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## REAL BUSINESS CYCLE THEORY – METHODOLOGY AND TOOLS

**ABSTRACT.** The Real Business Cycle (RBC) research program has grown spectacularly over the last two decades, as its concepts and methods have diffused into mainstream macroeconomics. In its primary version it bases on growth model with neoclassical production function which is subject to a stochastic supply shocks. Simultaneously employing in analysis rational agent which decides about labor input and deserved consumption allows to develop model following cyclical fluctuations observed in the economy. In order to do so multistage calibration-simulation procedure is used.

The main aim of the article is to present methodological innovations introduced by RBC proponents such as: Hodrick Prescott filter, and multistage calibration-simulation procedure.

**JEL Classification:** B21, B41    **Keywords:** modern business cycle theory, real business cycle, hodrick prescott filter, calibration-simulation procedure.

### Introduction

Real business cycle theory is built on the assumption that there are large fluctuations in the rate of technological progress. It is not a new idea that business cycle fluctuations might be driven by real factors<sup>1</sup>. Serious work has started after the publication of Kydland and Prescott's (1982) paper that described how to build a numerical stochastic general equilibrium model of the U.S. economy.

In addition, the transition from monetary to real theories of the business cycle was further stimulated by two other important facts. First, the supply shocks associated with the two *OPEC* oil price increases during the 1970s made macroeconomists more aware of the importance of supply-side factors in explaining macroeconomic instability (Blinder, 1979). These events, together with the apparent failure of the demand-oriented Keynesian model to account adequately for rising unemployment accompanied by accelerating inflation, forced all macroeconomists to devote increasing research effort to the construction of macroeconomic theories where the supply side has coherent micro-foundations. Second, the seminal work of Nelson and Plosser (1982) and Kydland and Prescott (1982) suggested that real shocks may be far more important than monetary shocks in explaining the path of aggregate output over

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<sup>1</sup> In particular D. Robertosn, J. Schumpeter, K. Wicksell emphasized real forces as the engine behind business fluctuations.

time. Nelson and Plosser argue that the evidence is consistent with the proposition that output follows a path, which could best be described as a 'random walks'.

### Cycles, Random Walks and the Hodrick-Prescott Filter

Because *RBC* school interprets deviations from stochastic trend as a cyclical component of macroeconomic time series, prior to further analysis methods of trend's estimation should be presented.

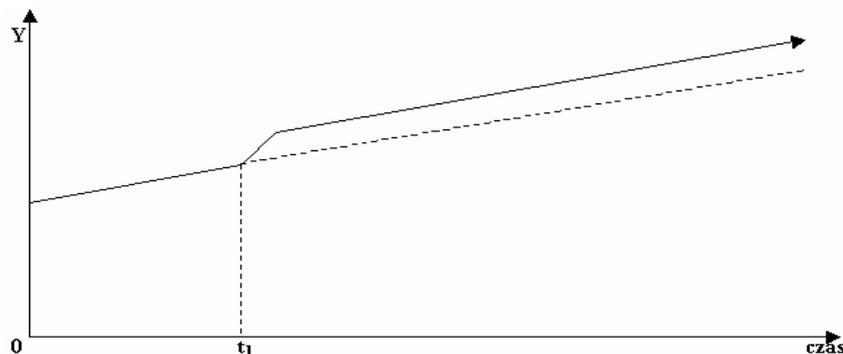
The conventional approach has been to imagine that economy evolves along a path reflecting an underlying trend rate of growth described by model with neoclassical production function. This view assumes that the long-run trend component of *GDP* is smooth, with short-run fluctuations about trend being primarily determined by demand shocks. This conventional wisdom was accepted by all mainstream economy schools until the early 1980s. In 1982, Nelson and Plosser published an important paper that has changed common point of view. At the beginnings of 80`s the methods of fluctuation's analysis proposed by R.E. Lucas (Lucas, 1980) were questioned, mainly due to development of New Econometric methods, especially *VAR* (*vector autoregression*), and econometric tests stemming from them. However his attitude towards business cycles was not completely rejected. It was only proved that monetary phenomenon in the short run were very poor explanation of production's fluctuations. Assumption of linear trend in macroeconomic trends was also rejected.

Tests conducted by Nelson and Plosser showed that majority of time series characterize random walk process with drift element, formally presented by equation below:

$$y_t = \mu + y_{t-1} + \varepsilon_t \quad (1)$$

where:  $\mu$ - drift constant;  $\mu > 0$

According to this equation one can plot a chart of time series. Graphical interpretation of this is presented on the graph 1.



Graph 1. The path of output where shocks have permanent influence

Source: B. Snowdon, H. Vane, *Modern Macroeconomic. Its Origins, Development and Current State*, Edward Elgar, Cheltenham – Northampton, p.302

If analyzed time series has drift then using linear trend is very difficult because it is changing over time. According to real business cycle theory standard procedure of estimations bases on stochastic trend finding and interpreting deviations from it as cyclical components. Trend is flat regression line estimated by ordinary least squares (*OLS*). Using this method allows to avoid sudden changes of trend. The *Hodrick-Prescott* filter (HP; Hodrick and Prescott, 1997)

is based on the assumption that a given time series  $y_t$  is the sum of a trend growth component  $g_t$  and cyclical component  $c_t$ :

$$y_t = g_t + c_t, \quad t=1,2,\dots,T \quad (2)$$

The cyclical component  $c_t$  represents deviations from  $g_t$  and over long time periods their average is assumed to be near zero. The growth component  $g_t$  is extracted by minimizing following loss function:

$$\underset{\{g_t\}_{t=1}^T}{\text{Min}} \left\{ \sum_{t=1}^T c_t^2 + \lambda \sum_{t=1}^T [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2 \right\} \quad (3)$$

where:

- $c_t$  - cyclical component;
- $g_t$  - growth component;
- $\lambda$  - smoothing parameter.

The most important element of this equation is  $\lambda$  parameter - the bigger it is the more „fixed” the trend is. If  $\infty \rightarrow \lambda$  results of filtering would be identical with linear trend. Usually there are three values of this parameter: for yearly data  $\lambda=100$ , for quarterly  $\lambda=1600$  and for monthly  $\lambda=14400$ . Of course there are many opinions about this method. When filtering data with near unit root, the optimal value of the smoothing parameter lies in the range 1000-1050, although the standard value of  $\lambda=1600$  does not lead to serious distortions (Mills, 2003). Explanations supporting this value of  $\lambda$  are provided by Hodrick and Prescott (1997) observations: 5% quarterly deviations from trend result in 8% change (growth) of trend. Authors showed that  $\lambda$  parameter can be interpreted as a change of cyclical component divided by growth of trend component, on condition that both cyclical component and second differences of trend have normal distribution with zero mean, so it can be written:  $5^2/(1/8)^2=1600$ .

The most important limit of this method is the length of time series that are filtrated. Due to properties of business cycles and “mechanics” of filter, minimal number of observations equals to 32, which in case of quarterly data suggests classical interpretation of business cycle phase. Seasonal adjustment prior to filtration is also recommended. Omitting this can significantly deform filtration effects. Filtration should also not be treated as forecasting method, however literature shows that there are some examples of *HP* filter adjustments, aimed at tailoring it to forecasting needs (Bruchez, 2003). General conclusion stemming from these research suggests that much better results of forecasting are achieved in the case of methods such as *ARMA*. This is caused by design of the tool that bases on the moving average, which in the case of last observation leads to its deformation.

*HP* Filter criticism bases mainly on improper employment of the tool. Only King and Rebelo (1993) question its usability in research on business cycles. According to them *HP* can be used only in the case of detection of long run tendencies.

Methods aimed at estimation of stochastic trend become an important element of quantitative analysis, much wider than neoclassical economics. *HP* filter is widely accepted also by opponents of neoclassical economics. It is commonly used in economic policy: in estimation of *GDP* gap, designing monetary policy, and analysis of markets and regional economies. Together with rational expectations hypothesis (REH), it has been developed by neoclassical economics significant element of modern economic analysis.

## Measurement of technological change

Following Frisch (1995), developers of *RBC* models have notified differences between impulse and transmission mechanisms. First causes initial shock which leads to deviation from stable state, while transmission (propagation) mechanism is responsible for sustaining deviation over the time and has permanent influence on long run path. The structural model determines the way the economy reacts to certain types of shocks.

Assuming that technological shocks are reasons of business cycles, measuring technical development becomes crucial issue of analysis. On the basis of the typical *RBC* model structure, variance of technological shock could be treated as a crucial element of the model (Prescott, 1986). In spite of the fact that it is some kind of simplification of the model, it underlines explanatory properties of the *RBC* model. At the time of model's presentation it was surprising that neoclassical growth model which was subject to stochastic shocks, could be employed to analysis of business cycle. Prescott showed that simulations on the basis of this model can follow changes of main macroeconomic indicators.

Solow's (1957) methodology defines technological progress as changes of global demand corrected by weighted capital and labor input. Consequently, it is a part of aggregate demand that cannot be explained by changes of capital and labor. One has to recall that stable state production function that can be defined by:

$$Y_t = A_t K_t^{1-\alpha} (N_t X_t)^\alpha$$

Where  $\alpha$  is a share of labor input in global production. Using time series of production, labor input, and capital input, one can estimate Solow residual using King, Plosser and Rebelo's methodology (2000):

$$\log SR_t = \log Y_t - \alpha \log N_t - (1 - \alpha) \log K_t$$

where:

$SR_t$  - Solow residual at a time  $t$ .

In order to estimate contribution of capital accumulation to economic growth, Solow assessed how average rate of labor share in product  $\left( \log \left( \frac{Y_t}{N_t} \right) - \log \left( \frac{Y_{t-1}}{N_{t-1}} \right) \right)$  is divided between increase of productivity  $(\log(SR_t) - \log(SR_{t-1}))$  and rise of share of capital related to labor input  $(\log K_t / N_t) - \log(K_{t-1} / N_{t-1})$ . The results were a revolution in the attitude towards understanding sustainable growth. However, for *RBC* school most important issue is to estimate how economy answers to a stochastic shock.

Assuming that stochastic component of production can be assessed on the basis of estimated Solow residual:  $\log SR_t = \log(A_t) + \alpha \log(X_t)$  Assuming that,  $\log(A_t)$  is autoregressive process  $AR(1)$ , one can state that  $\log(A_t) = \rho \log(A_{t-1}) + \varepsilon_t$ . Based on the fact that  $\log(X_t) = \log(X_{t-1}) + \log(\gamma)$  it is possible to calculate the stochastic process of productivity and parameters  $\rho$  and  $\varepsilon_t$ .

## Verification of the model

Properties of *RBC* models do not allow to use classical econometric verification. It was Kydland and Prescott who first demonstrated that a general equilibrium real business

cycle model, driven by exogenous technological shocks, was capable of generating time series data that possessed the statistical properties of US business cycles over the period 1950–79. In order to analyze quantitative implications of these structures, multistage calibration simulation procedures have to be used. The group of business cycle researchers working in RBC criticizes standard econometric practice for being uninformative on important questions. The researchers have chosen to use ‘calibration’ or ‘computational experiments’ as an alternative to statistical estimation.

Stepwise procedure includes (Cooley, 1997; Cooley, Prescott, 1995; Kydland, Prescott, 1996):

- Finding agent’s consumption and production decisions equations in the equilibrium.
- Linearization of equations and transformation of variables to deviations from existing state.
- Finding parameters of existing state (calibration), using collected statistical data and knowledge about “stylized facts”. If there’s no information values for parameters have to be chosen in such a way, one have to assure that model follows real changes of variables.
- Applying a computer software to generate a series of random supply side shocks to the artificial economy.
- Compared achieved statistics with observed economy behavior.

If the model “fits” the data, its quantitative implications should be taken seriously. A new label – quantitative theory – is sometimes used to describe this area of research.

On the negative side, one of the problems with calibration is that it currently does not provide a method that allows one to judge between the performance of real and business cycle models. Nevertheless, calibration has provided an important new contribution to the methodology of empirical macroeconomic research. While initially the calibration methodology was focused on business cycle research, more recently calibrated models have been used to investigate issues in public finance, economic growth, industry, firm and plant dynamics, and questions related to the choice of economic policy.

## Criticisms

The RBC school of thought has grown substantially since the early papers. Part of the reason is that it is compelling as science. We take the model seriously, expect it to actually match observations quantitatively, and when it doesn’t, we adjust the model. Another reason it has done so well is that the methodology is a natural “article generator”. One could bring it to the statement “Find something that has not been modeled yet”, add it to the baseline model, and see what you get. The main criticisms of the RBC methodology are:

- Why would you consider matching the moments in the data a desirable property in a model that you know leaves out important features?
- Statistical tests are meaningless except in the context of an alternative. It may be the case that there are hundreds of different models that do equally well.

Some key criticisms of the specific hypothesis that fluctuations in technical progress explain business cycles are:

- If we are to identify the Solow residual as the measure of short-term technological progress, we must be prepared to interpret many deep recessions as exhibiting technical regress (especially the Great Depression and the case of Japan).
- It is not clear what particular technological advances or disasters can be associated with any of the major short-term swings in the Solow residual.

- If the Solow residual measures what RBC model says it does, then it should be uncorrelated with the political party of the President, military purchases, and oil price movements (once energy usage has been accounted for). But it is correlated with all those things.

One approach that some proponents of the RBC theory have suggested is that the Solow residual is poorly measured. Capital and labor utilization rates tend to vary significantly and procyclically. If you use the capital stock to measure the flow of capital services, you will overstate the extent of fluctuations in technical progress.

## Summary

RBC theory has developed indigenous methods of business cycle analysis. Filter developed by Hodrick and Prescott aimed at removing time series from long run oscillations, became common tool for business cycle analysis. In spite of some reservations about achieved results, the method was adopted by competitive schools of economics. Similarly to REH (introduced and popularized by new classical economists), it became integral, widely accepted element of mainstream economics.

Properties of RBC models do not allow using classical econometric verification. In order to analyze quantitative implications of these structures, multistage calibration simulation procedures have to be used. Calibration procedure is a crucial element of quantitative analysis proposed by RBC school. It can be boiled down to proposing, on the basis of micro and macroeconomic data, parameters of equations that describe model economy. Values of these parameters have to be chosen in the way that assures they follow real economy in the long run.

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