New Trends and Issues Proceedings on Humanities and Social Sciences

Volume 4, Issue 10, (2017) 23-32

www.prosoc.eu

ISSN 2547-8818

Selected Paper of 6th World Conference on Business, Economics and Management (BEM-2017)

04-06 May 2017, Acapulco Hotel and Resort Convention Center, North Cyprus

The relationship between M3 and consumer price index in the Czech Republic

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Suggested Citation:

Cernohorska, L. & Klejzar, V. (2017). The relationship between M3 and consumer price index in the Czech Republic. *New Trends and Issues Proceedings on Humanities and Social Sciences*. [Online]. *4*(10), 23–32. Available from: www.prosoc.eu

Selection and peer review under responsibility of Prof. Dr. Çetin Bektaş, Gaziosmanpasa University, Turkey

Abstract

The aim of this paper is to analyse the influence of monetary aggregate M3 on consumer price index (CPI) in the Czech Republic. Co-integration of this selected indicator M3 is demonstrated in relation to the development of CPI using the Engle – Granger co-integration test. These tests are applied to selected statistical data from 2003 to 2016. First step is to determine the optimum delay using Akaike criteria for all-time series analysed. Then the presence of a unit root is analysed using the Dickey–Fuller test. Based on the test results, time series is excluded, which appears to be stationary. If the conditions are met, testing then continued with the Engle–Granger test to detect cointegration relations, which would determine a long-term relationship between selected variables. Based on these tests, it is found that at a significance level of 0.05 doesn't exist cointegration relationship between M3 and CPI in the Czech Republic. Conclusions resulting from the verification of the hypotheses are supported with graphical visualisation of data from which it is apparent that these hypotheses can be rejected.

Keywords: Akaike crieteria, Dickey–Fuller test, Engle–Granger cointegration test, CPI, M3.

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1. Introduction

Although the history of central banking in its current form can be counted only in decades, central banks are currently an essential part of economic life in developed countries. The mechanism of how monetary policy operates as an effective weapon against negative stages of the economic cycle – which decreases economic performance, increases unemployment and causes price instability – depends on the validity of theories assuming the effectiveness of monetary policy and its ability to at least partially influence real economic variables via changes in the amount of money in the economy. Central banks employ monetary policy tools, which they use to achieve their goals: to maintain price stability (the central banks' primary goal) and to support healthy economic development. The effect of these tools on real economic variables happens through the various channels of monetary policy's transmission mechanism. According to monetary theory, the central bank can, as a result, influence not only inflation but also the evolution of GDP, unemployment, the trade balance and other variables – including the economic cycle – over the short term.

The credibility of monetary policy is also an important factor, because expectations for future economic development, which can influence economic development more than the early effects of monetary policy on its own, play an important role in the real economy. If the central bank's policy is not credible and calculable, expectations can be at odds with the central bank's policy, and its measures may not have any repercussions and may cause the transmission mechanism to fail.

The effects of central bank policy appear in the economy with a certain delay. Generally, this is said to be a period of 12 to 18 months. This causes the central bank to take measures not in relation to its current state but in relation to its future development, on the basis of forecast. However, economic development is often very difficult to predict. Expectations for the economy and the delay in the effects of monetary policy can be definite barriers encountered by monetary policy. Another barrier that monetary policy can encounter is the situation where the interest rates they have announced are set at such a low level that lowering them further is ineffective, and there are no repercussions in the real economy. Most contemporary monetary tools for supporting an economy in recession and combating deflation are actually based on changing these interest rates; in doing so, the central bank attempts to influence monetary aggregates via the monetary base.

In connection with the financial crisis and the resulting economic crisis, the central banks were presented with the problem of seeking new monetary tools to combat deflation. The choice fell to unconventional monetary policy; the European Central Bank, the Bank of England and the FED resorted to quantitative easing. The Czech National Bank (CNB) selected currency intervention as its tool. Currency intervention is one of the unconventional tools used by central banks; it is used to stimulate the economy if standard monetary policy tools are not sufficiently effective.

The goal of this paper is to analyse the influence of the M3 monetary aggregate on the size of the price level in the Czech Republic for 2003 to 2016.

2. Literature Review

Paradoxically, the theoretical basis for the policy of quantitative easing is the quantity theory of money, which states that the growth of monetary reserves has a direct influence on inflation. Over the long term, this causality has been empirically proven. The growth of monetary reserves cannot influence real quantities; it influences only the price level. The question remains as to what its impact is in the short term. If it is possible to influence economic development via the quantity of money over the short term, quantitative easing as part of a suitably conducted monetary policy would be able to help in the struggle with the economic cycle.

Restrictive or, conversely, expansive monetary policy would be able to confront a fluctuating economy and smooth out the economic cycle. The development of the quantity theory of money is consequentially a history of seeking answers to the question of whether money is neutral even over the short term. In modern economic history, this closely relates to the role of central banks and the monetary policy they implement.

Central banks work with monetary aggregates and at the same time, define them as well. Using these aggregates, they influence the amount of money in the national economies. Monetary aggregates are funds that differ in their degree of liquidity. The European Central Bank (ECB) defines monetary aggregates as 'narrow' (M1), 'intermediate' (M2) and 'broad' (M3). 'Narrow' aggregates, M1, consist of the most liquid assets; i.e., including currency in circulation (banknotes and coins), as well as balances that can immediately be converted into cash or used for cashless payments (such as overnight deposits). 'Intermediate' aggregates, M2, include 'narrow' money (M1) plus deposits with an agreed maturity of up to 2 years, and deposits redeemable at notice of up to three months. 'Broad' money, M3, comprises M2 along with marketable instruments issued by the Monetary Financial Institution sector. (ECB, 2009)

As of the 1980s, price stability has been increasing its dominance as the primary goal of monetary policy. In the 90s, a number of countries – lead by New Zealand, Canada and the United Kingdom – switched to the regime of inflation targeting. The CNB also accepted this regime in 1998 as the eighth to do so.

Currently, nearly 30 countries use inflation targeting. In comparison to previous monetary policy regimes, this form of monetary policy focuses directly on inflation goals without the existence of intermediary goals. The intermediary goal is basically replaced by an inflation forecast, which has become a key element of inflation targeting (Zamrazilova, 2014).

As of 1993, the CNB had been implementing a conventional monetary policy. It used interest rates as its main monetary policy tool. During the period of 2007 to 2012, the CNB managed to get by with standard monetary policy tools, when it gradually lowered its interest rates by nearly 4% points between August of 2008 and November of 2012. At the same time, the spontaneous weakening of the koruna in reaction to a drop in international demand and the domestic economy markedly contributed to the relaxation of monetary conditions starting halfway through 2008. Specifically, at that time, the exchange rate had proven its ability to act as an automatic adjustment mechanism, which was available to the Czech economy with its independent monetary policy (Cernohorský, 2015). The CNB reached for an uncommon tool only in November of 2013, which entailed using the koruna's exchange rate as a tool (the element of reinforced forward guidance was also used before this at the end of 2012). The CNB arrived at this step later, only during the period of the gradual easing of the effects of the global financial and economic crisis, i.e., the related European debt crisis, when monetary conditions were completely relaxed by lowering the monetary policy rates to 'technical zero'. From the forecast and the CNB's supplemental analysis, it was nevertheless increasingly clear that this easing would not suffice to meet the inflation target, i.e., to lessen the pending risk of deflation. The CNB therefore announced that it would intervene (if necessary) on the exchange market to weaken the koruna's exchange rate by holding the koruna to the euro at CZK 27/EUR. At the same time, the CNB announced that it had decided to intervene at this rate for as long as necessary to achieve the required exchange rate amount, and thereby to meet its future inflation target in a steady way (Franta et al., 2014).

There have been many studies written in recent years on the subject of currency intervention. Most of these, however, focus only on how currency intervention influences exchange rate (e.g., Vitale, 2011; Reitz & Taylor, 2012). Fratzscher et al. (2015) investigated the currency intervention of 33 central banks (including the CNB) from 1995 to 2011. The authors came to the conclusion that currency intervention is a very effective monetary policy tool (although in the sense of its influence on exchange rate). The authors of these studies did, however, emphasise that the effectiveness of currency intervention always depends on the circumstances under which the intervention is implemented. For this conclusion to be understood correctly, it is necessary to realise that currency intervention's influence on the economy is essentially composed of two influences. The first is how the currency intervention influences the exchange rate, and the second is how the exchange rate influences other economic variables, e.g., inflation.

Using the exchange rate as a tool for overcoming inflation has been recommended by economic literature as of the start of this past decade in reaction to Japanese experience. For example, McCallum (2000) demonstrated that the central bank in open economies can, at the zero lower bound on interest rates, use devaluing domestic currency to stabilise inflation and the real economy.

3. Methodology

We have used data that has been regularly recorded at specific intervals to observe and analyse the evolution of economic variables. This type of data is called a time series and will be used for the subsequent evaluation of the individual hypotheses.

The analysis of experimental data that have been observed at different points in time leads to new and unique problems in statistical modelling and inference. The impact of time series analysis on scientific applications can be partially documented by producing an abbreviated listing of the diverse fields in which important time series problems may arise (e.g., economics, stock markets, environmental sciences or medicine). (Shumway and Stoffer, 2010)

Granger and Engle (1991) recent developments in the field of cointegration, which links long run components of a pair or of a group of series. It can then be used to discuss some types of equilibrium and to introduce them into time-series models in a fairly uncontroversial way. The idea was introduced in the early 1980s and has generated much interest since then amongst econometricians and macroeconomists. In the light of the paper's objective, the concept of cointegration – dealt with primarily by the authors Granger and Engle (1987) – is used to investigate the how M3 affect CPI in the Czech Republic.

For verifying whether the model is specified correctly, it is possible to use simple specification criteria, information criteria or various types of tests. One option for comparing the models that have been designed is to use information criteria. This method compares alternative specifications and includes the cleaning of the residual sums of squares by the range of the sample n and the number of regression parameters *p*. Inverse correlation applies when evaluating this procedure – the model with the lowest value for the information criterion is classified as the best. The Akaike information criterion, the Bayesian information criterion and the Hannan-Quinn information criterion are used the most often in practice. (Hampel et al., 2012)

The Akaike information criterion (AIC) was developed by Hirotsugu Akaike in 1971. The influence of the penalty term for this criterion is the lowest of all the criteria mentioned.

$$AIC = n \cdot \ln\left(\frac{RSS}{n}\right) + 2k \tag{1}$$

where RSS is the residual sum of squares,

k is the number of parameters,

n is the number of measurements, and

the term RSS/*n* is residual variance.

The Bayesian information criterion (BIC) was proposed by Gideon E. Schwarz in 1978. This criterion is related to the Akaike criterion, but the degree of penalty for adding parameters is greater here than in the AIC. The BIC is calculated by the relationship:

$$BIC = n \cdot \ln\left(\frac{RSS}{n}\right) + k \ln n \tag{2}$$

where RSS is the residual sum of squares,

k is the number of parameters, and

the term RSS/*n* is residual variance.

The Hannan-Quinn criterion (HQC) was proposed by E. J. Hannan and B. G. Quinn in 1979. It was original intended for time series models. This criterion has been designated HQC and is calculated by the relationship:

$$HQC = n \cdot \ln\left(\frac{RSS}{n}\right) + 2kc \ln \ln n \tag{3}$$

where RSS is the residual sum of squares

k is the number of parameters,

n is the number of measurements,

c is the additive constant, and

the term RSS/*n* is residual variance.

First, the time series that have been presented here are always tested for optimal lag length. This is done using the AIC, when the best lag (used later in the subsequent tests) is always taken to be the lowest AIC value. The time lag between when a macroeconomic shock or other adverse condition is recognised by central banks and the government, and when a corrective action is put into place. The response lag may be short or long, depending on whether policy makers have a definite course of action or must deliberate on the right action to take (Mankiw, 2014).

$$(M) = \ln \sigma a 2 + 2M / T \tag{4}$$

The tests are conducted on the basis of the relationship of the values in Eq. 4, where *M* expresses the number of parameters, $ln\sigma a2$ denotes residual variance and *T* is the number of observations (Arlt and Arltova, 2007).

Distinguishing between types of time series as stationary and non-stationary is very important when examining their relations, as the use of non-stationary time series could result in a situation, which is referred to as apparent or senseless regression.

There are several statistical tests to determine the order of integration, known as unit root tests. Here we have employed the probably most widely used of them, which is known by the name of its creators, the Dickey–Fuller test (hereinafter referred to as the augmented Dickey–Fuller (ADF) test). This test then is used to analyse whether the time series is of type I (0) – stationary or I (1) – non-stationary.

The analysis was conducted in the Gretl 1.9.4 program for econometric analysis; this program makes it possible to conduct an ADF test for this case. For more details, see Dickey and Fuller (1979).

Three versions of the ADF test are commonly used for verifying hypotheses – one with a constant, one without a constant and one with both a constant and a trend. When testing, we used the assumption that the process listed below (Eq. (2)), where we test that Ø = 0 (the variable contains a unit root), takes the following form (Arlt and Arltova, 2007):

$$\Delta X_t = (\phi_1 - 1) X_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta X_{t-i} + e_t \tag{5}$$

X_t expresses the dependent variable, p lag, and e_t the residual term. Deciding on the stationarity – or the non-stationary – of a time series will be conducted by evaluating the p values (the level of significance is in this paper always set at 0.05), which thus establishes whether the null hypothesis is rejected or accepted with 95% probability. For this test, this is formulated as follows:

H_0: the tested series are non-stationary (a unit root exists)

H_1: the tested series are stationary (a unit root does not exist)

Since non-stationarity can be assumed for the series analysed, and the said apparent regression cannot arise when using a stationary time series (the type I (0) series), the option is offered here to remove it by differencing (stationing) individual analysed series. However, research carried out by authors such as Banerjee et al. (1993) have demonstrated that this path cannot proceed, because it will result in the loss of important information on long-term relationships between the properties of time series. For the analysis of unsteady relationships between series, the EG test (Engle and Granger, 1987), was therefore used, which is able to analyse cointegration of non-stationary time series according to the following hypotheses:

H_0: Test series are not cointegrated

H_1: Test series are cointegrated

Decisions on the relationship between time series are based on *p* values defined by the EG test. If the null hypothesis ($p > 0.05$) is not rejected, the time series will be identified as non-cointegrated – thus, for series between which there is no long-term relationship, or for series which contain no common element and examining them as a system is irrelevant since they have developed over the long term independently. Otherwise (in cases where $p < 0.05$) the time series will be identified as cointegrated; i.e., for series between which a long-term relationship can be demonstrated at a level of significance.

4. Data

The primary goal of this paper is to statistically verify hypotheses on the causality of the relationships between the development of the quantity of money in the economy and the price level in the Czech Republic for the years 2003 to 2016. On the basis of the previous development of the M3 monetary aggregate, we test its influence on the evolution of the price level (CPI). Using the results, we will prove or reject correlation of the M3 monetary aggregate's development with the growth of the price level in the Czech Republic. We test the ties between the selected variables using the stationarity or non-stationarity of the time series and their resulting cointegration or non-cointegration according to the methods presented in Section 2.

We established the time period as the period between 2003 and 2016. We derived the data from the CNB statistics. We have performed tests on the statistical data selected from the first quarter of 2003 to the fourth quarter of 2016. The input data are quarterly in nature and have been cleaned from seasonal influence.

5. Results and Findings

With respect to the paper's goals, we used the concept of cointegration, which has been dealt with primarily by the authors Engle and Granger (1987), to investigate the influence of the M3 monetary aggregate on the price level in the Czech Republic.

The Engle-Granger cointegration test is used to test the causal relationship between the overall amount of the M3 monetary aggregate and CPI. The absolute values are tested for these values. If the deviation of the time series trends is only short-term (and disappear over time), then there is a limit beyond which the deviation cannot continue - it can then be stated that the time series are in equilibrium. The statistical expression of this condition is called a 'cointegrated time series'. If there is no such limit, then it cannot be said that they are in equilibrium; thus statistically speaking, such a time series cannot be said to be cointegrated. It is natural that when examining relationships between economic time series, mainly cointegrated series are of any interest, as only for these series can the nature of their relation be analysed. If the time series are not cointegrated, then for a long time they will not contain any common element and their investigation as a system can be regarded as irrelevant, as they have developed over the long term independently (Artl, 1997).

The time series used are listed for the period of all four quarters of the year 2003 up to all four quarters of the year 2016.

5.1. Testing for optimal lag length using the AIC, BIC and HQC

The first analysis investigates the influence of CPI development on the development of the M3 monetary aggregate in the Czech Republic. The model is based on the assumptions listed in Section 2. Both the variables have been observed using quarterly data for the years 2003 to 2016.

On the basis of the theoretical model, the first prerequisite before determining the time series' cointegration is the test verifying optimal lag length. The optimal lag length is determined using information criteria in a dynamic regression equation. The AIC, BIC and HQC were used for the dependent variable to determine optimal lag. The results of the optimal lag for the CPI are listed in absolute values for the test with a constant in Table 1, for the test with a trend in Table 2 and for the test with both a constant and a trend in Table 3.

Before using the EG test, it is necessary to test the time series for optimal lag, where the dependent variable is the value of CPI. Table 1 list the values of the AIC criterion for six lag lengths (the lowest value is always shown in bold type). The optimal lag results determined that, according to the Akaike criterion's lowest values, a lag length of 6 always appears to be optimal for the absolute values of the dependent variable of CPI. This optimum delay correspondents to the economic theory, where is mentioned the optimum time delay of 12 to 18 months. (Mankiw, 2014; CNB, 2016)

On the basis of the lowest value found for the information criterion, an optimal lag length of six is specified for the dependent variable of the CPI, which was determined for the AIC. For this time series, this concerned lag when including a constant and a trend. This lag will be taken into consideration in the subsequent tests.

Table 1: Results of optimum delay for CPI – test with constant

Order of delay	Information criterion		
-	AIC	BIC	HQC
1	1,783901	1,900851	1,828096
2	0,686232	0,842165	0,745159
3	0,650062	0,844979	0,723721
4	0,649525	0,883425	0,737916
5	0,585220	0,858104	0,688343
6	**0,060766**	**0,372633**	**0,178621**
7	0,082888	0,433739	0,215475
8	0,112645	0,502473	0,259964

Table 2: Results of optimum delay for CPI – test with trend

Order of delay	Information criterion		
-	AIC	BIC	HQC
1	1,833166	1,950116	1,877361
2	1,072732	1,228666	1,31660
3	0,827904	1,022821	0,901563
4	0,759668	0,993568	0,848059
5	0,653648	0,926532	0,767771
6	0,288058	0,599924	**0,405912**
7	0,23650	**0,588500**	0,370237
8	**0,218385**	0,608218	0,365704

Table 3: Results of optimum delay for CPI – test with constant and trend

Order of delay	Information criterion		
-	AIC	BIC	HQC
1	1,813576	1,969510	1,872504
2	0,630004	0,824921	0,703664
3	0,6525629	0,85929	0,714020
4	0,640040	0,912924	0,743163
5	0,590497	0,902364	0,708352
6	0,023284	0,374134	0,155870
7	0,052526	0,442359	0,199844
8	0,086920	0,515735	0,248970

5.2. The results of the ADF test

The second basic prerequisite before testing for cointegration is to verify and, if necessary, establish stationarity for the time series. Establishing stationarity for the time series will be conducted using an ADF. The null hypothesis is used for this test when the tested time series are not stationary.

Possible non-stationarity of data can lead to apparent regression; the difficulty with this lies mainly in the fact that using the least squares method would make it possible to obtain statistically significant parameter estimates of the regression function – even though the time series analysed do not relate to each other. For this reason, it is necessary to test the time series used here with the help of an ADF test. The results of the ADF test for a unit root in the model with constant and trend, are shown in Table 4. The results of the ADF unit root test, in this case using a model with a constant and a trend are shown in Table 4 (where all *p* values for each parameter of the variables analysed are displayed successively).

Table 4: The results of the augmented ADF test for a unit root in the model with constant and trend

	Value of *p* parameter	Evaluation of ADF test results	H_0:
Test with constant and trend for CPI	0,2547	Time series non-stationary	Not refused
Test with constant and trend for M3	0,2671	Time series non-stationary	Not refused

It can be seen from the results of the ADF unit root test that the original data for all the time series in the model with a constant are non-stationary. Non-stationarity of the time series means that illusory correlation could occur when conducting correlation analysis. Stationarity for all the time series was achieved only after they had been differenced; the time series are then integrated at the order of I (1) (Table 5).

Table 5: The results of the augmented ADF test for a unit root in the model with constant and trend – first differences

	Value of p parameter	Evaluation of ADF test results	H0:
Test with constant and trend for CPI	0,01057	Time series stationary	refused
Test with constant and trend for M3	0,03075	Time series stationary	refused

In the preceding test, we determined the original data's non-stationarity and, after correction by differencing, both series are now stationary at the same order. On the basis of these results, we proceeded to the cointegration test. We conducted the cointegration test using the Engle-Granger test. For this test, it is necessary for the original time series to be non-stationary and to have the same order of integration. We have demonstrated both conditions in Table 5. The null theory for cointegration is that the tested time series are not cointegrated.

5.3. Cointegration analysis – the Engle–Granger test

We have listed the results of cointegration analysis for the selected time series in Table 6. The number of the *p*-value distinguished the time series as non-cointegrated.

Table 6: Results of the Engel–Granger cointegration test and ADF test for CPI

Variable abbreviation	*P*-value	Length of delay	H_0:	Conclusion
CPI – M3	0.1577	6	Not refused	No cointegration

On the basis of the results, we can state that there was no mutual long-term relationship shown for these variables during the period under observation. We have also supported the conclusions resulting from the analysis with a graphic visualisation of the data, from which the rejection of the hypothesis is clear (Figure 1).

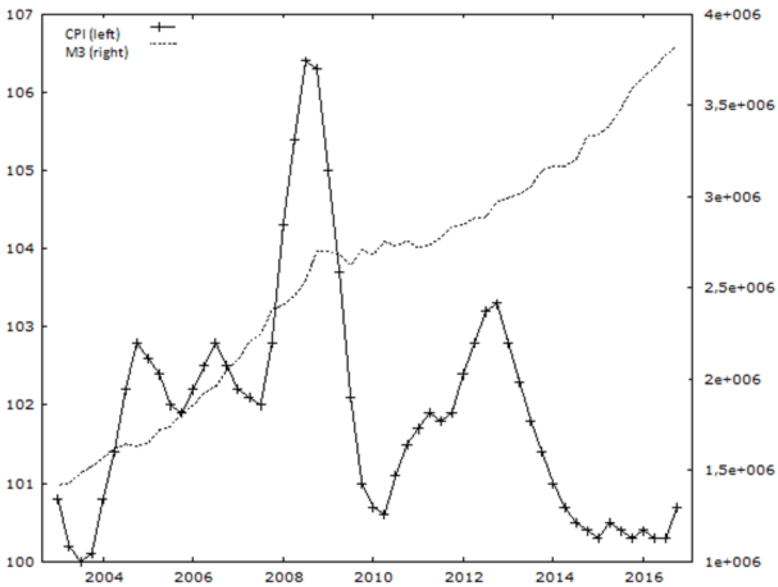

Figure 1.The development of M3 and CPI in the Czech Republic from 2003 to 2016

6.Conclusion

On the basis of the ADF test and the cointegration test, conducted using the Engle–Granger test, we determined that no mutual relationship between the M3 monetary aggregate and the CPI was proven in the Czech Republic for the period of 2003 to 2016. We rejected the proposed hypotheses.

At the time of writing this paper, it was too early to evaluate the effectiveness of the CNB's currency intervention (and thereby the growth of M3); the intervention's goal was to increase CPI. (For now, we can state that the Czech economy has ceased to act in a distinctly anti-inflationary way, as had been assumed). The implementation of currency intervention has most likely resulted in constraining a fall into deflation in the Czech Republic. We must point out that, in the Czech Republic, any possible deflation will not be caused by the economic crisis but by a gradual drop in the price level as a result of growing competition on the market for mobile phone operators, which has pushed the prices down sharply, and a decrease in the prices for electricity, natural gas and water since the second half of 2012. The Czech Republic has definitely not been faced with the threat of long-term deflation as in Japan, because the decrease in the price level there had a different cause than in the Czech Republic.

In further research, it would be possible for us to focus on models that allow for the endogenity of variables. Such studies do exist, but they primarily process data from the USA (e.g., Liang, 2011; Feldstein & Stock, 1994). It would certainly be interesting to apply the same models to other countries that have tried to face deflation using the growth of monetary reserves in the form of unconventional monetary policy. Using these methods, however, requires a greater amount of observation and longer time series.

Acknowledgements

The paper has been created with the financial support of The Czech Science Foundation (project GACR No. 17-02509S, 'Emerging financial risks during a global low interest rate environment') and financial support of The Scientific Research Activities (project No. SGS_2017_022).

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