Argumenta Oeconomica
Year 2026, Vol. 56, No. 2
ISSN 2720-5088
journals.uew.pl/aoe

Are real business cycles dead?

Mikuláš Zeman

Faculty of Economics, Prague University of Economics and Business, Czech Republic

e-mail: mikulas.zeman@vse.cz

ORCID: 0009-0004-3478-8534

Zdeněk Chytil

Faculty of Economics, Prague University of Economics and Business, Czech Republic

e-mail: zdenek.chytil@vse.cz

ORCID: 0000-0001-5091-8272

Michal Mec

Faculty of Economics, Prague University of Economics and Business, Czech Republic

e-mail: michal.mec@vse.cz

ORCID: 0009-0003-7060-2429

Quote as: Zeman, M., Chytil, Z., & Mec, M. (2026). Are real business cycles dead? *Argumenta Oeconomica*, *56*(2). 1-16

DOI: 10.15611/aoe.2026.2.01

JEL: E10, E32, E20

Abstract

Aim: This paper aims to assess whether technological changes and resource availability are the primary drivers of business cycles, as suggested by the Real Business Cycle (RBC) theory, and propose a suitable monetary policy response to shocks. If business cycles are a result of technological changes and the availability of resources, monetary management is often not desirable.

Methodology: The authors developed a standard RBC model from the class of DSGE models and then extended it by incorporating capital utilisation to enhance the model's realism. A step-by-step derivation of the model's equilibrium conditions is also presented, whilst the model was calibrated using US data and solved in Matlab and Dynare.

Results: The results showed that the inclusion of capital utilisation substantially amplified the impact of productivity shocks, so that even a relatively small total factor productivity shock generated realistic fluctuations in output.

Implications and recommendations: The findings suggest that monetary and fiscal authorities have limited scope to smooth fluctuations arising from supply shocks, and that excessive policy intervention may be counterproductive. Therefore, RBC models could serve as a useful tool for policymakers as it shows that government and monetary management are often not desirable. Future research could enrich the model through labour market heterogeneity, investment frictions, and open economy features.

Originality/value: The results are in contrast with the conclusions of earlier literature, which typically found that only large technology shocks are capable of producing such dynamics. The main added value of the paper results from the extension of the standard RBC framework through the incorporation of capital utilisation.

Keywords: macroeconomics, business cycles, monetary policy, general equilibrium

1. Introduction and literature review

Business cycle theories have been explored from the very beginning of economic science. The issue of what causes economic fluctuations is probably one of the most fundamental questions in economics, and there is still no agreement as to main factors regarding business cycles. In the 1920s the majority of economists believed that business cycles resulted from shifts in the demand and supply of goods and productive factors, thus were caused by real factors. Nevertheless, in the 1930s, in the aftermath of the Great Depression, most economists started to believe that business cycles were actually caused by the psychology of households and firms and monetary conditions. The boom of Keynesian macroeconomics meant that government interventions were considered essential and highly desirable (King & Rebelo, 1999).

A slight change began in the 1970s and was associated with R. Lucas (1973) and his theory of rational expectations. Later on many economists (e.g. Kydland & Prescott, 1982; Long & Plosser, 1983; Lucas, 1976; Sargent, 1982) made business cycle models which involved market clearing with no monetary factors and no macroeconomic management. Unsurprisingly, these ideas were often encountered with disregard and disbelief (King & Rebelo, 1999).

A breakthrough in the Real Business Cycle (RBC) models came at the end of the 1980s, when shifts in the Total Factor Productivity (TFP) started to be measured by Solow’s (1957) growth accounting approach. This meant that simple equilibrium models could generate time series with the same accuracy and precision as those of actual economies.

Nowadays, there is still debate regarding the fluctuations around the growth path. Some economists believe that business cycles are endogenous, created through monetary policies of central banks, as suggested by M. Friedman (1956) (cf. Ghalayini, 2018; Hellwig, 2010; Kim, 1998; Reichlin et al., 2019), whose theory brought completely different conclusions than RBC theories, namely that monetary policy plays no role in the RBC framework – a monetary policy cannot affect real variables (even in the short run).

Recently there has also been a huge increase in the popularity of behavioural economics, with its proponents trying to incorporate behavioural theories into business cycle theories, for example, in terms of household behaviour (Jaimovich & Rebelo, 2007; Prince, 2017; Rötheli, 2005).

Numerous authors also concluded that shocks causing economic fluctuations cannot be explained as easily as was claimed by Cochrane (1994) and Summers (1986).

Current critics of the RBC model see as its main disadvantage that it neglects market failures, the role of government and the irrational behaviour of economic agents. RBC models also work with the assumption that there is symmetric information across all agents, which is also a problematic assumption for many economists, yet several researchers, e.g. Plosser (1989) and Rogoff (1986), concluded that despite those drawbacks, RBC models can bring excellent and valuable results. The methods of the RBC research programme have been recently used in monetary economics, international economics, public finance, labour economics, and in asset pricing.

There are also alternative ways of explaining economic fluctuations. Čermáková et al. (2021) found that an economic cycle could be originated and fuelled by the behaviour of individuals. The study proved that the sum of output in a society is affected by the ratio of individual strategies. Game theory modelling of a strategic behavioural approach is presented as a valid theoretical foundation for explaining economic fluctuations. There is also debate regarding contemporary approaches to factors influencing economic growth. Srivastava and Řežábek (2022) studied the impact of digital payments on economic growth in the Czech Republic, and showed that an impact of digital payments exists but not strong enough for a switch or greater usage to be employed in such a payment system. Pala (2020) researched the relation between climate change and economic growth, and examined the effect of climate change on economic growth. The study used the data for the period from 1996 to 2014 for EU-28 countries and applied endogeneity, cross-sectional dependence and slope homogeneity tests. The results showed that increasing carbon emission contributes to economic growth in North and East European countries, relatively cold regions, whereas in South-West Europe the coefficient of CO2 was insignificant. Increasing carbon emission positively affected economic growth, especially through agricultural and tourism sector outputs in North and East Europe.

Eddine et al. (2021) examined how trade openness and tax structure influenced economic growth in Morocco in the period between 1985 and 2019. The results of the modelling using the Two-Stage Least Squares (2SLS) method confirmed that the reduction of customs duties had a negative impact on foreign trade revenue, and consequently, on total tax revenue. Setyari (2020) studied the impact of capital flows on economic growth, analysing the interaction between trade and international capital flows in ASEAN countries + 4 (ASEAN plus India, China, Japan, and Korea). The research results were consistent with the theory that capital will flow to countries that have a capital-intensive industrial structure, which then leads to an increase in the deficit in the country's current account balance.

New perspectives on economic cycles were brought by institutional economics stating that economic fluctuations are mainly created by institutional factors, such as property rights, freedom of corruption, level of freedom on different markets and other components of the Index of Economic Freedom and legal framework. Čermáková et al. (2020) proved that soft institutional factors could explain the differences in GDP per capita dynamics across countries, and presented new evidence on how institutional factors determine economic growth. Unlike previously conducted studies, they used panel data and a set of general control variables in an attempt to respect causal inference. Moreover, their study showed that the mainstream economic conviction – more economic freedom leads to higher economic growth – fails in some cases, and regulation does not always hamper economic growth.

The aim of this paper was to show that RBC models provide a valuable contribution to macroeconomic theory, and that technology shocks are a major source of business fluctuations. The model constructed in this paper is based on similar principles as that presented in *Resuscitating Real Business Cycles* by King and Rebelo (1999), however this basic RBC model was extended by capital utilisation. The main hypothesis of this paper is that the implementation of capital utilisation into the RBC model will demonstrate that technology shocks influence economic output more significantly than in the basic RBC model, therefore even small shocks can produce realistic business cycles, as opposed to King and Rebelo (1999), who concluded that only large technology shocks generate realistic business cycles.

2. Data, methodology and model

This paper used data for the US economy being the largest in the world, and covers the period from 1947 to 2019. The author constructed the dynamic stochastic general equilibrium (DSGE) in Matlab and Dynare. All working codes are available in the annex in order that other authors could replicate this work.

The RBC model constructed in this paper, belongs to the group of DSGE models. The meaning of single designations in DSGE (Adrian et al., 2022; Christiano et al., 2018; McDonald & Shalizi, 2022; Poudyal & Spanos, 2022) is briefly explained below:

- Dynamic – households solve the intertemporal problem: to consume or to invest? Investment gives returns tomorrow.
- Stochastic – the economy is affected by exogenous disturbances.
- General equilibrium – not looking at the single markets but at all markets simultaneously, and not just in terms of supply and demand but at the market structure where all the markets are clear; variables are endogenous. Only shocks are exogenous, thus supply and demand are not viewed separately because shocks have effects on both.

The following macroeconomic variables were employed: economic output, output per capita, consumption (non-durables + durables purchases), investment, government expenditures, total hours worked, capital, employment, labour productivity, real wages, real interest rate and TFP.

Data from National Income and Product Accounts (NIPA) tables (BEA, 2023) were used for GDP, consumption and investment as they provide the highest level of accuracy and relevancy. Another possibility was to use data from the Federal Reserve Economic Data (FRED) for these variables, which are also precise and accurate.

For population, data from the Bureau of Labor Statistics (US Bureau of Labor Statistics, 2023) were used for the time series of the labour force (population aged over 16, eligible for work), an excellent source of information.

With regard to labour productivity, the same measure was used as e.g., by King and Rebelo (1999), i.e. labour productivity was computed as output per man-hour.

To compute the variable total hours worked, the study used updated data Francis and Ramey, *Measures of per Capita Hours and Their Implications for the Technology-Hours Debate* (2009). Their method appears to be the best proxy for total hours worked, and non-farm total hours per capita were applied.

Regarding the other variables in this paper, data were obtained from the FRED database (FRED, 2023), as this source provides probably the widest range of data for the US economy.

Concerning the manipulation of the data, all the fundamentals were divided by population (labour force) to find data per capita. As mentioned earlier, data for the population were taken from the Bureau of Labor Statistics (US Bureau of Labor Statistics, 2023).

In order to eliminate any distortions, the dataset was divided into three Excel sheets for different periods of time.

- 1947–2007 Dataset 1
- 1947–2018 Dataset 2
- 2007–2019 Dataset 3

Eventually it was decided to omit data for 2020-2021 since this period had been significantly influenced by a negative supply shock caused by the COVID-19 pandemic, accompanied by a huge fiscal and monetary intervention. Moreover, not all the data for that period were available at this stage.

It was necessary to make the series stationary, thus a secular trend was removed. For detrending the variables, one can choose from several different approaches. The most common approaches are:

- deterministic detrending,
- first differencing,

- approximate Bandpass filter,
- Hodrick-Prescott (HP) filter.

The author used a filter established by Hodrick and Prescott, who analysed post-war business cycles in the US (1980); as was mentioned above, this procedure is called the HP filter,

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

where τ_t stands for a trend component and y_t for the observed series; the cyclical component is $y_t - \tau_t$. λ denotes the HP filter smoothing parameter. The first term of the equation is the sum of the squared deviations $d_t = y_t - \tau_t$, which penalises the cyclical component. The second term is a multiple λ of the sum of the squares of the trend component's second differences, and penalises variations in the growth rate of the trade component. The larger the value of λ, the higher the penalty (Hodrick & Prescott, 1980). The standard value chosen for the smoothing parameter λ was 1600 (King & Rebelo, 1999).

The HP filter delivers smoothed non-linear representation of a time series, more sensitive to long term than to short term fluctuations. The HP filter was chosen as it is the most accurate method for detrending variables, and recently probably also the most common – it is especially useful when working with data from the US economy.

The HP filter was applied to produce cyclical components for key US macroeconomic variables. All the variables were placed in logarithms (except for the real interest rate) and detrended with the HP filter.

2.1. The model

Now, the authors constructed the model that works on the assumption that companies and households form rational expectations about future economic conditions, and in fact all DSGE models work only with rational expectations.

First, the model with households was examined. There are households in the economy which want to maximize their utility, a function of consumption C_t and leisure L_t. The expected utility depends on the development of C and L. Next, the study addressed endowments. Each individual is limited by time as there are only 24 hours per day. A person must somehow divide his/her time between work N_t and leisure activities L_t (sleeping is also treated as leisure activity). Therefore, an individual faces the time constraint $N_t + L_t = 1$, where 1 represents total available time.

2.2. Households

The first order conditions had to be set. The first part of efficiency conditions states that the marginal utility of consumption must be equal to its shadow price and cannot exceed the budget constraints mentioned above. Thus,

$$\frac{1}{c_t} = \lambda_t, \tag{2}$$

where λ_t represents shadow price.

The second pair of efficiency conditions states that the shadow price must be equal to marginal utility to consume MU_c with marginal utility of leisure expressed in terms of hours worked in this case. Thus,

$$\frac{\theta}{1-N_t} = W_t \lambda_t, \tag{3}$$

where N_t represents labour (total hours worked), W_t denoted the real wage rate, and parameter θ governs the labour supply elasticity.

Next, the study considered the Euler equation, which states that the return on capital net of depreciation must be equal to consumption growth. Let γ_x denote the gross growth rate of technology, defined as

$$A_{t+1} = \gamma_x A_t \ .$$

Along the balanced growth path, consumption grows at the same rate, i.e.

$$\frac{c_{t+1}}{c_t} = \gamma_x.$$

Thus,

$$E_t \beta \left\{ \frac{\lambda_{t+1}}{\lambda_t} [R_{t+1} + (1 - \delta)] \right\} = \gamma_x, \tag{4}$$

where R_t represents return on capital as well as real interest rate adjusted by depreciation, E denotes the expectation of future values of c, and L based on the information available at time zero, δ is the rate of depreciation, β represents a modified discount factor satisfying 0 < β < 1.

2.3. Companies

The model works with a perfectly competitive market, and differs from the new Keynesian model which works with monopolistic competition (Ball et al., 1988; Wang, 2019; Weinrich, 2007). In this model, there is an anonymous Walrasian auctioneer who seeks to clear all markets; price is equal to marginal product.

For these reasons, there is a clearing effect in the labour market, and marginal product of labour must be paid to real wage. Thus,

$$\alpha A_t \left(\frac{K_t}{N_t} \right)^{1-\alpha} = W_t, \tag{5}$$

where A_t is a random 'productivity shock', K_t represents amounts of capital, N_t is the labour supplied by households. Parameter α is referred to as labour share because if labour is paid its marginal product, it will earn that fraction of output. Accordingly, this parameter must always remain between 0 and 1.

The same is true for the capital market. The marginal product of capital is equal to return on capital. Thus,

$$(1 - \alpha)\, A_t \left(\frac{K_t}{N_t} \right)^{-\alpha} = R_t. \tag{6}$$

In practice, one can usually observe that the competitive equilibrium is not valid. The real wage rate is rarely equal to the marginal product of labour and also the rent is usually not equal to the marginal product of capital.

The last equation represents the production function. As the study applied the assumption of perfectly competitive companies, they transform inputs to goods by:

$$Y_t = A_t {K_t}^{1-\alpha} N_t^{\alpha}, \tag{7}$$

which describes the standard Cobb-Douglas production function.

2.4. Market clearing

Clearly, the output of the economy Y_t can be used only between consumption c_t and investment i_t, therefore an additional resource constrain is

$$c_t + i_t = Y_t. \tag{8}$$

Another equation represents the law of motion of capital

$$\gamma_x K_{t+1} = (1 - \delta)K_t + i_t. \tag{9}$$

The next equation relates to TFP shock

$$a_{t+1} = \rho a_t + \varepsilon_{t+1}, \tag{10}$$

where ρ represents the persistence parameter of productivity and ε_{t+1} is the TFP innovation (white--noise shock) with standard deviation $\sigma_\varepsilon = \ 0.0072$.

The last equation relates to time endowment already discussed above. One can divide his/her time between work and leisure activities, thus

$$N_t + L_t = 1. \tag{11}$$

2.5. Utility function

Next, the model had to be transformed into a stationary state, first, deriving the utility function

$$U = \sum_{t=0}^{\infty} \beta^t \left(\frac{ct}{1-\sigma}\ At\right) v(Lt), \tag{12}$$

where σ represents a coefficient of risk aversion, hence

$$U = \beta^0 \left(\frac{c0}{1-\sigma} A_0\right)^{1-\sigma} v(L_0) + \beta^1 \left(\frac{c_1}{1-\sigma} A_1\right)^{1-\sigma} v(L_1) + \beta^2 \left(\frac{c_2}{1-\sigma} A_2\right)^{1-\sigma} \nu(L_2) + \cdots. \tag{13}$$

then divide and multiply by $(A_0)^{1-\sigma}$

$$U = (A_0)^{1-\sigma} \left[\left(\frac{c_0}{1-\sigma}\right)^{1-\sigma}\right] v(L_0) + \beta^1 \left(\frac{c_1}{1-\sigma} \frac{A_1}{A_0}\right)^{1-\sigma} v(L_1) + \beta^2 \left(\frac{c_2}{1-\sigma} \frac{A_2}{A_0}\right)^{1-\sigma} \nu(L_2) + \cdots. \tag{14}$$

Now, assuming that A_t grows by constant rate, then

$$\frac{A_2}{A_0} = \frac{A_1}{A_0}\frac{A_2}{A_1} = \gamma_x \gamma_x = \left(\frac{A_1}{A_0}\right)^2. \tag{15}$$

In cases when $A_t = A$, there is a unique stationary state that occurs in the transformed economy.

Showing the intertemporal utility function again as a sum, and using the fact that A_t grows at a constant rate γ_x, we rescale the utility function to obtain a stationary representation, which introduces the modified discount factor $\bar{\beta} = \beta \gamma_x^{1-\sigma}$. Thus,

$$U = (A_0)^{1-\sigma} \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t}{1-\sigma} \gamma_x^t\right)^{1-\sigma} v(L_t). \tag{16}$$

Defining the discount factor as $\beta * \ = \ \beta \Delta At$, then

$$U = (A_0)^{1-\sigma} \sum_{t=0}^{\infty} \beta^{*t} \left(\frac{c_t}{1-\sigma}\right)^{1-\sigma} v(L_t). \tag{17}$$

The model assumes CRRA preferences with parameter σ. In the limiting case as $\sigma \rightarrow 1$, the utility function converges to the logarithmic form. Specifically,

$$\lim_{\sigma \to 1} \frac{(c_t A_t)^{1-\sigma} - 1}{1-\sigma} = ln(\, c_t A_t).$$

Therefore, the logarithmic specification is consistent with the marginal utility terms used in the Euler equation.

2.6. Steady state

In order to calibrate the parameters, first it was necessary to find steady state values in terms of parameters.

From the Euler equation one can ascertain the stationary real interest rate

$$\bar{r} = \frac{\gamma_x}{\beta} - 1, \tag{18}$$

and real return on capital

$$\bar{R} = \frac{\gamma_x}{\beta} - 1 + \delta. \tag{19}$$

Marginal return on capital depends on the ratio of capital to labour (rather than on its levels – this is implied by the assumption on production function). The capital-labour ratio $\frac{k}{N}$ was determined as a function of productivity and the rental rate. From the data it was known that $\bar{N} = 0.2$, thus determining $\bar{K}$ from the equation of marginal product of capital as

$$\bar{R} = MP^k = (1 - \alpha)\, \bar{A} \left(\frac{\bar{K}}{\bar{N}}\right)^{-\alpha}. \tag{20}$$

The capital labour ratio also defines if labour is productive, thus steady state wage is derived from the equation of marginal product of labour which is equal to real wage. The real wage rate is determined independently of the total quantity of labour

$$\bar{W} = MP^l = \alpha\bar{A} \left(\frac{\bar{K}}{\bar{N}}\right)^{1-\alpha}. \tag{21}$$

The production function determines steady state level of output. Labour productivity is given again by how much labour is equipped by capital

$$\frac{\bar{Y}}{\bar{N}} = A \left(\frac{\bar{K}}{\bar{N}}\right)^{1-\alpha}. \tag{22}$$

From the law of motion of capital, one can find steady state investment as a fraction of capital

$$\bar{\imath} = (\gamma_x - 1 + \delta)\bar{K} . \tag{23}$$

Steady state investment must cover at least the depreciation and labour augmenting growth in productivity. Consumption is derived from the equation of output, and it is placed on the left side of the equation, whilst the output no the right side, thus

$$\bar{c} = \bar{Y} - \bar{\imath}. \tag{24}$$

λ is derived from the equation that marginal utility of consumption is equal to its shadow prices as it cannot exceed budget constrain, hence

$$\frac{1}{\bar{c}} = \bar{\lambda}. \tag{25}$$

The author assumed that $\bar{A} = 1$ and θ can be taken from the labour supply equation.

The variables in the original economy are connected to variables of the transformed economy, therefore if the transformed economy is in a stationary state, the original economy remains in a steady state with many variables, for example consumption, capital output and real wages, growing at the same time, whereas variables such as work effort and the real interest rate remain constant. In cases when work effort is endogenous, the transitional dynamics change dramatically (Gómez & Sequeira, 2012; Mulligan & Sala-i-Martin, 1992).

2.7. Calibration

In order to explore the operation of their multiple sector business cycle model, the study drew parameters from the input-output tables for the US economy. This approach is known as calibration and it was first used by Long and Plosser (1983). Its popularity relates to the rational expectations revolution.

2.8. Cobb-Douglas production function

Approximately constant capital and labour shares of output imply the following production function

$$f(K_t) = A_t N_t^{\alpha} K_t^{1-\alpha}, \tag{26}$$

where α denotes the labour share of output, while $1-\alpha$ corresponds to the capital share, implying the standard expressions for MP_l and MP_k.

In competitive equilibrium, the real wage rate is equal to the marginal product of labour as $W_t \ = \alpha\, Y_t/N_t$. This implies that total wage income is $W_t N_t \ = \ \alpha Y_t$. Analogically one can derive for capital $(1 \ - \ \alpha)\ Y_t = \ R_t^k\ K_t$

The following equations are known

$$\alpha\ At\ K_t^{1-\alpha}\ N_t^{\alpha-1} = W_t \tag{27}$$

and

$$(1-\alpha)\ At\ K_t^{-\alpha} N_t^{\alpha} = R_t^k. \tag{28}$$

Parameter α is chosen to match the average ratio of wage income to real GDP in US data, yielding a value of approximately $\alpha = 2/3$. This is a standard value for the long-term US labour income share.

2.9. Technological growth factor $\varGamma$

The technological growth rate can be obtained from the average common trend growth rate of output, consumption, and investment, of about 1.6% annually. This implies that

$$\varGamma_x = (1+0.016)^{0.25} = 1.004, \tag{29}$$

ignoring growth in population in the calibration, as in most studies. If one incorporates population growth, the value of $\varGamma_x$ would be higher by approximately 0.002.

2.10. Discount factor β

The average real return to equity, which in the model corresponds to $r+1-\delta$, was around 6.5% per annum in the US. Note that the effective discount factor in the model with growth was

$$\beta = \frac{\gamma_x}{r+1-\delta} = 0.984. \tag{30}$$

2.11. Depreciation rate δ

The average level of TFP $\bar{A}$ did not play any role in the model dynamics and was just a scaling factor. Hence, without loss of generality one can normalise output in the deterministic steady state to unity, i.e. $A = 1$. Taking the average ratio of investment to GDP in the US, one arrives at 0.295. From the capital accumulation equation, the $\frac{\bar{\imath}}{\bar{y}}$ ratio is given by

$$\frac{\bar{\imath}}{\bar{Y}} = (\gamma_x - 1 + \delta)\frac{\bar{K}}{\bar{Y}} = 0.295. \tag{31}$$

Thus,

$$\frac{\bar{K}}{\bar{Y}} = \frac{0.295}{(\gamma_x - 1 + \delta)}. \tag{32}$$

From the Euler equation and MP_k one finds

$$\bar{R} = \frac{\gamma_x}{\beta} + \delta - 1 = MP^k = (1-\alpha)\frac{\bar{Y}}{\bar{K}}. \tag{33}$$

When applying this equation into the previous one, one obtains $\delta = 0.025$.

2.12. Leisure preference parameters η and θ

First, find $\bar{N} = 0.20$, which is the fraction of the time endowment spent in the workplace in the deterministic steady state. This value corresponds to the average workweek as a fraction of total weekly hours in US data, which determines the value θas

$$\theta = \frac{\bar{W}}{\bar{c}} \frac{(1-\bar{N})}{\bar{N}}. \tag{34}$$

Note that η is closely related the wage elasticity of labour supply, which equals $\frac{1-\bar{N}}{\bar{N}_{\eta}}$. The baseline calibration in King and Rebelo (1999) assumed an intermediate value of $\eta = 1$, which corresponded to a wage elasticity of a 4.1% change in the wage rate increases hours worked by 4%. The author followed King and Rebelo (1999) and set in the code $\rho = 0.979$ and $\sigma_{\varepsilon} = 0.0072$, however the wage elasticity of labour supply is lower in reality and therefore the value of η is higher, yet it was decided to remain with King and Rebelo (1999) values. In the calibration, θ determines the elasticity of labour supply, whereas η serves as a scaling parameter in the utility function.

Table 1. Calibration of baseline model

β	θ	Γ	α	δ	ρ	η	σ_{ε}
0.984	3.48	1.004	2/3	0.025	0.979	1	0.0072

Source: own calculation.

The table below summarises the parameters.

2.13. Extension of the model by capital utilisation

The standard version of the model brings a significant contrast between the short and long run elasticities of capital supply. Whereas the short-run elasticity of capital supply is zero, the long-run elasticity of capital supply is infinite, hence there is no opportunity to increase the capital stock inherited from the previous period in the short run. On the contrary, there is only one real interest rate consistent with the steady state in the long run, given by the assumption that capital services are proportional to the stock of capital. This assumption arrives at production function $Y = F(K, N)$. However, equipment and machinery are used much more intensively in times of economic booms than in times of recession, therefore the assumption is rather problematic for analysing business cycles. The flow of capital is high in an expanding economy, whereas capital has a tendency to lie idle during recession.

There are several assumptions which are usually connected to capital utilisation: households own the capital stock, households choose the level of utilisation, and households lease capital services to firms at rental rate R_t.

Next, incorporate capital utilisation into the model, starting with the production function. The utilisation rate is denoted by z_t. Capital services are then given by $z_t K_t$ Benefits from capital utilisation are clear from the production function where z_t increases the output.

One can write the production function as

$$Y_t = A_t (z_t K_t)^{1-\alpha} N_t^{\alpha}, \tag{35}$$

where z_t represents the utilisation rate.

It is also necessary to incorporate it into the equation of the law of motion of capital, then the costs of capital utilisation are clear from the equation the in form of faster depreciation:

$$\gamma_x K_{t+1} = \{1 - \delta(z_t)\}K_t + i_t. \tag{36}$$

The depreciation rate will be quicker due to capital utilisation, since if capital works harder, it also depreciates faster.

A company maximises its profits by holding fixed its future capital stock in order to determine its optimal rate of utilisation. Efficient utilisation implies that the marginal benefit in terms of additional output produced should be equal to the marginal cost in terms of additional units of capital being used up.

The first order conditions for consumption and labour were the same as before:

$$\frac{1}{c_t} = \lambda_t, \tag{37}$$

$$\frac{\theta}{1-N_t} = W_t \lambda_t. \tag{38}$$

Then Euler equation for capital looks different. The depreciation rate is increased by capital utilisation as well as R, hence

$$E_t \beta \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[R_{t+1\, z_{t+1}} + (1 - \delta(z_{t+1})) \right] \right\} = \gamma_x. \tag{39}$$

It is also necessary to add the equation for capital utilisation itself

$$\alpha \frac{y_t}{z_t} = \delta_0 \emptyset z_t^{\emptyset - 1} k_t, \tag{40}$$

$$\emptyset_1 + \emptyset_2 (z_{t-1}) = R_t, \tag{41}$$

where $\emptyset_1 + \emptyset_2$ are constants assosiated with capital utilization, $\emptyset$ represents the level of capital utilisation.

The first derivation of depreciation is equal to rental rate $\delta^{'}(z_t) = R_t$.

The equations of the labour market and the capital market are only adjusted by z_t which multiplies capital stock. Thus

$$\alpha\, \mathrm{A_t}\, z_t^{1-\alpha} K_t^{1-\alpha} N_t^{\alpha-1} = W_t, \tag{42}$$

$$(1-\alpha)\, A_t z_t^{1-\alpha} K_t^{-\alpha} N_t^{\alpha} = R_t. \tag{43}$$

The equations of the resource constraint, TFP shock and time endowment remain the same as in the classic RBC model. Thus,

$$c_t + i_t = Y_t, \tag{44}$$

$$a_{t+1} = \rho a_t + \varepsilon_{t+1}, \tag{45}$$

$$N_t + L_t = 1. \tag{46}$$

2.14. Steady state and calibration

To perform a normalisation of z^* to solve the steady state, the value is set to 1. This normalisation provides a parametric restriction on $\emptyset$. Thus

$$\emptyset = \frac{1}{\delta}\left((1-\alpha) \frac{y^*}{k^*} \right) \tag{47}$$

with $z^* = 1$, and from previous equations $MP^k = \left((1-\alpha) \frac{y^*}{k^*} \right)$. Therefore

$$\emptyset = \frac{\frac{1}{\beta} - (1-\delta)}{\delta} = \frac{\frac{1}{\beta} - 1}{\delta} + 1. \tag{48}$$

As $z^* = 1$, the average rate of depreciation remains at the same value as calibrated before, i.e. 0.025. Other parameters also have the same values. For setting the value of $\emptyset$, add the values into the equation:

$$\emptyset = \frac{\frac{1}{\beta}-(1-\delta)}{\delta}, \tag{49}$$

$$\emptyset = \frac{\frac{1}{0.984}-(1-0.025)}{0.025}, \tag{50}$$

$$\emptyset = 1.65. \tag{51}$$

One can summarise the calibration of baseline model with capital utilisation as

Table 2. Calibration of extended model

β	θ	Γ	α	δ	ρ	η	σ_ε	$\emptyset$
0.984	3.48	1.004	2/3	0.025	0.979	1	0.0072	1.65

Source: own calculation.

3. Results and discussion – comparison of results for the RBC model without capital utilisation, with results for the RBC model with capital utilisation

Capital utilisation rises in response to the TFP shock. In situations when TFP is high, companies usually need more capital, however they cannot receive more capital immediately – they must wait for it for some time. Thus, they utilise their own existing capital as that brings them almost the same benefit. Utilisation causes significantly higher growth of output. Accordingly, the output in the model extended by capital utilisation rises faster than in the basic RBC model.

Consumption and investment also increase faster in the model with capital utilisation, along with wages rising quicker due to the increase in labour demand exceeding the increase in the labour supply. There is a huge rise in the marginal product of labour due to the increase in utilisation and TFP. Conversely, the interest rate rises faster in the basic RBC model.

One can also see that even a relatively small TFP shock may cause significant output volatility in the RBC model with capital utilisation. Output volatility is significantly higher in the model with capital utilisation, which means that business cycles could be caused even by fairly small technology shocks.

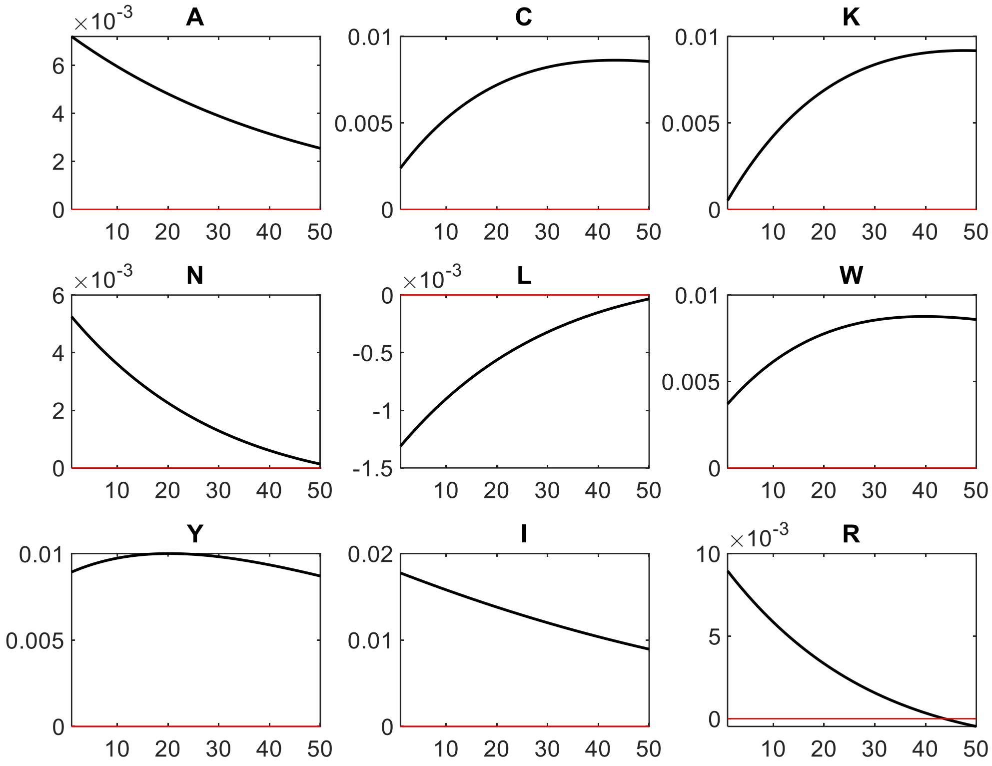

Fig. 1. IRFS-RBC model without capital utilisation

Source: (BEA, 2023; FRED, 2023; US Bureau of Labor Statistics, 2023), own processing in Matlab and Dynare.

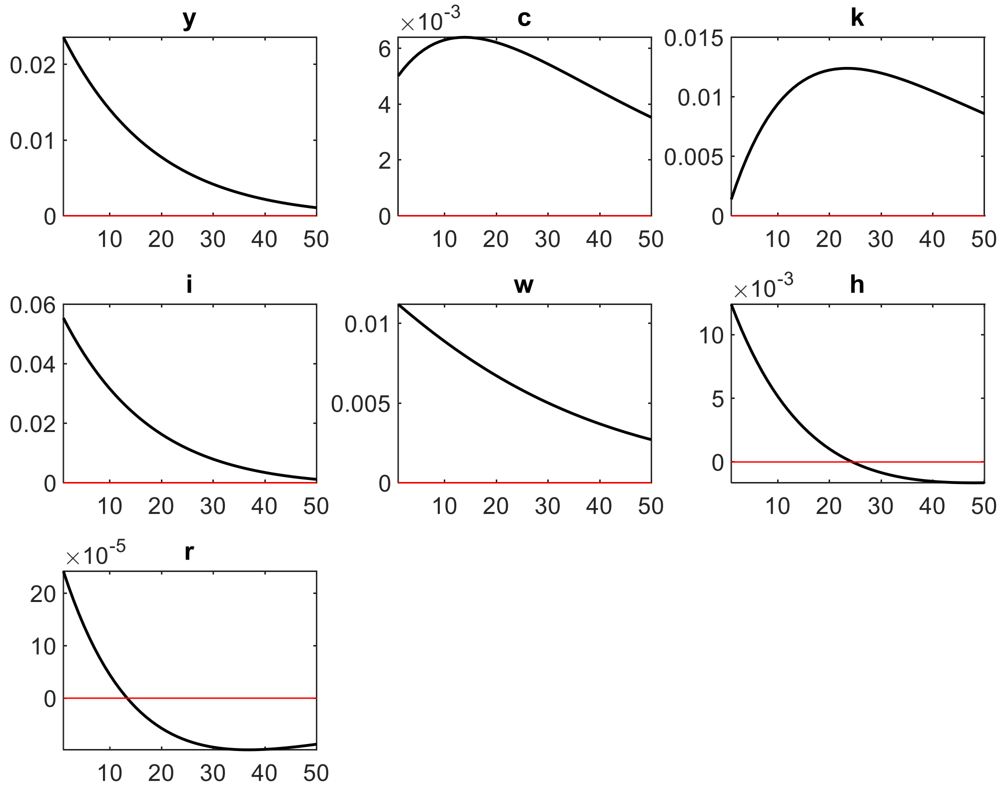

Fig. 2. IRFS-RBC model with capital utilisation

Source: (BEA, 2023; FRED, 2023; US Bureau of Labor Statistics, 2023), own processing in Matlab and Dynare.

One can see from the model that a rise in A directly increases output through $t = A_t N_t^{\alpha} K_t^{1-\alpha}$, thus it is possible to produce more with the same input. TFP actually plays a more important role than was thought in the past.

Interestingly, Solow (1957) tried to evaluate the importance of capital accumulation to economic growth, and discovered that capital accumulation accounted only for one-eighth of the total with the remainder attributable to growth in productivity.

Households know that there is more wealth going out, and if W and r remain constant, they would smooth consumption and leisure over time.

As was shown, the model works with perfect competition and perfect market clearing, consequently an individual can ask for a higher wage when his/her work becomes more productive. There will always be the optimum $\mathrm{MP}_l = W$.

The same applies for capital. If the yields from capital increase, the owner of the capital will ask for higher rents, thus $\mathrm{MP}_k = \mathrm{R}$ is the optimum.

Higher wages lead to an increase in the labour supply $\frac{\theta C_t}{1-N_t} = Wt$. Since individuals know that wages rise only temporarily, households buy more for current consumption as well as for future consumption and less for leisure, which increases the output even higher.

R is higher from $A_t \left(\frac{K_t}{N_t}\right)^{\alpha-1} \alpha = R_t$, K_t will increase only in the situation when investment increases first. A higher R also leads to a rise in $r = R - \delta$, which stimulates consumption growth from the Euler equation. From equation $E_t \beta\{1 + r\} = \gamma_x \frac{c_{t+1}}{ct}$, one can see that a higher *r* leads to the postponement of consumption and to an increase in savings, namely the higher interest rate income, the higher future consumption with the same amount of savings.

Rents and wages decrease as soon as A returns to a steady state. The drop in R and W is amplified by the accumulated capital. At the point $> K^e$, there the process of de-investment occurs, leading to a situation when depreciation exceeds investment. As the return on capital is small and the real interest rate is even negative, one will disinvest. After that, the income effect from wages outweighs the substitution effect, and thus one can enjoy less work for a higher salary.

4. Conclusion

This paper defends real business cycle theories and extends the basic RBC model by incorporating capital utilisation into the model. It also provides a full set of equilibrium conditions for the case of capital utilisation. The key finding was that business cycles could be generated even by small technology shocks since the impact on the output in the extended RBC model was much larger than in the basic RBC model. This is an important difference between these research results of this paper and those presented by King and Rebelo (1999), who concluded that only large technological shocks can generate realistic business cycles. This is the main added value of this study. The main differences between the results of the basic RBC model and the RBC model with capital utilisation are also discussed in this paper.

The constructed RBC model also proved extremely resilient to alternative parameterisations, similarly to King and Rebelo (1999). This study also successfully incorporated realistic price behaviour into the model, and its conclusions could provide a new perspective of the model by incorporating capital utilization into the RBC model, as well as valuable knowledge for monetary and fiscal policymakers, demonstrating that their interventions into their economies are often not essential. This is a different conclusion compared to those of New Keynesian, institutional or monetarist models.

There is still room for extending an already very complex model. Other researchers could, for example, focus on the volatility of investment. There is a general belief that company investment is 'lumpy' in character (Abel & Eberly, 1996; Caballero & Engel, 1999), therefore the RBC model may be extended by lumpy investment decisions of companies. In this regard, attempts to measure how lumpy investment decisions could influence aggregate dynamics have already been made by several economists (cf. Alvarez & Veracierto, 1999; Thomas, 2002; Winberry, 2021). Another way to extend the RBC model could be to enrich labour market dynamics through the incorporation of heterogenous agents. In this regard, there are several works of economists which may be used as the baseline (cf. Haan Den, 1995; Krusell & Smith, Jr., 1998).

References

Abel, A. B., & Eberly, J. C. (1996). Optimal Investment with Costly Reversibility. *The Review of Economic Studies*, *63*(4), 581-593. https://doi.org/10.2307/2297794

Adrian, T., Gaspar, V., & Vitek, F. (2022). *A Medium-Scale DSGE Model for the Integrated Policy Framework*. https://www.imf.org/en/Publications/WP/Issues/2022/01/28/A-Medium-Scale-DSGE-Model-for-the-Integrated-Policy-Framework-511926

Alvarez, F., & Veracierto, M. (1999). Labor-Market Policies in an Equilibrium Search Model. *NBER Macroeconomics Annual*, 14, 265-304. https://doi.org/10.2307/3585315

Ball, L., Mankiw, N. G., Romer, D., Akerlof, G. A., Rose, A., Yellen, J., & Sims, C. A. (1988). The New Keynesian Economics and the Output-Inflation Trade-Off. *Brookings Papers on Economic Activity*, *1988*(1), 1-82. https://doi.org/10.2307/2534424

BEA. (2023). National Economic Accounts | U.S. Bureau of Economic Analysis (BEA). https://www.bea.gov/data/economic-accounts/national

Caballero, R. J., & Engel, E. M. R. A. (1999). Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach. *Econometrica*, *67*(4), 783-826.

Christiano, L. J., Eichenbaum, M. S., & Trabandt, M. (2018). On DSGE Models. *Journal of Economic Perspectives*, *32*(3), 113-140. https://doi.org/10.1257/jep.32.3.113

Cochrane, J. H. (1994). Permanent and Transitory Components of GNP and Stock Prices. *The Quarterly Journal of Economics*, *109*(1), 241-265.

Čermáková, K., Bejček, M., Vorlíček, J., & Mitwallyová, H. (2021). Neglected Theories of Business Cycle – Alternative Ways of Explaining Economic Fluctuations. Data 2021, 6, 109. https://doi.org/10.3390/data6110109

Čermáková, K., Procházka, P., Kureková, L., & Rotschedl, J. (2020). Do Institutions Influence Economic Growth? *Prague Economic Papers*, *29*(6), 672-687. https://doi.org/10.18267/j.pep.749

Eddine, S. S., Ooussama, R., & Abdellah, E. (2021). Trade openness and tax structure in Morocco: Evaluation and impacts. *International Journal of Economic Sciences*, *X*(1), 100-127. https://doi.org/10.52950/ES.2021.10.1.007

Francis, N., & Ramey, V. A. (2009). Measures of per Capita Hours and their Implications for the Technology-Hours Debate. *Journal of Money, Credit and Banking*, *41*(6), 1071-1097.

FRED. (2023). GDP, NIPA – Economic Data Series | FRED | St. Louis Fed. https://fred.stlouisfed.org/tags/series?t=gdp%3Bnipa&ob=pv&od=desc

Friedman, M. (1956). *The Quantity Theory of Money – A Restatement – Items – Collected Works of Milton Friedman*. https://miltonfriedman.hoover.org/objects/58154/the-quantity-theory-of-money--a-restatement

Ghalayini, L. (2018). Monetary policy and business cycle fluctuations of the Lebanese economy. *Journal of Economic Structures*, *7*(1), 28. https://doi.org/10.1186/s40008-018-0126-y

Gómez, M. A., & Sequeira, T. N. (2012). The Transitional Dynamics of an Endogenous Growth Model: Generalizing Production Functions. *Studies in Nonlinear Dynamics & Econometrics*, *16*(5). https://doi.org/10.1515/1558-3708.1937

Haan Den, W. (1995). The term structure of interest rates in real and monetary economies. *Journal of Economic Dynamics and Control*, *19*(5-7), 909-940.

Hellwig, C. (2010). Monetary Business Cycles (Imperfect Information). In: S. N. Durlauf & L. E. Blume (Eds.), *Monetary Economics* (pp. 181-188). Palgrave Macmillan UK. https://doi.org/10.1057/9780230280854_23

Hodrick, R., & Prescott, E. (1980). Postwar U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking*, *29*(1), 1-16.

Jaimovich, N., & Rebelo, S. (2007). Behavioral Theories of the Business Cycle. *Journal of the European Economic Association*, *5*, 361-368. https://doi.org/10.1162/jeea.2007.5.2-3.361

Kim, S. (1998). *Monetary policy rules and business cycles*. Banco de España.

King, R. G., & Rebelo, S. T. (1999). *Resuscitating Real Business Cycles* (Working Paper No. 7534). National Bureau of Economic Research. https://doi.org/10.3386/w7534

Krusell, P., & Smith, Jr., A. A. (1998). Income and Wealth Heterogeneity in the Macroeconomy. *Journal of Political Economy*, *106*(5), 867-896. https://doi.org/10.1086/250034

Kydland, F. E., & Prescott, E. C. (1982). Time to Build and Aggregate Fluctuations. *Econometrica*, *50*(6), 1345-1370. https://doi.org/10.2307/1913386

Long, J. B., & Plosser, C. I. (1983). Real Business Cycles. *Journal of Political Economy*, *91*(1), 39-69.

Lucas, R. E. (1973). Some International Evidence on Output-Inflation Tradeoffs. *The American Economic Review*, *63*(3), 326-334.

Lucas, R. E. (1976). Econometric policy evaluation: A critique. *Carnegie-Rochester Conference Series on Public Policy*, *1*, 19-46. https://doi.org/10.1016/S0167-2231(76)80003-6

McDonald, D., & Shalizi, C. (2022). *Empirical Macroeconomics and DSGE Modeling in Statistical Perspective*.

Mulligan, C. B., & Sala-i-Martin, X. (1992). *Transitional Dynamics in Two-Sector Models of Endogenous Growth*.

Obstfeld, M., & Rogoff, K. (1986). Ruling Out Divergent Speculative Bubbles. *Journal of Monetary Economics*, *17*, 349-362.

Pala, A. (2020). The Relation between Climate Change and Economic Growth: The Investigation of The Regional Differences with RCM Model in EU-28 Countries. *International Journal of Economic Sciences*, *IX*(1), 135-155. https://doi.org/10.20472/ES.2020.9.1.008

Plosser, C. I. (1989). Understanding Real Business Cycles. *Journal of Economic Perspectives*, *3*(3), 51-77. https://doi.org/10.1257/jep.3.3.51

Poudyal, N., & Spanos, A. (2022). Model Validation and DSGE Modeling. *Econometrics*, *10*(2), 17. https://doi.org/10.3390/econometrics10020017

Prince, T. (2017). *Behavioral Finance and the Business Cycle*. ArmgPublishing. https://armgpublishing.com/journals/bel/issue-4/article-3/

Reichlin, L., Giannone, D., & Lenza, M. (2019). *Money, credit, monetary policy and the business cycle in the euro area: What has changed since the crisis?* Publications Office. https://data.europa.eu/doi/10.2866/32939

Rötheli, T. F. (2007). Business forecasting and the development of business cycle theory. *History of Political Economy*, *39*(3), 481-510. https://doi.org/10.1215/00182702-2007-019

Sargent, T. J. (1982). The Ends of Four Big Inflations. In R. E. Hall (Ed.), *Causes and Effects* (NBER Chapters, pp. 41-98). University of Chicago Press. https://www.nber.org/books-and-chapters/inflation-causes-and-effects/ends-four-big-inflations

Setyari, N. P. W. (2020). Factors proportion in trade pattern and international capital flows interaction in ASEAN+4 Countries. *International Journal of Economic Sciences*, *IX*(2), 94-110. https://doi.org/10.20472/ES.2020.9.2.006

Srivastava, A., & Režábek, P. (2022). Impact of Digital Payments on the Economic growth of a country: the case of the Czech Republic. *International Journal of Economic Sciences*, *XI*(1), 85-104. https://doi.org/10.52950/ES.2022.11.1.006

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, *39*(3), 312-320. https://doi.org/10.2307/1926047

Summers, L. H. (1986). *Some Skeptical Observations on Real Business Cycle Theory*. Federal Reserve Bank of Minneapolis. https://www.minneapolisfed.org:443/research/quarterly-review/some-skeptical-observations-on-real-business-cycle-theory

Thomas, J. (2002). Is Lumpy Investment Relevant for the Business Cycle? *Journal of Political Economy*, *110*(3). https://www.journals.uchicago.edu/doi/full/10.1086/339746?casa_token=dJCcpibYM9IAAAAA%3AjoUhD9Q1QEMLpLFbLFbAJnYi3y9vEU79IfQNqqSH1l6Djx5AO_szk81dOWb6p1xBFZebNc4x_P8

U.S. Bureau of Labor Statistics. (2023). U.S. Bureau of Labor Statistics. https://www.bls.gov/

Wang, R. (2019). Monopolistic Competition and Nominal Stickiness in Generalized New Keynesian Model. *Discussion Papers*. https://ideas.repec.org//p/koe/wpaper/1913.html

Weinrich, G. (2007). New Keynesian monopolistic competition and objective demand. *Journal of Mathematical Economics*, *43*, 153-173. https://doi.org/10.1016/j.jmateco.2006.08.003

Winberry, T. (2021). Lumpy Investment, Business Cycles, and Stimulus Policy. *American Economic Review*, *111*(1), 364-396. https://doi.org/10.1257/aer.20161723

Received: March 2024, May 2024

Acknowledgment: *This research was supported by IGA VŠE IG506014*.