Analysis of economic activity movements in the Czech Republic – frequency approach

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Abstract

The primary purpose of this work is identification of the business cycle types in the Czech Republic 1996/Q1 – 2008/Q3. In the light of business cycles problematic, viewed from frequency analysis perspective, harmonic analysis will be used. For obtaining cyclical fluctuation, deterministic as well as stochastic methods are applied. According to the empirical results, two approaches to business cycle are discussed, classical and growth type. From the range of de-trending techniques first order difference, linear filtering, unobserved component model and Hodrick-Prescott filter are used. In the case of Hodrick-Prescott fitler, cyclical fluctuation estimate with derivation of smoothing parameter especially for the Czech Republic case is investigated. The aim is, on the basis of empirical analysis, to distinguish types of cyclical fluctuations in the Czech Republic according to the work of Schumpeter. Consequently analysis of potential sources of cyclical movement is done.

Keywords
harmonic analysis, deterministic trends, stochastic cycles, economic activity, business cycle

JEL
E32 Business Fluctuations, Cycles C16 Econometric and Statistical Methods, C51 Model Construction and Estimation

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Introduction

In many studies, economic activity of a country is being discussed in respect to business cycle theory. Recall for example Canova (1998, 1999) business cycle study from de-trending and dating turning-points point of view. Also King and Rebelo (1993) using Hodrick – Prescott (HP) filter in time and frequency domain or Harding and Pagan (2006) with description of different measuring ways of business cycle. There are variety of approaches to de-trending methods, approximations between filtering methods and effect of used techniques on obtained results. Nevertheless, the empirical analysis results are different to the data approach ones. Correctness of the business cycle identification consists of stabilization function of monetary and fiscal policy.

Most of these studies work with advanced market economy, like US economy which having at disposal large data sample size. The case of the Czech Republic is different. The type of economy in this country is denoted as transition, while economy was transformed from central planned economy to market economy with shocks, structural breaks and with small sample size of available data.

Thus, this paper is focused on the business cycle in the Czech Republic from frequency domain point of view using harmonic analysis for identification possible types of cycles. Available data are quarterly values of Gross Domestic Product (GDP) 1996/Q1 – 2008/Q3. Consequently, analysis of potential sources of cyclical movement is done. Identification sources of cyclical movements can notably contribute to the effectiveness of economic policy during economic activity stabilization.

Methodology

Standard theory of Burns and Mitchel (1946) business cycle is used: "Business cycles are a type fluctuations found in the aggregate economic activity of nations that organise their work mainly in business enterprises: a cycle consists of expansion occurring at the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; in duration business cycles vary from more than one year to ten to twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own." There exist two approaches to business cycle. The first one is called classical business cycle and is based on fluctuation in the level. The second one is known as the growth cycle and is based on fluctuation around a trend. The dating of cycles is usually done by identified of turning-points. Time period is usually too short, full of structural breaks and shocks. On the other hand growth cycle, where turning-points are characterized by changes relative to the trend, represents more promising version of the business cycles (Artis & col, 2004). And, the dating procedure of the growth cycle is less sensitive to the growth trend than that of the classical cycle.

In the field of business cycle, cyclical movements of a time series, that exhibit trends and cycles, are studied. If the models are designed to characterize the cyclical behavior, the trends are eliminated prior to analysis. It is often useful to build model, where both trend and cyclical behavior are in the model and eliminate trend from the model and from actual data in parallel fashion. The specification of the model is subject to the constraint that it must successfully characterize trend behavior. Having satisfied the constraint, trends are eliminated appropriately and the analysis proceeds with investigation of cyclical behavior. The isolation of cycles is closely related to the trends removal. Indeed, for time series exhibiting cyclical deviations about trend, the identification of the trend automatically serves to identifying the cyclical deviations as well. Denotes, that the removal of the trend will leave such fluctuation intact, and its presence can have a detrimental impact on inferences involving business cycle behavior.

Economic activity in this paper is measured by absolute values of GDP (y_t) transformed to the natural logarithms and denoted as Y_t. For analysis of business cycle additive decomposition method in the form

$$Y_t = g_t + c_t,\ i=1,\dots,n \qquad (1)$$

is used. There are three leading approaches to removing time trend from macroeconomic time series. The first two approaches to trend removal are de-trending and differencing. De-trending is usually accomplished by fitting linear trend to log input values using an ordinary least square method (OLS). The third approach to de-trending involves the use of filters designed to separate trend from cycle, but given admission of slowly evolving trend. We use Hodrick – Prescott filter, which has proven as popular in business cycle applications. Thus, the set of chosen de-trending method is following: first order difference (FOD), autoregression with/without constant (AR), regression analysis (linear and quadratic trend) and Hodrick – Prescott filter (HP filter).

In our study, we are not discusing if these methods are "the best" for trend removing as well as which one is more or less suitable and why. We just overtake some of standardly used methods as the result of other studies, for example Canova (1998), Baxter and King (1999), Hodrick and Prescott (1980) or books Mills (2003) or Dejong, Chetan (2007), and search for statistically significant periods. Usage of several methods for de-trending gives support to the robustness of periodicity analysis in the sense cyclical movement source identification. Because calculating FOD as well as estimating process of random walk with/without drift and regression curve using OLS is well known, we are not discussing its in detail. In case resultant deterministic models, quadratic one and AR (with or without constant) were chosen according to the standard statistical techniques for quality model evaluation

The procedure of HP filter was first introduced by Hodrick and Prescott in 1980 in the context of estimating business cycles. HP filter decompose Y_t (macroeconomic time series) into nonstationary trend g_t (growth component) and stationary residual component c_t (cyclical component)

$$Y_t = g_t + c_t,\ t=1,\dots,T,$$

g_t and c_t are unobservables. Measure of the g_t path smoothness is the sum of the squares of its second difference. Application of the HP filter involves minimizing the variance of the cyclical component c_t subject to a penalty for the variance in the second difference of the growth component g_t

$$\min_{\{g_t\}_{t=1}^{T}} \sum_{t=1}^{T} (Y_t - g_t)^2 + \lambda \sum_{t=1}^{T} \left[(g_{t+1} - g_t) - (g_t - g_{t-1})\right]^2 ,$$

where $c_t = Y_t - g_t$. The parameter λ is a positive number which penalizes variability in the growth component series. As Harvey and Jager (1993) have shown, the infinite sample version of the HP filter can be rationalized as the optimal linear filter of the trend component. King and Rebelo (1993) find that the business cycle component and the second difference of the growth component must have the same moving average representation for the HP filter to be the linear filter, which minimizes the mean squares error. That is, this filter minimize the mean square error

$$MSE = (1/T) \sum_{t=1}^{T} \left(ets(c_t) - c_t\right)^2 ,$$

where c_t is the true cyclical component and est(c_t) is its estimate. Hodrick and Prescot found that if cyclical component c_t and the second difference of growth component g_t ($\Delta^2 g_t$) are identically and independently distributed normal variables, $c_t \sim N(0, \sigma_c^2)$, $\Delta^2 g_t \sim N(0, \sigma_g^2)$, then the best choice in the sense of MSE for smoothing parameter is $\lambda = \sigma_c^2 / \sigma_g^2$. In many papers, recommended lambda value for quarterly data is $\lambda=1600$, Ahumada, Garegnani (1990), Guy, St-Amant (1997), Hodrick-Prescott (1980) and others. On the basis of this, let's formulate the rule which helps us to find optimal smoothing parameter.

Let's have input time series of positive values Y_t, $t=1,\dots,n$, set of lambdas $L = [100/n; 100 \cdot n]$ and indexed set $I = [1,\dots,length(L)]$. Thus, for every $L_i \in L$, $i \in I$ we can calculate Hodrick – Prescott estimate of growth and cyclical component of Y_t. Let cyclical component c_t and the second difference of growth component g_t ($\Delta^2 g_t$) be identically and independently distributed normal variables, $c_t \sim N(0, \sigma_c^2)$, $\Delta^2 g_t \sim N(0, \sigma_g^2)$. Thereafter, the optimum value of smoothing parameter λ is such, that

$$\lambda_{opt} = \sigma_c^2 / \sigma_g^2 \Leftrightarrow L_i \approx \sigma_c^2 / \sigma_g^2, \quad \text{for any i} \in I$$

where the difference $d = \left|L_i - \sigma_c^2 / \sigma_g^2\right| \le 100/n$.

For periodicity analyse in the time series following harmonic analysis was used. After removing trend T_t, residuals were obtained, i.e.

$$e_t = Y_t - T_t,\ t = 1,\dots,n.$$

For the analysis of random sequence in the form

$$e_t = \mu + \sum_{j=1}^{n/2} (a_j \cos(\omega_j t) + b_j \sin(\omega_j t)) + \varepsilon_t,\ t = 1,\dots,n ,$$

where μ, a_j, b_j and ω_j $(0 < \omega_j \leq \pi)$ are unknown parameters, e_t is stationary process, periodogram is usually used. In points $\omega_1,\ldots, \omega_r$ periodogram constructed for given sequence of realization have relatively big values, and thus makes it possible to find estimates of the parameters $\omega_1,\ldots, \omega_r$ including value r (corresponding statistical procedure is called Fishers test of periodicity and is discussed later in the text). Coefficients a_j, b_j are estimated using ordinary least squares method (OLS) in standard, they represent regression parameter for the j-th smoothing sinusoida, resp. cosinusoida, and for its calculation holds following formula derived on the basis of OLS

$$a_j = \frac{n}{2}\sum_{t=1}^{n} e_t \sin(\omega_j t), \quad b_j = \frac{n}{2}\sum_{t=1}^{n} e_t \cos(\omega_j t), \quad j = 1,\ldots,n/2 .$$

Next, variability corresponding to the j-th smoothing sinusoida and cosinusoida is calculated according to the formula

$$\mathrm{var}_j = 1/2(a_j^2 + b_j^2) .$$

Testing of statistical significancy of all possible periods and connected theoretical variance is done by Fisher test (Anděl, 1976). As was mentioned above, it is suitable to use some stationary test, so we propose augmented Dickey-Fuller (ADF) test (Wooldridge, 2003).

Empirical analysis

Input data set for economic activity measurement in this paper are values of Gross Domestic Product (GDP) in the Czech Republic. Available data are quarterly values 1996/Q1 – 2008/Q3. Denote, GDP values in absolute form (y_t) were before analysis transformed into natural logarithms and denoted as Y_t (figure 1).

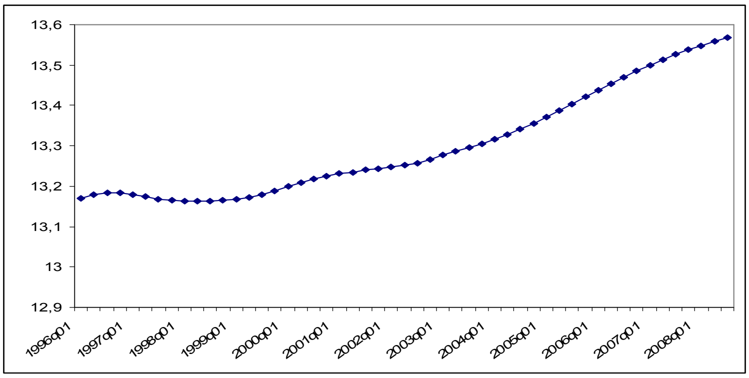

Fig. 1: GDP (natural logarithm values) for the Czech Republic 1996/Q1 – 2008/Q3

In the first step of empirical analysis stationary test of input values was done. According ADF test logarithmic values of Czech Republic GDP are trend stationary on 5% significance level with lag p=2. We can permit the effects of random disturbance disappears gradually over time, because our variable grows along a trend. Chosen methods for de-trending were first order difference (FOD, e_1), autoregression with/without constant (AR, e_2; ARc, e_3), regression analysis (linear and quadratic time trend; e_4) and Hodrick – Prescott filter (HP filter, e_5, e_6). Table I below describes OLS estimates of some models. In case of deterministic model quadratic regression gives better results then linear regression, thus in next analysis this type of regression is used. For AR process OLS estimated with and without constant are significant. Hence, both cases were involved in the analysis of periods. Hodrick – Prescott filter is calculated for two types of smoothing parameter λ. At first λ = 1600 (e_5) on a regular basis value for quarterly data is taken. At the second as ratio of variances calculated from values for the Czech Republic $\lambda_{opt} = \sigma_c^2 / \sigma_g^2 = L = 115$ (e_6).

Table I. Estimates of some chosen models

	Parameter estimate	SE	t-value	F-test	p-value	R_{adj}^2	n
Quadratic regression				4609,24	$1{,}4\cdot10^{-55}$	0,9946	51
const.	13,1757	0,0042	3127,1802		$4\cdot10^{-129}$		
t	-0,0023	0,0004	-6,0495		$2{,}1\cdot10^{-7}$		
t^2	0,0002	$7\cdot10^{-6}$	29,3705		$2{,}5\cdot10^{-32}$		
AR const				4280,1	$1{,}7\cdot10^{-72}$	0,9988	50
const.	-0,4527	0,0665	-6,8089		$1{,}4\cdot10^{-8}$		
Y_{t-1}	1,0346	0,0050	206,8868		$1{,}7\cdot10^{-72}$		
AR				$2{,}3\cdot10^{8}$	$4\cdot10^{-162}$	0,9796	50
Y_{t-1}	1,0006	6,6·10-5	15273,9762		$3\cdot10^{-165}$		

Statistical significance at the 1% (***), 5% (**), 10% (*)
Source: Own calculation

Before applying harmonic analysis, residuals obtained by application of de-trending methods are tested for zero mean stationarity (ADF1). Table II shows results. Figure 2 shows residuals in correspondence to the used de-trending method. Notation is used "name of detrending method, corresponding residuals", for example "FOD, e_1".

Table II. Results of ADF stationarity test

	FOD, e_1	quadratic, e_2	AR cons., e_3	AR, e_4	HP1600, e_5	HP115, e6
ADF1	No	Yes, ***	Yes, ***	Yes,**	Yes, ***	Yes, ***
Lag		2	3	3	2	2

Statistical significance at the 1% (***), 5% (**), 10% (*)
H_0: non-stationarity of e_t, t-stat. > quantil, (No)
H_1: stationarity of e_t, t-stat. < quantil, (Yes)
Source: Own calculation

The basic assumption for FOD procedure applications are, that trend component of analysed time series is random walk with no drift and, that cyclical component is stationary and both components are uncorrelated (Canova, 1998). Thus, $g_t= Y_{t-1}$, $t=1,...,T-1$, should be in the Czech Republic case random walk with no drift. This condition can be taken as satisfied even knowledge that random walk with drift gives statistically better results. But stationarity test (ADF1) for the cyclical component (tabular II, denotation FOD, e_1) showed non-stationarity (even in case stationarity around constant). From this reason FOD can not be taken for the Czech Republic as de-trending method. From economic point of view values of ΔY_t more corresponds to the classical business cycle concept then growth type of cycle. Even though, FOD doesn't give stationary residuals, we do periodicity test to see results for classical business cycle.

Unobserved component (UC) model (Canova, 1998) for de-trending method in the Czech Republic is mentioned above as random walk process with drift and with stationary cyclical component of finite order AR process type. From the table I we can see statistically significant values for estimated model, table II present stationarity result for corresponding cyclical component (AR cons., e_3). Therefore, this method is suitable. But comparing FOD and AR residuals shape and AR cons. residuals in the figure 3 we can "eyemetrically" see similarity in the second half of period the curve shape with FOD residuals. Thus, even satisfaction assumptions of UC method, it was decided not to recommend take this method as de-trending for the Czech Republic case.

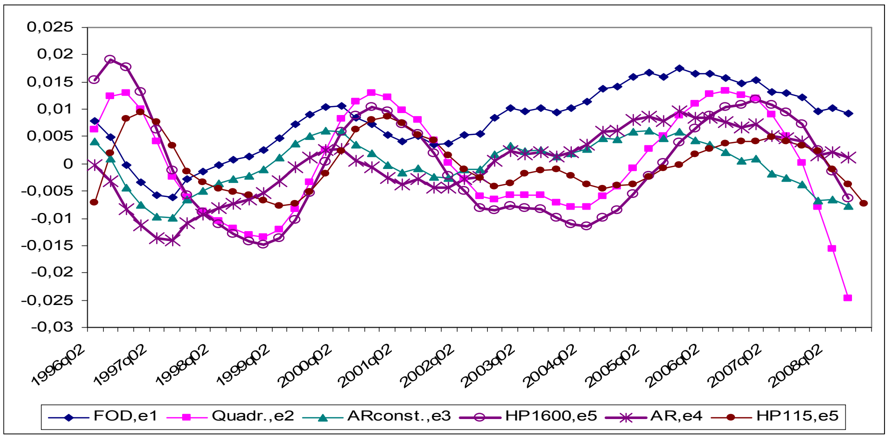

Fig. 3: Corresponding residuals for used de-trending methods.

In following step application of harmonic analysis for identification possible types of cycles on all given residuals is done. Denote, de-trending using AR and FOD one value was lost. Results of calculated periodicity and testing statistical significancy are given in table III below. Two lengths of sample size and two corresponding periods for used de-trending methods are caused by loosing one value in case of FOD and AR models. This difference is quite small, thus periods in one column are considered as similar.

Table III. Results of statistical significance of periods.

periods	50	25	16,6667	12,5	10	8,33333	7,14286	6,375
FOD,e1		**						
ARc,e3	***	***	***	***	**			
AR,e4	***	***		**				
periods	51	25,5	17	12,75	10,2	8,5	7,28571	6,375
HP1600,e5	***	***	***	***	**	***	***	
HP115,e6		***	***	***		***	***	***
Quadrat.,e2		***	***	***				

Statistical significance at the 1% (***), 5% (**), 10% (*)
Source: Own calculation

As discussed above, FOD technique and its residuals don't satisfy assumptions for application and taken it as de-trending method doesn't to give a reasonable result. Because of economic reasons these values correspond better to the classical type of business cycle theory, we can use result for thinking about periodicity in classical business cycle. If eye-metric analysis of given figure 2 is done, we can see some similarity in FOD, AR residuals trending. In addition, the FOD residuals are not stationary opposite to AR residuals. Thereby periodicity analysis of AR residuals will be taken as confirmative for the FOD residuals.

According to the periodicity Schumpeter (1939) proposed following group of cycles named by the scientist, who identified their existence in time series. The shorter one is the Kitchin inventory cycles of 3-5 years. Then the Juglar fixed investment cycles of middle length 7-11 years. And the longer one, the Kuznets infrastructural investment cycles of 15-25 years. The longest one, Kondratieff waves of long technological cycle of 45-60 years are not considered, because available sample size for the Czech Republic is small. These authors identified cycles from the aspect of their source, the cycle length can be different in the countries and time.

The success of dating growth cycles crucially depends on quality of the approximation of trend component. In our case Hodrick-Prescott filter, random walk with drift and quadratic de-trending helped identifing growth cycle, while FOD and AR are used for classical business cycle dating. All residuals time series approvingly denoted as significant period of 6,25 years. This cycle duration is of the Juglar type caused by fixed investment.

Periodicity of FOD residuals showed as significant only 25 periods, i.e. 6,25 years periodicity. Using AR residuals more significant periods were found. In other cases residuals describe growth business cycle. Comparing all of them, cycles of length 6,25, 4,25 and 3,19 years were detected. Using Hodrick-Prescott filter additional cycles, shorter ones, was detected with cycle duration of 2,125-1,6 years. For special λ, derived for the Czech Republic, Hodric-Prescott identified also the longest period of 12,75 years. For ARc residuals, results show similar statistical significance period as quadratic and Hodrick-Prescott filter. All these three cyclical components agreed with three kind of periodicity, namely 6,375, 4,25 and 3,18 years. Comparison of classical and growth business cycle concept validates for the Czech Republic observation (Bonenkamp, 2001) fact, that classical cycle peaks come later in time than growth cycle peaks.

Hence, the basic type of cycle can be found in the Czech economy evolution - the shortest Kitchin cycles caused by the inventories as well as the middle one Juglar cycles caused by the fixed investment. On the basis of harmonic analysis, results completed by economic research of cycle correlation analysis were proceeded. For classical BC as well as for growth BC the Kitchin inventory, the Juglar fixed investment cycles were identified as well as the Kuznets infrastructural ones. In case of growth BC also shorter type of cycle was identified.

Table IV. Correlation coefficients between residuals and economic factors

Correlation	final consumption expenditure	final consumption expenditure of households	final consumption expenditure of general government	gross capital formation	gross fixed capital formation	changes in inventories	exports of goods and services	imports of goods and services	net exports of goods and services
Quadrat.,e2	0,1687	0,3039 **	-0,0973	0,4655 ***	0,4077 ***	0,1837	0,3444 ***	0,4638 ***	0,0590
ARc,e3	0,1278	0,2204	-0,0581	0,3645 **	0,2440 *	-0,2359	0,2643 *	0,2397	-0,1251
HP1600,e5	0,1945	0,3313 **	-0,0875	0,3981 ***	0,4713 ***	0,2445 *	0,3210 **	0,4283 ***	0,1913
HP115,e6	0,2036	0,2987 **	-0,0233	0,4618 ***	0,4372 **	0,2498 *	0,3351 **	0,5107 ***	0,1072

Statistical significance at the 1% (***), 5% (**), 10% (*)
Source: Own calculation

Hence economic factors possibly influencing cyclical fluctuation in the Czech Republic based on data availability were chosen - final consumption expenditure, final consumption expenditure of households, final consumption expenditure of general government, gross capital formation, gross fixed capital formation changes in inventories, exports of goods and services, imports of goods and services net exports of goods and services all in time 1996/Q1 - 2008/Q3 as percentage change to the corresponding previous period. With the aim of the study, relation tightness correlation coefficients between economic factor and de-trended time series were calculated (Table IV above).

Thereafter source of cyclical movements in the Kitchin sense caused by inventory was statistically significant only on 10% level for one de-trending method. From the correlation coefficient result (r = 0,24) is this dependence rather weak. In the Czech Republic cyclical movements of the short type is more influenced by consumption of households, correlation showed significant results for several de-trending time series on 5% significance level.

Further, source of cyclical movements in the Juglar sense was highly significant for gross capital formation (correlation from 0,36 to 0,46) and gross fixed capital formation (correlation from 0,40 to 0,46) and can be denoted as the middle one. Question is which type of cyclical movements is influenced by export and import in the Czech Republic. Results of correlation showed high statistical significance for middle level of correlation.

Conclusion

This paper is focused on the business cycle in the Czech Republic from frequency domain point of view using harmonic analysis for identification of possible types of cycles. For obtaining cyclical fluctuation, deterministic as well as stochastic methods were applied. According to the empirical results, two approaches of business cycle are discussed, classical and growth type. Consequently, analysis of potential sources of cyclical movement is done.

Chosen methods for de-trending were first order difference, autoregression with/without constant, quadratic time trend and Hodrick – Prescott filter. In case of Hodrick – Prescott filter two types of smoothing parametr were used ($\lambda=1600$ and $\lambda=115$). The success of dating growth cycles crucially depends on quality of the approximation of trend component. In our case, Hodrick-Prescott filter, random walk with drift and quadratic de-trending helped to identify growth cycle, while first order difference and autoregression process without constant are used for classical business cycle dating. Next, harmonic analysis for identification possible types of cycles in all given residuals (include first order difference and random walk process residuals) was done. All residuals time series approvingly denoted as significant period 6,25 years. This cycle duration is the Juglar type caused by fixed investment.

As mentioned in introduction part, the Czech Republic post-transforming economy dispose with limited sample size of available data. Even if we study classical BC concept, this length gives possible one period with respect to the shocks, structural breaks and development of the country. Growth business cycle better react to this features and is less sensitive to the trend. Thereafter, application of HP filter, random walk with drift and quadratic regression detected wide scale of significant periods. From the longest one (12,5 years), through the medium (around 6 years), to the shorter one (between 2-4 years). In both cycle concepts same effects of nested loops took place.

Thus, the basic type of cycles in the Czech economy evolution were identified, the shortest Kitchin cycle caused by the inventories as well as the middle Juglar cycle caused by the fixed investment. In case of growth BC also shorter type of cycle was identified. Hence, economic factors possibly influencing cyclical fluctuation in the Czech Republic based on data availability were chosen and correlation between cyclical movements and economic factors was investigated.

Thereafter, source of cyclical movements in Kitchin sense caused by inventory was statistically significant only on 10% level for one de-trending method and this dependence is rather weak. Cyclical movements of the short type cycles are more influenced by consumption of households, correlation in this case showed significant results for more de-trendingtime series. Further, source of cyclical movements in the Juglar sence was highly significant for gross capital formation and gross fixed capital formation and can be denoted as middle one.

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