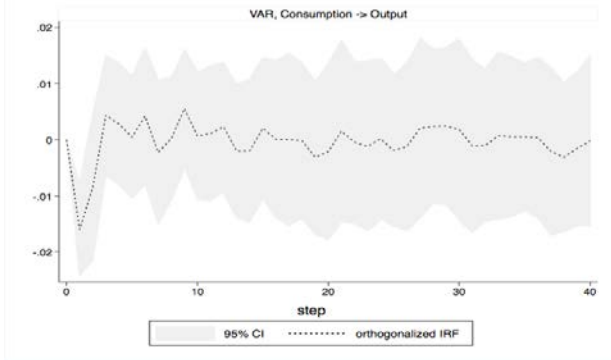

Fig. 6. Response of output to a consumption shock

Figure (7) indicates the response of output to an unexpected capital shock. The response of output consists in a reduction by less than 0.1 percentage points in the first period, and a

reduction by 0.1 percentage points after the 5th period. Afterwards, the effect of the shock dies. This is consistent with the theory of business cycles.

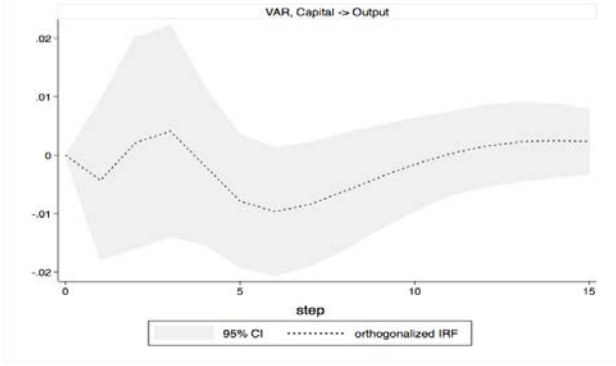

Fig. 7. Response of output to a capital shock

Figure (8) indicates the response of output to an investment shock. After the first period, output increases by 0.5 percentage points and it falls by less than 0.4 percentage points after 5 periods. Then, the effect of the shock vanishes.

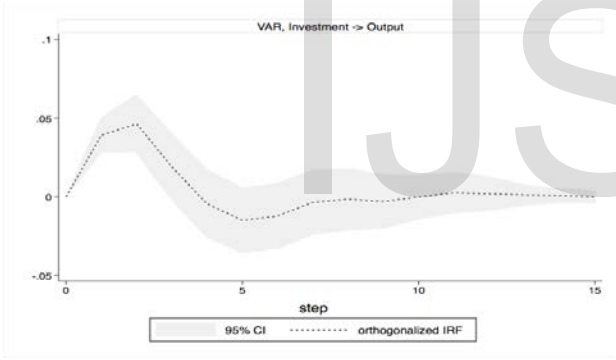

Fig. 8. Response of output to an investment shock

Lastly, Figure (9) presents the IRF of an employment shock. The detrended series of output experience a slight rise during the first period of the shock and then drop by almost 0.2 percent in the third period. Afterwards, the effect of the shock fluctuates around zero.

The results are partly inconclusive regarding the persistence of the shock. That is more evident in the case of a consumption and employment shock. Perhaps, using the average working hours as a measure of labor supply instead of employment and the consumption of durables instead of the total private consumption, the results would have been consistent with the expectations of the RBC model. In addition, the results could have been more relevant if the data frequency would have been quarterly, or if the length would have been greater than 50 years.

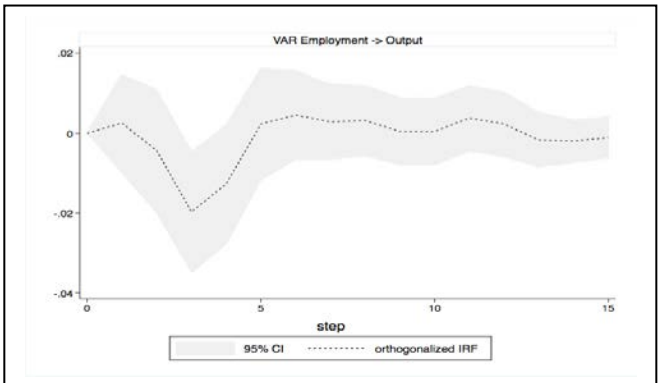

Fig. 9. Response of output to an employment shock

4 Conclusion

This paper aims at bringing the RBC model to the data for the case of Albania. The analysis concludes that the most volatile series is investment, and the least volatile is employment. While employment is the most correlated variable with output, the correlation with consumption is negative and less that 10 percent, indicating that the cyclical components of output and consumption do not move along. Regarding the IRF functions, the shock persistence of capital and investment are more consistent to what we observe in reality. In contrast, it takes a considerable time for the shock of consumption and employment to vanish. Nevertheless, the results could improve under higher data quality, i.e., greater frequency or more realistic measures.

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