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THE IMPACT OF RESERVE REQUIREMENTS OF CENTRAL BANKS ON MACROECONOMIC INDICATORS

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Abstract. This article explores the central banks' awareness of the potential and application of reserve requirements for stimulating economic growth. The authors examined the differences in the impact of reserve requirements of central banks on the economic indicators in five countries, namely: Japan, Norway, South Africa, Brazil, and China. These countries have different levels of economic development and different banking systems and required reserve systems, which determined their inclusion in the study. The article assesses the possible impact of central banks on GDP and GNI through changes in reserve ratios. Thus, this research contributed to the discussion about the role of reserve requirements of central banks in the development of a country's economy and industry. The results were obtained with a new mathematical apparatus that analyzed and assessed various aspects of the impact of monetary policy tools on macroeconomic indicators that are not considered in classical econometric models. The authors made an assumption that the reserve requirements of the central banks should not be considered as the controlling factor in the changes in the economic indicators of the countries under study or as a tool that can operate independently of other instruments.

Keywords: monetary policy tool; reserve requirements; obligatory reservation system; required reserve ratio; gross domestic product; gross national product

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JEL Classifications: E00, E02, E50, E59, E6

1. Introduction

Reserve requirements allow central banks to influence the active part of the balance sheet of banks, thereby forcing the banking sector to make certain types of investments. The changes in reserve requirements are most often driven by the changes in reserve ratios. Depending on a country, there are different approaches to the use of reserve ratio as an element of monetary policy, namely, the amount of required reserves (Malhasyan, 2013; Barmuta *et al.,* 2019). There are two main reasons why banks have reserves. First, in most countries, banks have

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to keep a certain amount of cash as a reserve for various types of deposits (required reserve ratios). Second, banks use excess reserves to settle payments, for example, on overnight loans. In this paper, we analyzed the monetary policy of six countries and the impact of changes in the required reserve ratio on major economic indicators.

2. Literature review

According to A. K. Kashyap, J. C. Stein (1995), and C. E. Walsh (2010), a contractionary monetary policy may lead to a decrease in bank deposits if the central bank increases the volume of required reserves or manipulates the multiplier. In addition, B. S. Bernanke (2007) and P. Disyatat (2011) claim that attracting deposits and market financing becomes more complicated and expensive due to a contractionary monetary policy. F. S. Mishkin (1995) believes that monetary policy influences the economy and the price level through various instruments: setting interest rates, asset prices, exchange rates, the impact on expectations, accepting risks, checking the balance sheet, and refinancing lending institutions.

D. H. Dutkowsky and D. D. VanHoose (2017) assume that under the conditions that have developed since 2008 and considering the interest in reserves, the adopted monetary policy can lead to regime changes. The latter brings about quantitatively and even qualitatively different reactions to external changes in bank balances, as well as the outcomes in the loan market and deposits. In contrast to the view that the structural change that took place in 2008 was non-recurrent, it is likely that there will be a switch among several different modes depending on the settings of the reserve ratio, federal funds rate, and reserve interest rate. Dutkowsky, D. H, VanHoose, D. D. (2018) considers the impact of the Federal Reserve Service payments of various interest rates on required and excess reserves. The transition of the Federal Reserve Service mode to banks with positive excess reserves and minimal interbank lending enhances the effect on the bank loan of the current main policy tool of the interest rate on excess reserves compared to the effect of its previous main instrument, the federal funds rate. This mode also mitigates the impact of deposit supply shocks on the volatility of bank credit, while also enhancing the impact of demand shocks on loans. Dutkowsky, D. H, VanHoose, D. D. (2018 a) revealed that a change in the Federal Reserve Services policy of paying interest on reserves at a rate significantly higher than the federal funds rate has led to a shift in the banking environment with a large volume of wholesale loans to financial institutions and almost zero excess reserves by one in which wholesale lending has become minimal, and excess reserves substantial.

Tatom A. John (2014) concludes that the U.S. Congress could improve reserve management by outlawing the payment of interest on excess reserves, discontinuing the existing subsidy to banks to hold required reserves, and setting the discount rate on mandatory reserves to a level slightly lower than the treasury rate bills and rates on federal funds.

S. Dressler, E. Kersting (2015) noted that excess reserves act as an extensive bank-lending margin that is inactive in traditional limited participation models, where banks assume minimal reserves. Their study showed that this extensive bank-lending margin could weaken and even reverse the standard effect of liquidity on cash reduction. When the liquidity effect is canceled, the contraction of the money supply leads to an increase in output. In addition, changes in the interest rate paid on reserves can give large short-term answers.

Cochrane H. John (2014) explores the regime for calculating interest on reserves, in which reserves always pay market interest and the balance remains large. S. D. Williamson (2015) argues that changes in central bank balances and changes in reserve interest rates can have a similar influence on nominal interest rates, but have very different effects on economic welfare. An increase in the balance sheet of the central bank may lead to a decrease in wealth due to book costs of holding reserves in the retail-banking sector.

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J. R. Hendrickson (2017) claims that paying an interest rate on excess reserves that exceeded comparable short-term rates, the Federal Reserve probably discouraged Bernanke's portfolio rebalancing channel. For instance, the payment of interest on reserves increased the efficiency of payment processing, possibly by limiting the influence of monetary policy on economic activity.

W. Whitesell (2006) evaluates reserve regimes in comparison with interest rate corridors, which have become a competing factor in the implementation of monetary policy. The system of voluntary weighted average reserve obligations can be equally beneficial for smoothening the rate. If central banks created symmetrical opportunity costs associated with meeting weighted average reserve requirements (or obligations) or failure to fulfill them, they could maintain a single fluctuation stock on the settlement day.
D. D. VanHoose (1986) assesses the potential role of interest in required reserves as an instrument of monetary control. It has been established that an increase in the interest rate on reserves held in the Federal Reserve has a counteracting effect on the volatility of money supply. Therefore, there is an optimal interest rate on required reserves, which theoretically can include or lie somewhere between extreme cases of the absence or highest possible interest payment.

A. Hoffmann and A. Loffler (2014) emphasize the relationship between interest rate policies in large advanced economies and international financing and reserve currencies (the United States and the Eurozone) and the application of reserve requirements in emerging markets. Having analyzed the data on the reserve requirements in 28 emerging markets from 1998 to 2012, they prove that central banks in emerging markets tend to increase reserve requirements when interest rates in international finance markets decrease or financial flows accelerate, which most likely contributes to maintaining financial stability. On the contrary, when global liquidity risk increases and the financing of large advanced economies go down, emerging markets reduce reserve requirements.

D. H. Dutkowsky and D. D VanHoose (2019) point out to the fact that from the second half of 2018, the federal funds rate was equal to or almost equal to the interest rate on excess reserves (IOER). Consequently, the Federal Reserve System (the Fed) wanted to increase interbank lending within the target range at the federal funds rate. The authors consider these actions within the bank behavior model and argue that the resulting spread between the federal funds rate and the IOER over this period forced banks to switch to the third regime. The latter differs from the regime of zero excess reserves of the time before October 2008 or the regime of zero wholesale loans after October 2008 and up to the period described above. Having compared the statics of general equilibrium decisions, one can see that during this third regime, in which banks choose a positive amount of excess reserves and wholesale loans, they have the strongest reaction to changes in the rate of federal funds and IOER when granting loans to individuals. In addition, the authors give an outline of how the Fed can strategically use monetary policy to stabilize the macroeconomy during the next recession.

Some previous works have argued that interest rates on mandatory and excess reserves should not be equal. For example, Friedman M. (1960) encourages banks to earn interest on required reserves, but not necessarily on the excess. Taylor J. (2016a, 2016b, 2016c) and Selgin G. (2017) argue that establishing an IOER equal to IORR is not necessary to ensure the effectiveness of the monetary policy, especially after 2008. Sun Rongrong (2020), using an event-study approach, claims that interest rates response to announced changes in the regulated retail interest rate and reserve requirements are positive and significant for all interest rate maturities, but less at the long end of the yield curve. In contrast, market interest rates barely respond to quality statements about the position of monetary policy.

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3. Research methods

3.1. Mathematical model

To analyze the effectiveness of monetary policy tools aimed at controlling macroeconomic factors, we used the model implemented in (Maslennikov, Korovin, Afanasyeva, 2019). Regression analysis is often used to determine the dependence of factors. However, in our case, we considered not the dependence of factors, but the efficiency of control over the dynamics of macroeconomic factors with a monetary policy tool, i.e. how effective the tool is in achieving the set indicators. The concept of "dependency" in classical regression and econometric models originates from the classical theory of probability and formally means that random events A and B are independent if the condition is met

$$P(AB)=P(A)P(B)$$

In our case, one of the events is not random (the value of the parameters of the monetary policy tools is determined by the government). Thus, this dependence, acting as the basis for all the theorems that determine the accuracy and significance of conclusions, cannot be used to analyze "controllability". The classical approach, based on an econometric approach, in the opinion of the authors, has a number of limitations at the stage of using the found dependencies for factor management. Indeed, the determination of the values of the coefficients in the econometric equation can be interpreted

$$y_t = c_1 y_{t-1} + \cdots + a_1 x_{1t} + a_2 x_{2t} + \cdots + a_n x_{nt} + a_0$$

as the force and direction of influence on the value y_t. However, the fact that the determination of these coefficients is based on time series, the implementation period of which covers the moments of multidirectional changes in the directive factors xi (which researchers often consider random to fulfill the conditions of the Gauss-Markov theorem), indicates that we are forced to take into account other factors the external environment. The economic environment is changing, and on a one-time interval, the results of the significance of the coefficients and their values can be interpreted in one way, on another time interval, otherwise. For adjustment, it is necessary to introduce a parameter of the influencing factor (new variable xj) to explain the change in this interpretation. Therefore, the real effects of exposure are blurred and averaged. For example, the mathematical relation that defines the Taylor rule is represented as follows

$$y_t = i_t + a \cdot (i_t - i^*) + b \cdot x_t + y^*,$$

where y_t is the nominal short-term interest rate set by the Central Bank; i_t is the current inflation on an annualized basis; i^* is the annual inflation target; x_t is the percentage deviation of real GDP from potential in percentage terms; y^* is the long-term equilibrium value of the real interest rate; a and b are the coefficients responsible for the behavior of the Central Bank - response to shocks. However, in different economic conditions (which cannot be indexed by only two parameters $i_t \ and \ x_t$), the behavior of economic agents will be different, and as will be shown later, even in different directions. The construction of this model over a long time will lead

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to incorrect control. Thus, we can recognize the econometric approach as successful only for stable periods of economic development.

Our algorithm does not require the use of significant periods to draw conclusions, even if in the considered period there is a change in the reaction to the control action, then the presented algorithm will demonstrate the emerging error by changing the indicator. Let's discuss the algorithm in more detail. Let us assume that factor A controls the values of factor B if a change in the values of the indicator characterizing A entails a uniquely determined change in the indicators of factor B (with an error level admissible in advance). Let $\{X_k\}$ and $\{Y_k\}$ be two time series. If the exponent ρ calculated as a correlation function of this series modulo is equal to 1, then there is a linear function connecting the values of these series as

$$Y_k=a_1X_k+a_0$$

If we assume that X_k is the values of the control factor, and Y_k is the result of the reaction to this control, then in the case $|\rho|=1$, we can claim that there is control over a given period of time. At the same time, a significant deviation from 1 (or from -1) does not indicate the presence or absence of control. Let us consider sequences $\{X_{k+s}\}$ and $\{Y_{k+s}\}$. They differ from the previous ones due to the exclusion of s of the oldest elements and the inclusion of s of new elements at the next s points in time. If ρ is still $|\rho|=1$, but its sign has changed for the opposite, this indicates that there is no control over the time interval containing all the values of the sequences. We used this principle to draw conclusions about the effectiveness of management. Let us build a function

$$F(\{X\},\{Y\},s,t)=\frac{\sum_{k=0}^{n-1}x_k(t)y_{k+s}(t)-\sum_{k=0}^{n-1}x_k(t)\sum_{k=0}^{n-1}y_{k+s}(t)}{D(\{X\},t)D(\{Y\},s,t)},$$

Where

$$D(\{X\},t)=\sqrt{\sum_{k=0}^{n-1}x_k^2(t)-\left(\sum_{k=0}^{n-1}x_k(t)\right)^2},$$

$$D(\{Y\},s,t)=\sqrt{\sum_{k=0}^{n-1}y_{k+s}^2(t)-\left(\sum_{k=0}^{n-1}y_{k+s}(t)\right)^2},$$

$x_k(t)$ is the values of the control parameter at time t+wk (the monetary policy tool), $y_{k+s}(t)$ is the values of the controlled parameter at time t+w(k+s) (the macroeconomic indicator), w is the time interval determining the discreteness of time series, s is the time lag parameter selected so that the time lag of the control delay is equal to sw. Time points t are estimated at w intervals.

Obviously, the function built, which is essentially the operation of calculating the correlation coefficient for two sequences x_k (t) and $y_{k+s}(t)$, has the same characteristics as indicated above and at the same time is the function of discrete-time t. Studying it as a function of the variable t makes it possible to determine the effectiveness of control.

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At the same time, we do not declare the variables as random variables, but consider them as some "mechanical" system in multidimensional space. In this case, we interpret the proximity of objects as the cosine of the angle between two vectors. If on a certain interval t the function is close to 1 or -1 (its trajectory lies in the neighborhood of 1 or -1), then this means that on this time interval the use of the control determining the values of x_k is effective for the action on indicator y_{k+s}. If the trajectory oscillates, then we can assume that control is ineffective at a given time interval.

If the trajectory of the function takes the form of "steps", then we can conclude that there is another control element. A "step" (the values of function F, which is "almost" constant for some time) means that the control parameters were in agreement for some time (did not change together), and the departure from the "step" was determined by a different combination of control parameters.

If the behavior of the indicator under study changes, and there is no change in the controlled indicator $x_k(t)$ during this period, then we can assume that this indicator $x_k(t)$ is not the control one. However, the established values of the indicator $x_k(t)$ can be basic or background, supporting the trend in the dynamics of the indicator y_k. Thus, to interpret the results, we should consider the fact that the indicator $x_k(t)$ changes during the period *nw*. If during this period there are no changes, then there is no point in assessing controllability. If during the implementation of "control" the y_k indicator does not change its trend or its dynamics, that is, does not respond to disturbance, while the correlation graph lies in the range of values (near) +1 or -1, then the conclusion about "controllability" is not valid. In this case, the "negative" correlation results observed on this time interval, such as a change in the sign of the function or the approximation of the graph to zero, are not significant.

3.2. Economic interpretations of possible results of the modeling

Here is a model example that demonstrates the principle of analysis used in the work.

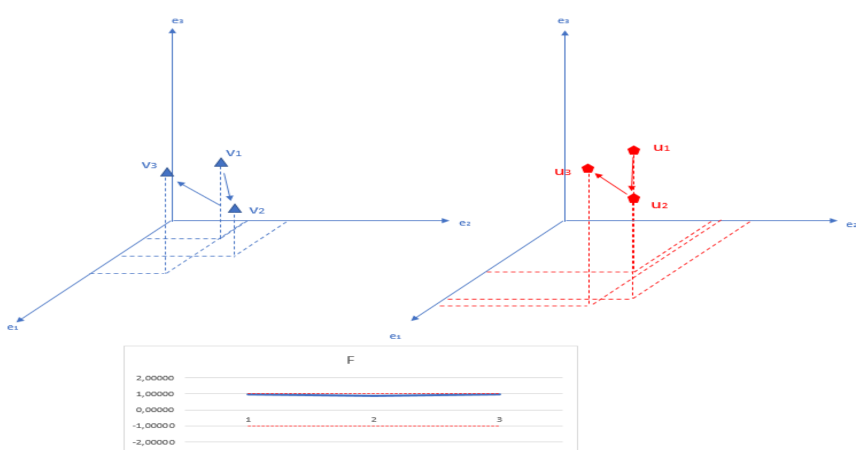

Figure 1. Demonstration of the behavior of F in the case of close series

Source: compiled by the authors

We consider two time series a = (1; 2; 3; 2; 4) and b = (3; 4.5; 5; 4; 5.5), the values of which differ by 2, with the exception of two perturbations, the second and fifth components. We consider vectors of dimension 3 that dynamically arise when the time factor v_1 = (1; 2; 3) and u_1 = (3; 4.5; 5), v_2 == (2; 3; 2) and u_2 = (4.5; 5; 4), v_3 == (3; 2; 4) and u_3 = (5; 4; 5.5). The function F(t) in this case is defined as $F(1)=\cos(v_1;u_1)$, $F(2)=\cos(v_2;u_2)$, $F(3)=\cos(v_3;u_3)$. Thus, if the relationships between the elements of the time series change significantly, then the

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angles between the corresponding vectors will change. In this case, the dimension determines the time that establishes the existing regularity. A demonstration of the angles and values of F in the given case is shown in Figure 1.

We introduce a violation of relations; now let b=(3;4.5;5;2;3), u_1=(3;4.5;5), u_2=(4.5;5;2), u_3=(5;2;3). Obviously, the angles between the vectors have changed, the values of the function F began to deviate from 1. An example is shown in Figure 2.

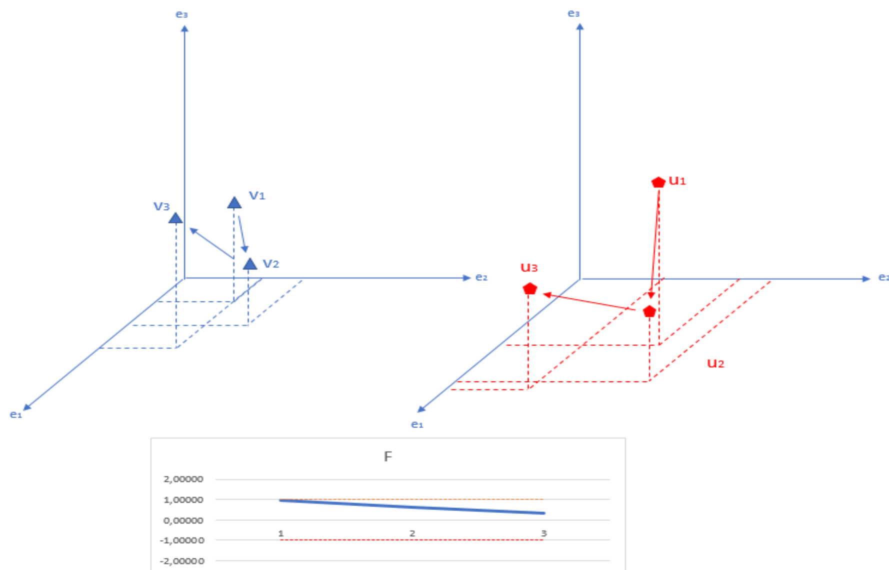

Figure 2. Demonstration of the behavior of F in the case of not close series

Source: compiled by the authors

Obviously, in the practice of analysis, we consider a higher dimension to obtain more information about the formation of patterns. The situation is clearly interpreted if the graph of the function $F(\{X\},\{Y\},s,t)$ fluctuates in the neighborhood of 1 (less than 1) or -1 (more than -1). This means that over the entire studied period of time t on which the graph is built the factor X is a controlling one. Depending on the point of the graph, the effect is either positive (higher X is accompanied by a growth in Y indicator, with a parallel decrease in both X and Y indicators) or negative (an increase in X is accompanied by a decrease in Y indicator, and Y increases, while X decreases). The unambiguously interpreted result is the oscillation of trajectory $F(\{X\},\{Y\},s,t)$ with high amplitude in the strip containing both the set in the negative and in the positive semi-plane. This means that variable X cannot be selected as the control variable.

A poorly interpreted situation is the one in which the trajectory deviates slightly from zero. This means that the values do not correlate, and the control is neither registered nor significant. If at some point the trajectory had an "oscillation" into a semi-plane with a different sign, and then returned to the previous area of localization, then this can be due to the lack of information. Let us ignore such oscillations in the trajectory, assuming that the temporary deviation is a correction of the macroeconomic factor or due to unreliable data.

3.3. Analysis of the input data

In this study, we examined five countries: Japan, Norway, South Africa, Brazil, and China. We selected countries with different development levels of both banking systems and economies. The data for analysis were obtained from the websites of central banks of the above countries and were transformed as follows. The data on reserve requirements (reserve ratios in China, Japan, South Africa, and Brazil, as well as the volumes of required reserves in Norway) were given per month, while GDP data were presented per quarter. To make these data comparable, we filled the missing periods with the last value. We established the data period from January 1, 2000, to January 1, 2018, since the results after this date were not available for some countries at the time we began working on the research. We included the data on GDP (volume) in local currency in Norway and Brazil; GNP (volume) – in China; real GDP – in South Africa and Japan; nominal GDP – in Japan; and GNI (per capita) in USD in South Africa.

China

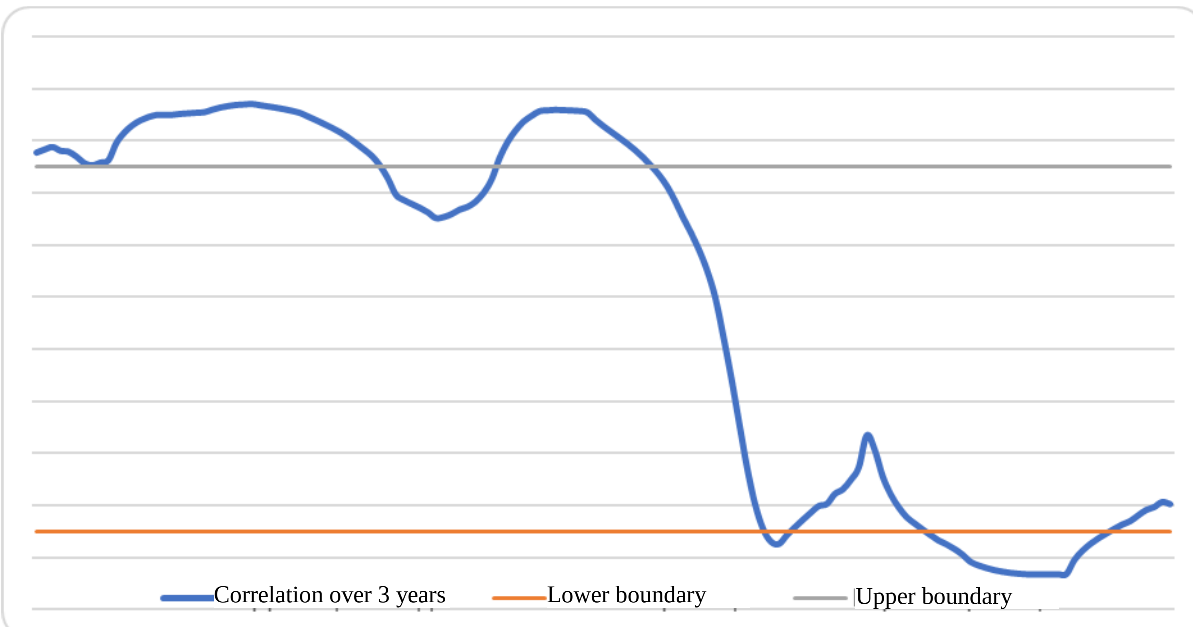

Figure 3. The correlation between the reservation rate and GNP in China

Source: compiled by the authors

To analyze the controllability, we built the function $F(\{X\},\{Y\},s,t)$, where {X} is the time series of reserve ratios, {Y} is the time series of China's GNP, the time lag is s=0, and w is a month, like in all further cases considered. We chose the zero-lag since changing the values of s from 0 to 12 we could observe an insignificant change in the shape of the graphs, while for s=0 the graph of the function was closest (in the metric of the functional space C([01/01/2000; 01/01/2015)) to the levels of 1 or -1.

Having analyzed the behavior of function $F(\{X\},\{Y\},s,t)$, we observed a steady strong positive correlation in the periods from 2004 to 2007 and from 2008 to 2010. At the same time, a strong negative correlation was observed from the second half of 2013 to the end of 2014. This behavior contradicts the logic, as one would expect that the required reserve ratios could control a macroeconomic factor, for example, GDP. Indeed, an increase in the required reserve ratio objectively reduces the interest of commercial banks in intensifying lending, which, in turn, should limit production activities, and, hence, GDP growth. According to this logic, the growth of reserve ratios leads to a decrease in GDP; therefore, the correlation should have a negative sign.

A positive correlation was observed between 2003 and 2009, which contradicts the hypothesis that the reserve ratio can be used as a control tool to maintain GDP growth. Most likely, at this time interval, this tool was a sort of martingale aimed at maintaining the control effect implemented by other tools in a given position for a long period. It can be assumed that, for example, if the refinancing rate and the reserve ratio are used in combination, the expected effect is not instantaneous, but "stretched" over a long time. This behavior can be observed in the activities of other central banks in the pre-crisis period (for instance, in Japan, South Africa, and Norway).

Thus, we could identify two periods on the trajectory: before 2010 and after this year. In this study, the mutual behavior of two factors was determined over the period of three years, which means that the strongest positive correlation coefficient observed before 2010 reflects the period of economic recovery before 2007, and the changed sign in 2010 refers to the period of 2007, including the moment when the global economic crisis, which lowered China's GNP, forced the People's Bank of China to increase the reservation rate. A change in sign indicates a new type of relationship: an increase in the reserve ratio was accompanied by a decrease in GNP. It is interesting that the proximity of two factors began to decrease even before 2008: the trajectory went below the confidence level with the correlation coefficient that estimated 0.7 on March 31, 2010. Given the three-year period over which the correlation was calculated, the trends began to change in March 2007. This is when the crisis of high-risk mortgage loans in the USA began, which had no direct influence on China's GNP.

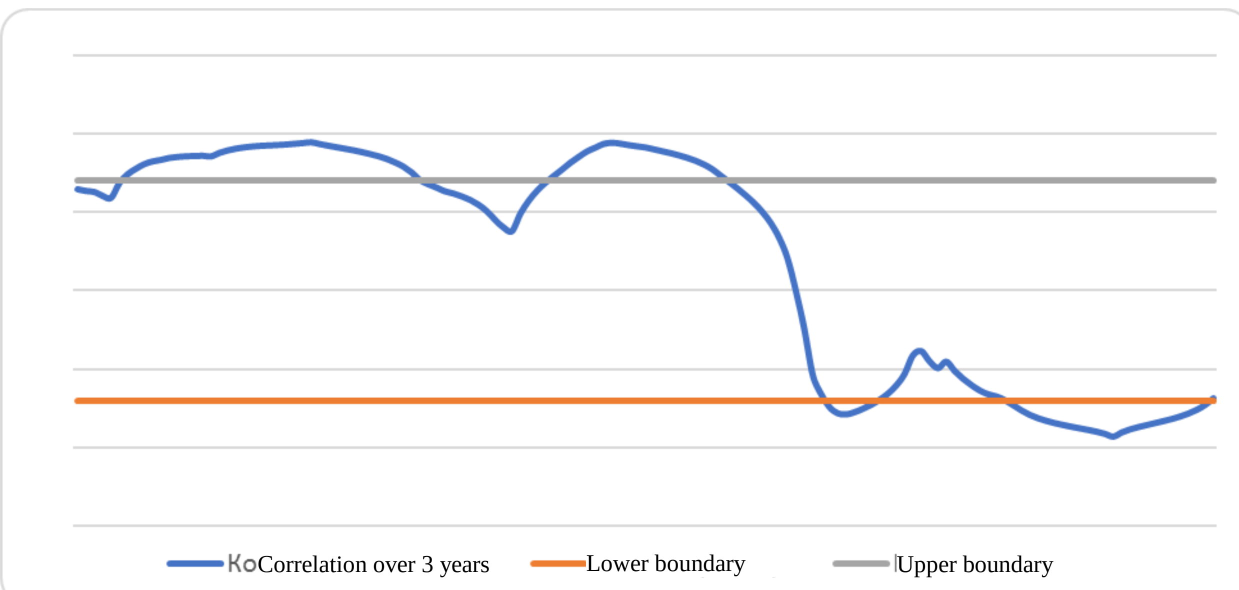

Figure 4. The correlation between the reservation rate and GDP in China

Source: compiled by the authors

Figure 2 presents graph $F(\{Z\},\{Y\},s,t)$, where {Z} is the time series of the reservation rate, {Y} is the time series of the volume of China's GNP, the time lag is s=0, and w is a month, like in all other cases considered. Until 2010 (except for the beginning of 2008), the relationship between the reservation rate and GNP was stable, strong, and direct. During the crisis period, at the end of 2008, China's GDP indicator decreased significantly and began to grow only from the middle of 2009 to 2010. Consequently, over this period, the People's Bank of China adjusted the reservation rate: the bank lowered it in 2008 and increased from 2009 to 2010. This measure was effective.

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Since 2011, an opposite course of action was chosen: an increase in the rate led to a decrease in GDP and vice versa. At the same time, reserve ratios also changed the sign of correlation. The People's Bank of China skillfully reversed the impact of the refinancing rate: after the transition period, there were no significant oscillations of the correlation function, which proved the efficiency of the strategy and understanding how this tool should be used.

Japan

It was difficult to analyze Japan's GDP due to the fluctuations that made it impossible to determine the influence of the tools used. That is why we had to consider such macroeconomic indicators as nominal GDP per capita or real GDP of Japan at current prices (USD).

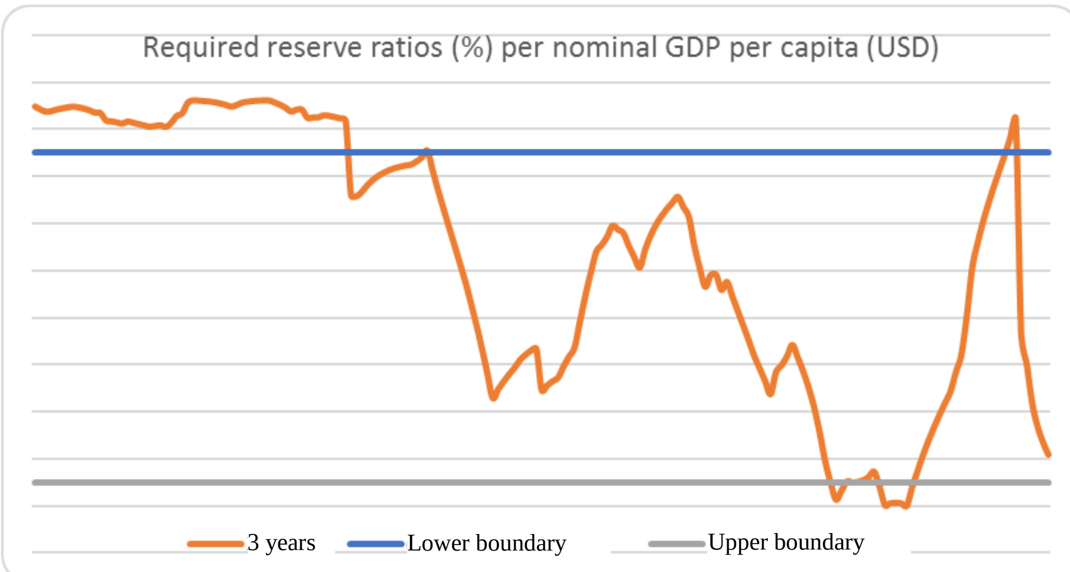

Figure 5. The correlation between the average effective reserve ratio and nominal GDP in Japan

Source: compiled by the authors

A positive correlation of reserve requirements and nominal GDP per capita (USD) was observed in Japan in the periods from 2000 to 2004 and from the end of 2014 to the beginning of 2015, and a slight negative correlation – in 2012 and 2013. Significant correlation fluctuations indicate that the attempts to use reserve ratios to correct dynamics did not lead to a significant positive effect.

Since 2013, the mutual behavior of reserve ratios and GDP changed. Most likely, this was due to a change in the Bank of Japan's course: in 2013, the head of the Bank, Masaaki Shirakawa, who held this post since 2008 and did not support the policy of Prime Minister Shinzo Abe, was replaced by Haruhiko Kuroda, who supported the Prime Minister's policy and tried to overcome deflation by loosening the Bank's policy. The goal was to bring annual inflation in the country to 2%. All available tools were used to achieve this aim, which primarily led to an increase in the money supply. Koichi Hamada (Yale University) substantiated this approach. This financial research school traditionally determines the policy of the US Federal Reserve, which often resorts to such methods. The latter is connected with the traditional "martingale" behavior of the correlation function of reserve ratios and GDP after 2013. Figure 3 presents graph $F(\{Z\},\{Y\},s,t)$, where {X} is the time series of reserve ratios, {Y} is the time series of Japan's nominal GDP per capita, the time lag is s=0, and w is a month.

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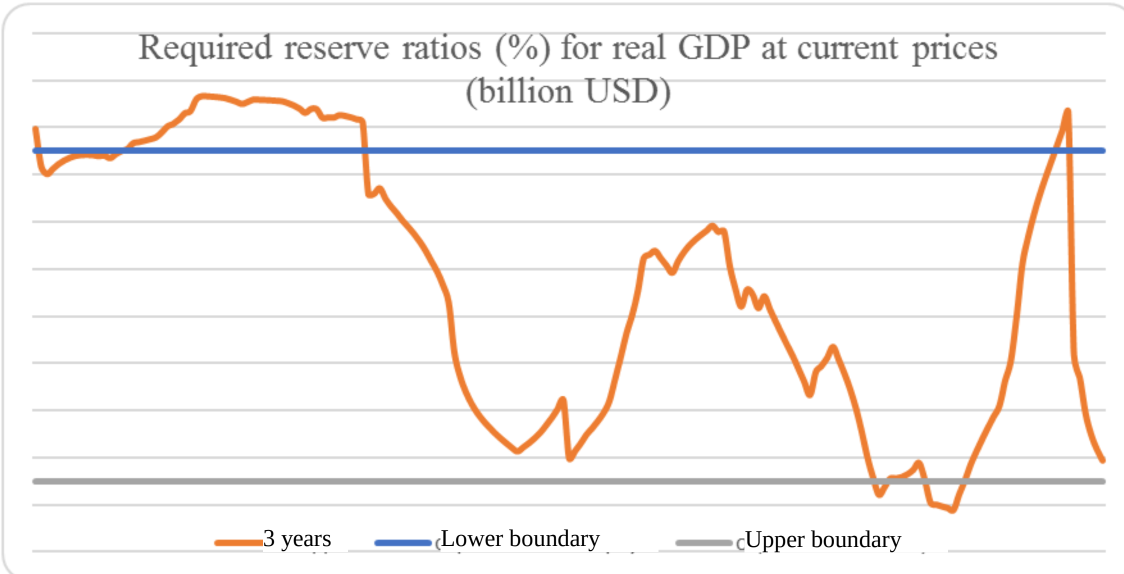

Figure 6. The correlation between the average effective standard of required reserves and real GDP in Japan

Source: compiled by the authors

A similar situation was observed when we analyzed the "control" over real GDP at current prices by changing reserve ratios. A positive correlation of reserve requirements and real GDP at current prices (billion USD) was observed in Japan from 2001 to 2004, and a slight negative correlation – in 2012-2013.
The Bank of Japan was pursuing a policy of quantitative easing since April 2013. In the periods, there were no significant correlations of the changes in the refinancing rate by the Bank of Japan, so it could not be an additional impact factor. Significant fluctuations in both correlations indicate that the attempts to use reserve ratios to improve the dynamics did not lead to a significant positive effect.

Thus, the required reserve ratio did not affect the long-term growth of either nominal or real GDP in Japan.
Figure 4 presents the parameters of the analyzed function $F(\{X\},\{Y\},s,t)$, where {X} is the time series of the required reserve ratios, {Y} is the time series of Japan's real GDP at current prices, the time lag is s=0, and w is a month.

The Republic of South Africa

Figure 5 presents the parameters of the analyzed function $F(\{X\},\{Y\},s,t)$, where {X} is the time series of the required reserve ratios, {Y} is the time series of South Africa's real GDP at current prices, the time lag is s=0, and w is a month. We concluded that this tool did not exert any control. Indeed, the values of function F are higher than 0.7 only at two short intervals. These intervals are short, which indicates that the South African Reserve Bank could have applied analytical methods based on statistical data to justify the expected result if this tool was used to control real GDP.

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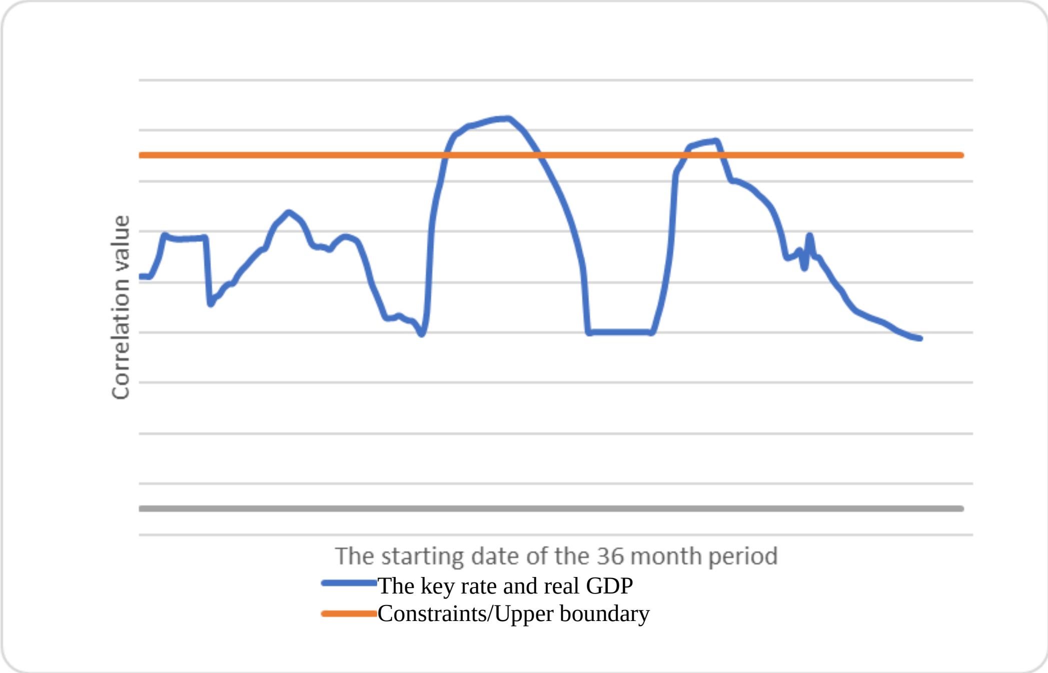

Figure 7. The correlation of reserve ratios and real GDP
Source: compiled by the authors

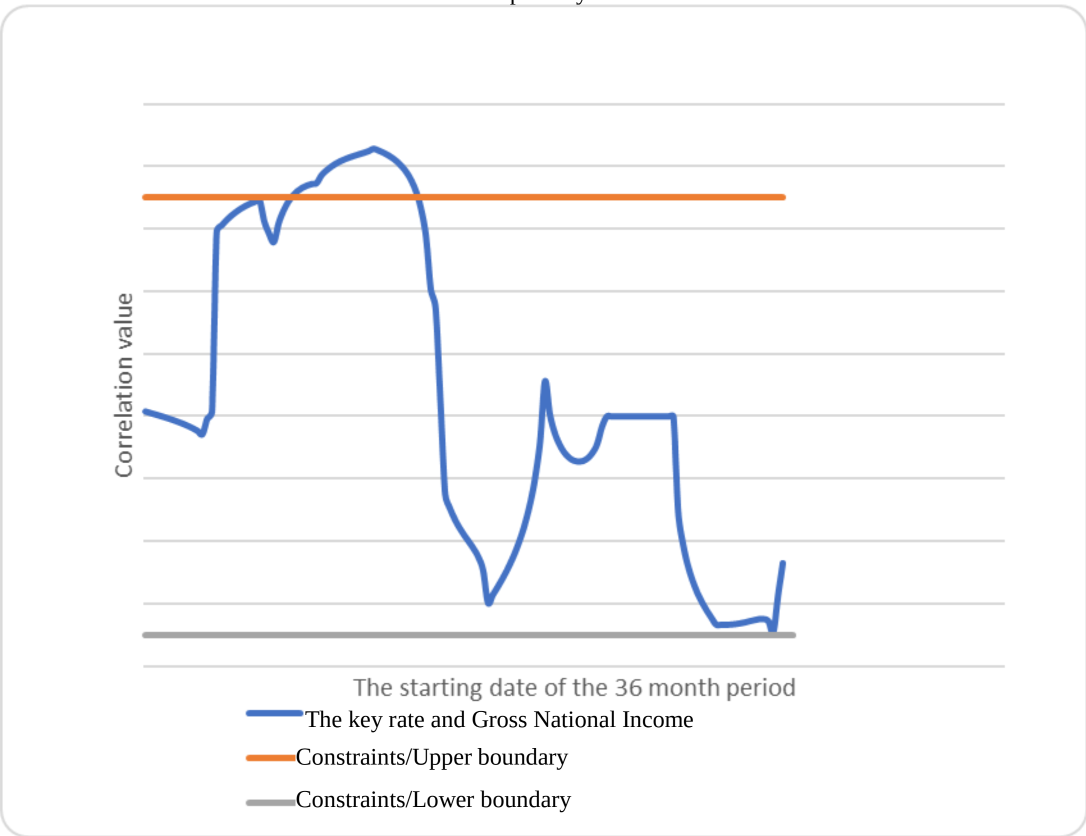

Figure 8. The correlation of reserve ratios and Gross National Income per capita, USD
Source: compiled by the authors

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If another control goal is chosen, for instance, Gross National Income per capita, again, one cannot conclude that this tool could be used as a control element. A positive correlation between the required reserve ratio and Gross National Income per capita in South Africa can be observed from 2002 to 2004. From 2008, South Africa gradually reduced required reserve ratios. At the same time, since 2006, real GDP was declining, with sharp drops in 2008, 2009, and 2015.

The refinancing rate also changed during positive correlations. The refinancing rate was increased in 2006, while from 2002 to 2004, and from 2009 to 2010, it was reduced. It is possible that at certain time intervals the correlation was influenced by a decrease in the refinancing rate. Thus, it can be concluded that the reserve requirements established by the South African Reserve Bank cannot be regarded as the controlling factor in GDP or GNI. Considering the above, one cannot draw a conclusion on the effect of the tool, as it was not used for controlling GDP.

Brazil

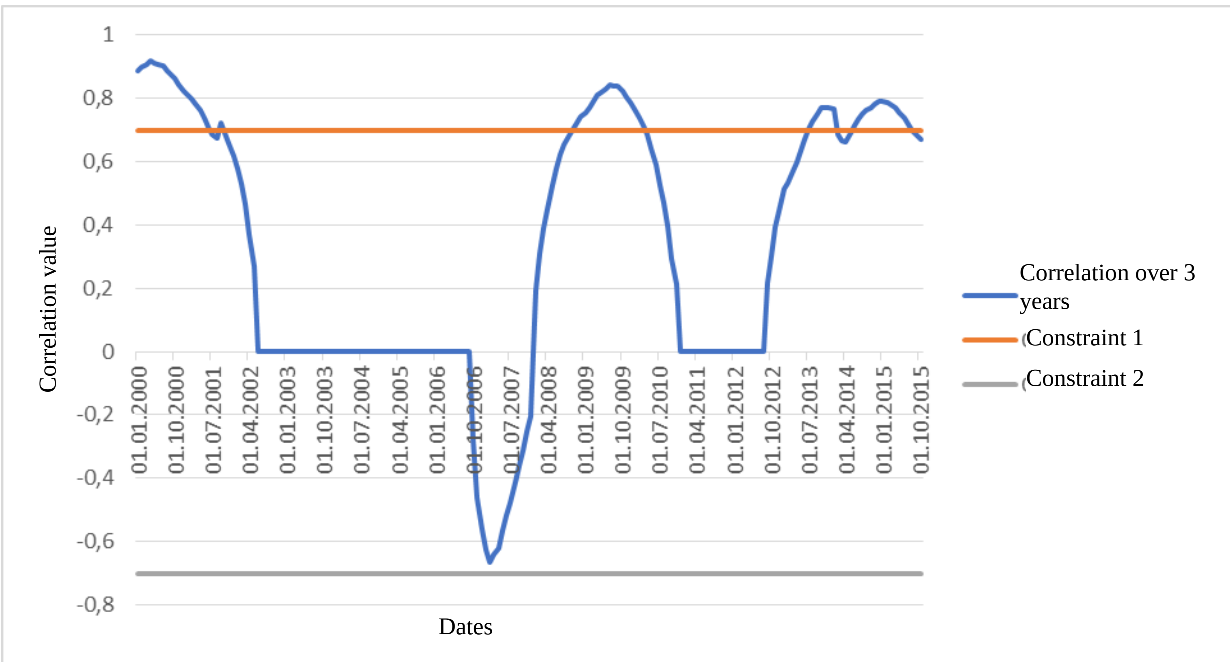

Figure 9. The graph of the correlation between the required reserve ratio (%) and GDP (BRL)
Source: compiled by the authors

Having studied the properties of the correlation function $F(\{X\},\{Y\},s,t)$, where {X} is the time series of the required reserve ratios, {Y} is the time series of Brazil's GDP, the time lag is s=0, and w is a month, we could conclude that this tool cannot be effectively applied to control the dynamics of GDP. In Brazil, a positive correlation between reserve requirements and GDP (BRL) was observed in the periods from 2000 to 2001, from 2009 to 2010, and from 2012 to 2015. The positive correlation was strongest in 2000 and amounted to 0.89. We did not register a negative correlation.

The required reserve ratio in Brazil was gradually increasing since 2001. The main spikes occurred over the periods from 2001 to 2002, in 2010, 2015, and 2016. At the same time, GDP was also growing steadily. At each time interval where a positive correlation was observed, the refinancing rate changed: it either increased in 2001, 2010, from 2012 to 2015 or decreased in 2000 and 2008. From the moment Henrique de Campos Meirelles

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became the President of Brazil's Central Bank in 2003, there were practically no changes in the reserve ratio affecting GDP. The preference was given to such an instrument as SELIC – the special overnight rate of the Central Bank of Brazil. The aim of short-term manipulations with reserve ratios during the crisis period was not connected with the control over GDP. This conclusion can be drawn if we look at the small period of stable positive correlation. After 2012, the oscillation was observed in the positive semi-plane. This stage was proclaimed by the head of the Central Bank, Alexandre Tombini, as the period of targeting inflation by changing the refinancing rate, and, as we could see, in other countries, the required reserve ratio could be considered a "constraint". Therefore, there is no evidence that the required reserve ratios are a successful tool to control GDP in the long and midterm, so even if this tool was used for this purpose, it was ineffective.

Norway

The control over GDP by changes in the required reserve ratios was analyzed on the basis of the constructed function $F(\{X\},\{Y\},s,t)$, where {X} is the time series of the required reserve ratios, {Y} is the time series of Norway's GDP, the time lag is s=0, and w is a month (Fig. 8). Until 2008, there was a stable positive correlation, which could be due to the martingale property. An increase in reserve ratios, accompanied by a decrease in the refinancing rate, makes it possible to prolong the management effect – either to lower inflation or to intensify lending to the real sector of the economy, which leads to GDP growth.

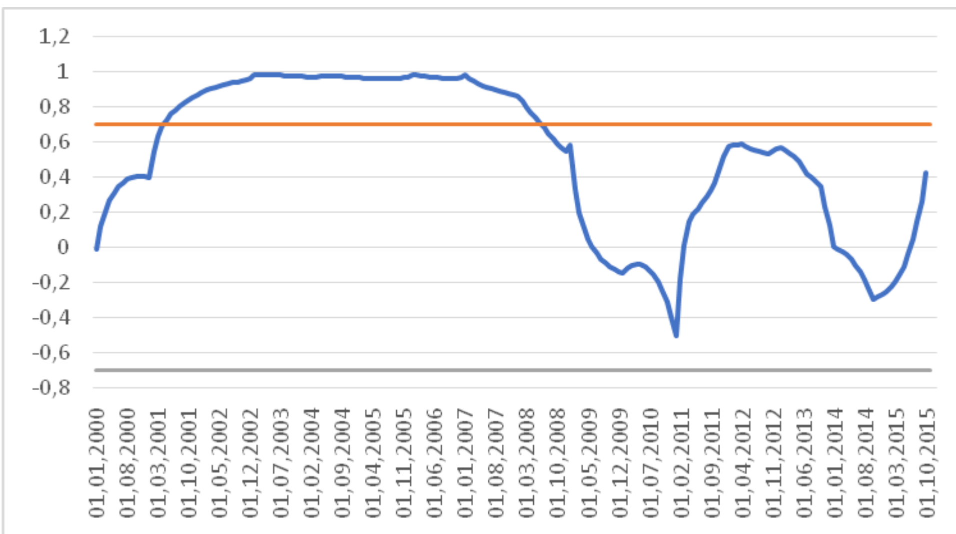

Figure 10. The correlation of the volumes of required reserves and GDP (billion NOK)
Source: compiled by the authors

Therefore, we could observe a positive correlation between the volume of required reserves and GDP from 2001 to 2008. The volume of required reserves over the entire time was growing stepwise. A slight decrease in the volume of required reserves was observed since 2002, in 2008 and 2015. At the same time, GDP was gradually increasing since 2000, with slight decreases in 2015 and 2016. The refinancing rate was changed throughout the identified correlation period. For instance, the refinancing rate was reduced before March 2004 and then increased.

At the same time, a weak correlation and the graph oscillations during the period after 2011 indicate that for Norway, the tool that implied controlling the volume of required reserves by changing the dynamics of GDP was ineffective in the long term.

Having studied the correlations of the volume of required reserves and GDP in Norway, we concluded that from 2001 to 2008 this country had a strong correlation. In this regard, we share the view of D. Kondratov and A. A. Amaev (2018) that the main goal of the Bank of Norway's policy was price stability, which in turn ensured an increase in welfare. This is confirmed if the martingale hypothesis we put forward above is valid.

Conclusions

Summing up the research results, we can conclude that in most of the studied countries, reserve requirements cannot be considered a factor in the control over the dynamics of GDP. As long as other factors are not considered, changes in reserve requirements do not guarantee a detectable effect on GDP.

In a number of countries, we registered a positive correlation between required reserve ratios and GDP over some long time intervals. Since this contradicts the logical thesis that an increase in required reserve ratios should limit lending activity and slow down GDP growth, we proposed a hypothesis called "martingale". To target macroeconomic indicators effectively, central banks assume that "a lower refinancing rate leads to an increase in GDP" and take measures to curb the effect of changes in rates by simultaneously imposing a regime of tightening reserve requirements. This can be done to prolong the expected effects and to make the growth more elastic. If this hypothesis is true, we can conclude that the required reserve ratio becomes an important auxiliary element in the targeting of macroeconomic indicators.

In this research paper, we considered completely different changes in reserve requirements and their impact on the change. Consequently, such a monetary policy tool as the reserve requirements cannot be considered as the main factor in changing GDP.

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