Variations in the Effects of a Single Monetary Policy: The Case of Russian Regions

Vadim Napalkov, *Bank of Russia*

napalkovvv@mail.cbr.ru

Anna Novak, *Bank of Russia*

ananova7@gmail.com

Andrey Shulgin, *Bank of Russia*

andrei.shulgin@gmail.com

This research analyses regional heterogeneity in the reaction of core inflation to shocks of a single monetary policy on the example of Russia. We use a global vector autoregression model to estimate impulse response functions of core inflation in Russian regions to monetary policy shocks. The average 5-year cumulative response of regional core inflation to a MIACR shock of 1 percentage point (p.p.) is -0.74 p.p. For 77 out of 80 regions, the 5-year cumulative core inflation response is found to be statistically significant. If we exclude three statistically insignificant responses and discard the four regions with the highest and lowest responses, we get a range of -0.55 to -0.93 p.p. with a standard deviation of 0.12. We show that, over a one-year horizon, the heterogeneous response to monetary policy shocks can moderately reduce the heterogeneity of the response of regional inflation to exchange rate shocks. However, the magnitude of this effect is limited. According to the analysis of the regional heterogeneity factors, the higher are the share of extractive industries in the gross regional product of a region, the share of loans to manufacturing sector, the share of loans to small enterprises, as well as the unemployment rate, the stronger will be the reaction of the core inflation to the monetary policy shock. The degree of heterogeneity in the Russian regions' core inflation response to monetary policy shocks, the set of factors explaining this heterogeneity, and the explained variation of the regional response (30–40% depending on the model specification) turn out to be comparable to similar indicators in other countries with pronounced regional heterogeneity.

Keywords: *GVAR, monetary policy, heterogeneity, regional effects, monetary transmission*

JEL Codes: *E52*

Citation: Napalkov, V., Novak, A., Shulgin, A. Variations in the Effects of a Single Monetary Policy: The Case of Russian Regions. *Russian Journal of Money and Finance*, 80(1), pp. 3–45.

doi: 10.31477/rjmf.202101.03

1. Introduction

Russia belongs to a group of countries with pronounced regional heterogeneity,¹ for which a single monetary policy, firstly, does not fully correspond to the business cycle of each specific region, and, secondly, has an uneven impact on the economies of non-identical regions. In this paper, we discuss the second of these issues and raise the question of how much the responses of Russian regions to a single monetary policy differ: we also investigate the factors that help to explain the observed heterogeneity in the response of regional core inflation to the actions of the monetary authorities.

The issue researched in this paper refers to the broad topic of analysing optimal currency areas, which is historically rooted in the discussion of the optimality of the gold standard system. Divergent business cycles (resulting from both regional shocks and a heterogeneous reaction to general shocks), non-immediate adjustment of relative prices, a historical analogue for which would be the slow price-specie flow mechanism of adjustment during the gold standard era, as well as obstacles to the redistribution of resources between heterogeneous regions in the absence of monetary autonomy lead to welfare losses in the regions.² It should be noted that the divergence of business cycles in the regions is not a problem in itself. For example, it may be due to a greater proportion of the manufacturing or extractive industries in a region, which are more responsive to fluctuations of relative prices in the global market. A problem that leads to welfare loss arises only if differences in business cycle emerge in the context of imperfect mechanisms for adjustment of relative prices and real markets that inhibit the optimal response to shocks by the region's economic agents. We assume that monetary policy can partially solve the problem of non-optimal adjustment and reduce the losses of economic agents. Since the regions lack monetary autonomy, they do not have this option. Finally, even if a number of regions suffer losses from regional heterogeneity, this does not yet mean that the existing currency area is not optimal, since these losses are offset by a number of advantages from the regions being part of the single currency area (see the classic works of Mundell, 1961; McKinnon, 1963; Kenen, 1969; Eichengreen, 1993) – in the same way as under the gold standard, the idiosyncratic shocks themselves are not a reason for giving it up but are rather compensated by the advantages of participating in the gold standard system. In this paper, we do not attempt to weigh the losses and gains from the regions' presence in the single currency area but focus on a positive analysis of the properties of the regional response to general shocks.

¹ For example, Kwon and Spilimbergo (2005) find that the regional variance of income in Russia is second only to that of China and is significantly higher than in the USA and Canada. The authors show that, if regional trends are taken into account, Russia is among world leaders in regional income differentiation. Perevyshin et al. (2017) demonstrate that regional price differentiation in Russia is also one of the highest in the world.

² Kwon and Spilimbergo (2005) showed that weak adjustment mechanisms for strong regional shocks generate large fluctuations in regional income in Russia, which may indicate losses associated with regional heterogeneity.

The primary object of our study is the regional heterogeneity of core inflation response to a monetary policy shock. In examining the differentiation of the regional inflation response to a certain shock rather than the differentiation of regional inflation itself,³ we abandon the global objective of presenting a complete model of regional inflation. We set a more limited objective: to propose an adequate model of regional inflation that will make it possible to identify the contribution of shocks associated with the most important general factors. We focus on single monetary policy shocks because, firstly, it makes it possible to clearly reveal the sources of the heterogeneity of the regional structure of the economy, and secondly, knowledge of the characteristics of the inflation and economic activity response of the regions to the general monetary policy is important in itself for more effective communication in the inflation targeting regime. Finally, awareness of the specifics of the regional inflation response to monetary policy shocks can help to see a clearer picture of the situation in the region when determining the parameters of a stabilising regional fiscal policy.

Monetary policy shocks also differ from other general shocks in that a stabilising discretionary monetary policy, under certain conditions, can also contribute to the regional stabilisation of the business cycle: a strong regional response to country-wide demand shocks can be partially offset by a strong regional response to monetary policy shocks. For example, heterogeneous growth of regional consumer prices due to the income effect arising from fluctuations in world commodity prices may make it necessary to adjust the single monetary policy, which will have a stronger effect on precisely those regions where this problem arose. In certain cases, this could mitigate the well-known ‘one size fits all’ problem (Nechio, 2011; Malkin and Nechio, 2012). In our study, we confirmed that the heterogeneity of the regional response to monetary policy shocks helps reduce the spread of regional inflation generated by the heterogeneous response to other general shocks (exchange rate and oil prices). However, this effect is very limited.⁴

The most common approach to analysing the impact of the single monetary policy on various regions of a country is to study the response of a regional indicator of economic activity (personal income, employment, unemployment, gross regional product (GRP), etc.) to monetary policy shocks. This approach is attributed to Beare (1976), who analyse monetary influence on regional business

³ This issue has been addressed in many papers on the Russian economy. For example, Zhemkov (2019) studied the structural levels of inflation in the Russian regions, Perevyshin and Egorov (2016) and Deryugina et al. (2019) researched the role of general, sectoral, and regional factors in regional prices, Perevyshin et al. (2017) explained regional price differentiation using a number of regional factors, Gluschenko (2010) explored issues of regional convergence, and Kirillov (2017) assessed the spatial connectedness of regional inflation processes.

⁴ In the long-term, the losses of agents from imperfect adjustment no longer play a significant role: they are replaced by the issues of regional inequality that arise in the long-term heterogeneous reaction of consumer prices in response to general shocks, including monetary policy shocks. We show that, for an average region, the contribution of monetary policy shocks to the long-term dynamics of consumer prices is quite large.

cycles in Canada. In our paper, we also aim to study the heterogeneous impact of a single monetary policy on the regional business cycle but using regional core inflation response as a measure. We proceed from the assumption that core inflation, first, contains the same information on the intensity of the impact of monetary policy shock on the regional business cycle as any indicator of economic activity; second, it has longer series and, in most cases, a more stable calculation methodology in comparison with indicators of economic activity; third, it is free of the high volatility inherent in consumer inflation; finally, its spatial regional interconnectedness is no less pronounced than that of other indicators characterising the response of regional economies to monetary policy shocks. Among other things, the emphasis on the response of regional prices will allow the Bank of Russia to develop better communication at the regional level, which is necessary in the inflation targeting regime.

After Sims (1980) introduced vector autoregressive models (VAR) into mainstream practice of econometric analysis, this methodology became standard tool for identifying the response of the economy to shocks. This methodology has been used to analyse the response of regional economic activity indicators to monetary policy shocks for most countries with pronounced regional heterogeneity: USA (Carlino and DeFina, 1998, 1999), Brazil (Rocha et al., 2011), China (Guo and Masron, 2017), Indonesia (Ridhwan et al., 2014), Canada (Georgopoulos, 2009), Turkey (Duran and Erdem, 2014), Australia (Vespignani, 2015), India (Nachane et al., 2002). All these studies examine the response of one or more indicators of economic activity to monetary policy shocks and pay insufficient attention to the response of regional inflation. In our paper, we close this gap.

To obtain regional inflation responses to monetary policy shocks, we need a tool that would make it possible both to identify the monetary policy shock itself and to study the response of each region to such shock (and other structural shocks), taking into account existing spatial effects. Dominguez-Torres and Hierro (2019) provide an overview of the various techniques that were used in the literature for this task, noting the dominant role of the VAR methodology. At the same time, unrelated VAR models for each region do not satisfy the requirements for taking into account spatial effects, which makes it necessary to calculate panel VARs, factor-augmented VARs (FAVARs), mixed-frequency VAR models, and other modifications. In this paper, we also opt for a model from the VAR family: the global vector autoregressive model (GVAR) proposed by Pesaran et al. (2004). This methodology has been used to analyse the heterogeneity of the EU countries' GDP response to the shock of the European Central Bank rate (Georgiadis, 2015; Burriel and Galesi, 2018). This methodology has the major advantage of enabling the use of a large array of regional information and, at the same time, the reduction of the number of estimated parameters due to structural limitations. For example, the influence of external variables on regional variables is assumed through an intermediary:

a separate VAR model for aggregate variables. Spillover effects are taken into account in a VAR model for each region using specially introduced variables that aggregate the impact of adjacent regions (Pesaran et al., 2004).⁵

In addition to taking spatial relationships into account, the model used should correctly identify monetary policy shocks, which requires restrictions on the mutual influence of variables. In our paper, we used Cholesky decomposition, a most common technique for specifying limitations used in the literature. At the same time, since we work with a monthly frequency, we additionally assume that a monetary policy shocks does not affect inflation during the first three months (quarter), which is also a standard approach to this task.

The emphasis on the regional core inflation response to monetary policy shocks allowed us to obtain a more substantial, compared to most studies focused on the economic activity variables response, percentage (77 out of 80 for the basic model specification⁶) of statistically significant responses of regional inflation, which potentially increases the quality of further analysis of factors that can explain the existing differentiation of these responses. The average 5-year cumulative response of regional core inflation to a monetary policy shock of 1 p.p. is -0.74 p.p. for the baseline specification. The highest cumulative inflation response was recorded in the Republic of Ingushetia (-1.1 p.p.) and the Sverdlovsk Region (-0.94 p.p.); the lowest response, in the Chukotka Autonomous District (-0.35 p.p.) and the Moscow Region (-0.53 p.p.). If we discard the four regions with the highest and lowest response, truncating the sample by 10% and at the same time excluding three statistically insignificant responses, we get a range from -0.55 to -0.93 p.p. with a standard deviation of 0.12.

Like most authors studying regional heterogeneity of the response to monetary policy shocks, we explore three hypotheses which we will refer to as ‘the hypothesis of interest rate channel’, ‘the hypothesis of the currency channel’ and ‘the hypothesis of the credit channel’,⁷ according to which the corresponding channel statistically significant in explaining the revealed heterogeneity of inflation response to monetary policy shocks.

‘The interest rate channel’ is represented by various elements and includes interest rate pass-through effect, interest rate sensitivity of output, price and wage rigidity, income effect, and wealth effect (Suardi, 2001). However, the papers that explore this hypothesis are mainly focused on estimating the interest rate sensitivity of output and use indicators related to the sectoral structure of the economy as proxy

⁵ Adjacent in the broad sense: geographic proximity is only one of the options for identifying adjacency.

⁶ The various model specifications differ primarily in the matrices that identify spatial effects in the GVAR.

⁷ From here on we use quotation marks referring to the channel names, since we use them not in a rigid sense conventional for the literature on monetary policy transmission, but rather to denote certain patterns revealed by the literature studying the factors of the heterogeneity of the monetary policy response of the regional variables. For a review of works demonstrating the role of the various channels in explaining a region’s response to monetary policy shocks, as well as a list of works that study various factors of the heterogeneous regional response, see Dominguez-Torres and Hierro (2019).

variables (Carlino and DeFina, 1998, 1999). Predominance of manufacturing and extractive industries, which are closely related to the supply and demand of real investment, increases the impact of interest rates on a region's economy. This results in a stronger reaction of regional aggregate demand to monetary policy shocks and, therefore, a stronger reduction in output and prices (inflation) in response to monetary contraction. Like most studies by other authors, our paper shows that the higher the share of extractive industries in the GRP and the share of loans issued to enterprises in the manufacturing sector, the stronger the response of regional core inflation to monetary policy shocks is.

The second hypothesis of 'the currency channel' is associated with the dependence of the regional business cycle on fluctuations in the foreign exchange rate arising from monetary policy shocks (Anagnostou and Papadamou, 2014; Ridhwan et al., 2014). As a proxy for this channel, the authors of the mentioned papers use indicators characterising a region's involvement in foreign trade, which can partly explain the excessive reaction of the regional business cycle to monetary policy shocks through a higher sensitivity of demand to exchange rate fluctuations. However, the analysis is complicated by the fact that the impact of fluctuations in the foreign exchange rate on the region's economy can be uncertain. Strengthening of the national currency arising from an increase in the interest rate, on the one hand, discourages the regional aggregate demand due to the effect of international competition with foreign producers, but, on the other hand, it reduces the debt burden for borrowers in foreign currency, providing more opportunities for investment and consumption under imperfect financial market (Céspedes et al., 2004). If we observe different combinations of these effects for different regions, then the proxy variable for the degree of openness may be weakly related to the strength of the regional core inflation response to monetary policy shocks. This was observed in our study as well. After we had tried various options for specifying a proxy for the currency channel used in the literature: regional trade balance, net exports, imports and exports, we discovered that all of them do little to explain the heterogeneity of the regional core inflation response to monetary policy shocks. This result is not unique: for example, Ridhwan et al. (2014) find no empirical evidence for the significance of the contribution of this channel in the regions of Indonesia, and Barran et al. (1996) and Clements et al. (2001) obtain a similar conclusion for the euro area countries in the period before the introduction of a single currency.

The third hypothesis, known as 'the credit channel', reflects the impact of financial market imperfections that lead to premiums on the cost of external financing for firms and commercial banks (Bernanke and Gertler, 1995), on the cost of borrowing in a given region. This channel is divided into narrow and broad credit channels. 'The narrow credit channel' is associated with the supply of credit resources by the banking sector: deteriorating collateral and asset quality resulting from an increase in interest rates reduces the ability and willingness of

banks to lend to firms and households (Kashyap and Stein, 2000; Anagnostou and Papadamou, 2014). We use two common proxies for this channel: the share of loans to firms and households of a region issued by regional banks and an indicator of banking sector concentration – the share of individuals' funds placed with major regional commercial banks. A greater share of regional banks means a stronger reduction in the supply of credit resources during monetary contraction and, therefore, a steeper drop in demand for investment and consumption of the region, which intensifies the response of output and prices. A highly monopolised banking sector can exacerbate the contraction in lending during a period of rate hikes due to non-competitive distribution of loans between banks (Owyang and Wall, 2009). This will lead to more significant reductions in output and core inflation during monetary contraction. Our calculations show that, in Russian data, this channel manifests weakly, which we are inclined to attribute to a fairly high degree of monopolisation of the banking sector, varying little from region to region.

The broad credit channel is associated with financial market imperfections that affect the behaviour of firms and households in the context of fluctuating interest rates (Suardi, 2001). Monetary contraction leads to a decrease in the prices of financial assets, which through the net wealth channel leads to a deterioration in lending terms for firms and households (increased external financing premium). Due to the positive correlation of the external financing premium with the policy interest rate, regions with tighter financial constraints for firms will react more strongly to monetary contraction. In such regions, the decline in aggregate demand and, consequently, the decrease in output and core inflation will be more pronounced. We obtained a correct sign for the proxy variable of this channel, the percentage of those employed in micro- and small enterprises in the region (Owyang and Wall, 2009). Small firms are more sensitive (than large firms) to external financing constraints, so in regions with a higher share of micro- and small enterprise employment, the decrease in core consumer price index (CPI) is more pronounced in response to monetary contraction (Oliner and Rudebusch, 1996). As a proxy for investigating the role of the broad credit channel, we tried an additional variable characterising the strength of household financial constraints – debt on loans per capita.⁸ This variable is associated with the wealth effect and could be attributed to the broad credit channel, but it turned out to be statistically insignificant.

In addition to the three hypotheses studied by most authors, we consider two additional factors that are also potentially capable of explaining the reasons for regional differences: the unemployment rate and the ratio of regional public debt to GRP. Both variables may relate in part to the broad credit channel. Other things being equal, the unemployed have more limited access to the financial market and may be more affected by monetary contraction (Beckworth, 2010; Burriel and

⁸ A similar effect was observed by Mandalinci (2015), who showed that for the UK regions, the level of mortgage debt is a significant factor in the regional heterogeneity of the response to monetary policy shocks.

Galesi, 2018). High regional public debt negatively affects the fiscal sphere during rate hikes (Vespignani, 2015), which can intensify the decrease in output and core inflation during rate hikes. In our calculations, the unemployment rate in the region turned out to be a statistically significant factor, while the regional public debt proved to be insignificant.

In the final regression of the regional response of 12-month cumulative core inflation to monetary policy shocks, we did not discover any significant spatial component. This means that the existing spatial effects were internalised through factors explaining the regional heterogeneity of the core inflation response. In the final regression for the 5-year cumulative response of core inflation, the significance of most of the factors decreases, and spatial autocorrelation appears. We attribute this to the existence of (incomplete) beta convergence in price levels.⁹

As in most papers on this topic, all the factors that appear in the final equation in one way or another reinforce or weaken the response of regional aggregate demand to monetary policy shocks. In this case, the response of volumes (GRP, employment, income, etc.) and prices (core inflation) will be co-directional.¹⁰

At the same time, we do not expect full correspondence of the response of the variables characterising economic activity and core inflation to monetary policy shocks in reaction to different factors: different channels may in one way or another involve different mechanisms of real price rigidity in a region. Then in the two regressions, one explaining the response of the core inflation to a monetary policy shock and the other explaining the response of the economic activity to a monetary policy shock, may have different sets of significant factors, as well different coefficients for the significant factors.

Thus, the degree of the heterogeneity in the core inflation response to monetary policy shocks in the Russian regions, the set of factors explaining this heterogeneity, and the explained part of the regional response variance (30–40% depending on the specification) turned out to be comparable to similar figures in other countries with pronounced regional heterogeneity¹¹ (Australia, Indonesia, Canada, China, USA and Turkey).

Hereafter, the work is organised as follows. In Section 2, we discuss the choice of methodology for obtaining core inflation impulse responses to monetary policy shocks. Section 3 contains the analysis of the properties of regional heterogeneity of the inflation response to monetary policy shocks. Section 4 contains the main findings and conclusions of the paper.

⁹ Full beta convergence would lead to insignificance of all regional factors and the disappearance of regional heterogeneity.

¹⁰ An example of work paying significant attention to the supply-side factors is the study by Beckworth (2010). It considers the factors of an optimal currency area (wage flexibility, labour mobility, degree of diversification of the state economy, level of fiscal transfers in the region) as factors explaining the heterogeneity of income response to monetary policy shocks in the US.

¹¹ For example, Dominguez-Torres and Hierro (2019) estimate the typical percentage of explained regional variance in the regional output response to monetary policy shocks to be in the range of 40–65%.

2. Application of GVAR modelling to estimate the impact of monetary policy on inflation in Russian regions

In the first part of the section, we discuss the GVAR methodology; in the second part, a GVAR model is used to estimate the regional inflation response to monetary policy shocks.

2.1. Construction and specification of the GVAR model

GVAR is a high-dimensional VAR that makes it possible to account for the various relationships between markets, countries, and regions when analysing economic variables (Pesaran et al., 2004). Inclusion of spatial dependence in the modelling makes it possible to identify and take into account several transmission channels of macroeconomic shocks. Ultimately, the use of GVAR makes it possible to build *ex ante* forecasts and impulse response functions (IRFs) for shocks of any variables in the modelled economy. For example, GVAR allows both to study the impact of shocks in global prices for energy or food resources on the macroeconomic indicators of different countries and to analyse the consequences of a crisis in a particular region for other economies. As shown by the authors of the approach, in practice such analysis of the interdependence of economies cannot be implemented using the traditional econometric methods due to the limitations on the data used. In GVAR, the problem of high dimensionality is overcome by estimating region-specific models that include special external variables.

To estimate the regional inflation response to monetary policy shocks, we first built a **baseline GVAR model**. The indicators for this model were selected on the ground of their necessity and their interpretation in the simulated economic system, also taking into account the availability of the regional statistical data of the required frequency for the selected estimation period. In general, spatial interaction is modelled by explaining the dynamics of domestic macroeconomic indicators by the dynamics of the corresponding external and global variables. The domestic variables are endogenous and define each other as indicators of a region's economy. External variables represent a key spatial feature of the model. They are the same domestic indicators of other regions, weighted according to a set matrix. As a rule, the matrix is built on the basis of interregional trade flows, but it can also be determined by the structure of regional economies, their geographical proximity, and other indicators of spatial interaction. Global variables are formed at the supra-regional level and must be determined, i.e. be endogenous either in one dominant region (if applicable) or in a dominant unit model.

The model includes the following variables.

1. Two domestic regional variables.

The first regional variable is inflation, a key indicator whose response is estimated and subsequently analysed. A Rosstat indicator characterising price

changes and guiding the Bank of Russia's inflation-targeting measures is the CPI for all goods and services. It is calculated as the weighted average of 520 items across all regions of Russia on a monthly basis.¹² However, this paper uses the core inflation indicator, which is also calculated by Rosstat and covers most items (415 items or 70%, taking into account their weight) in all three components (food, non-food products, and services), with the exception of highly volatile and regulated prices.¹³ These include, for example, tariffs for housing and utility services, prices for public and a number of passenger services, vital and essential medicines, and some types of fruits and vegetables. The value of these goods and services is less affected by market factors (supply and demand) and, therefore, less responsive to monetary policy measures. Core inflation cleared of such goods and services is also called monetary inflation and is used in a number of studies to analyse the impact of central bank measures on inflation (see, for example, Nessén and Söderström, 2001; Reis and Watson, 2010; Dementiev and Bessonov, 2012; Deryugina et al., 2015).

The second regional variable is the weighted average rate on household loans. It is included to take into account the stage of transmission of monetary policy shocks from changes in the key rate to changes in rates on banking operations. Modelling this stage makes it possible to naturally factor in the consistent nature and larger lag of the transmission process and also to take into account a possible heterogeneity of adjustment of the regional rates. The rates for households and not for firms were selected due to the focus of the study on inflation: consumer demand factors, including the conditions and volume of household lending, have a greater effect on changes in consumer prices.

2. Two external variables are, respectively, weighted average inflation rates and lending rates in other regions, which are necessary for taking spatial effects into account. Inflation is weighted based on the interregional trade matrix and rates are weighted based on the financial matrix of credit flows.

3. Three global variables. The dollar exchange rate was added to approximate those external shocks that affect inflation through changes in the exchange rates and the exchange rate pass-through effect, i.e. changes in the prices of imported or import-dependent goods and services. Oil prices are included as a factor of the global environment, influencing both the exchange rate and budget revenues and the economy of the regions (especially those characterised by predominance of oil production and oil refining industries). The short-term interbank lending rate (MIACR for overnight rouble loans) is used as an indicator of the monetary policy of the Bank of Russia. Currently, its dynamics are close to the dynamics of the Bank of Russia key rate, as in the case of other overnight interbank rates, since this convergence is the operational goal of monetary policy.

¹² See 'Consumer price indices and average prices for goods and services' at Rosstat website: <https://rosstat.gov.ru/storage/mediabank/ipc.html> [In Russian].

¹³ See 'Descriptive characteristics of representative goods (services) for observing consumer prices and tariffs in 2020' at Rosstat website: <https://rosstat.gov.ru/storage/mediabank/bUwgHeap/nabor-2021-2018.XLSX> [In Russian].

Table 1 shows the definitions of these indicators and the sources of data for their calculation. The baseline model consists of individual equations for regions where inflation dynamics depend on regional rates, weighted inflation in trading partner regions, weighted rates in financially linked regions, exchange rates, oil prices, and monetary policy. The global variables (exchange rate, oil prices, and interest rate) are determined endogenously in the dominant unit VAR model. In addition, the interest rate equation in the dominant unit model is supplemented with the lags of nationwide inflation, endogenously calculated in each period as the weighted average regional inflation.¹⁴ This helps to take into account in the function of the central bank's response the current dynamics of inflation and the factors influencing it.

Table 1. Definitions of indicators used in the GVAR model

Indicator	Description	Source
Inflation	Growth rate of the regional core consumer price index (CCPI) for all goods and services, % against the previous period	EMISS (Unified Interdepartmental Statistical Information System)
Lending rates	Regional weighted average rates on household rouble bank loans in the reporting period, % per annum	Bank of Russia
Foreign exchange rate	Growth rate of the exchange rate of the dollar against the rouble, % against the previous period	Finam
Oil prices	Growth rate of Brent crude oil exchange price, % against the previous period	Finam
MIACR	Weighted average rate on overnight rouble interbank loans of Moscow banks, % per annum	Bank of Russia

The scheme of interaction of variables in the baseline model is shown in Figure 1.

Figure 1. Scheme of the GVAR model for estimating the effects of monetary policy

Source: compiled by the authors

¹⁴ The shares of consumer household spending of the regions in the total household spending of Russia were used as regional weights, as this corresponds to Rosstat's methodology for calculating the nationwide CPI from regional indicators.

Thus, each of the equations for region i is a VAR with the additional exogenous variables $\text{VARX}^*(p_i, q_i)$:

$$\begin{aligned} x_{it} = & \alpha_{i0} + \alpha_{i1}t + \Phi_{i1}x_{i,t-1} + \dots + \Phi_{ip_i}x_{i,t-p_i} \\ & + \Lambda_{i0}x_{it}^* + \Lambda_{i1}x_{i,t-1}^* + \dots + \Lambda_{iq_i}x_{i,t-q_i}^* \\ & + \Psi_{i0}\theta_t + \Psi_{i1}\theta_{t-1} + \dots + \Psi_{iq_i}\theta_{t-q_i} + u_{it}, \quad (1) \end{aligned}$$

where p_i is the order (maximum lag) of the model in terms of endogenous variables; q_i is the order of the model in terms of exogenous variables; x_{it} is the $k_i \times 1$ vector of domestic (endogenous) variables; Φ_i is the $k_i \times k_i$ matrix of coefficients of domestic variables; x_{it}^* is the $k_i^* \times 1$ vector of external variables; Λ_i is the $k_i \times k_i^*$ matrix of coefficients of external variables; θ_t is the $k_\theta \times 1$ vector of global variables; Ψ_i is the $k_i \times k_\theta$ matrix of coefficients of global variables; and u_{it} is the $k_i \times 1$ vector of idiosyncratic regional shocks.

External variables for region i are determined as a weighted average of similar domestic indicators of all other regions:

$$x_{it}^* = \sum_{j=1}^N w_{ij}x_{jt}, \quad (2)$$

where the weights w_{it} characterise the relative strength of the influence of the economy of region j on the economy of region i , $w_{ii} = 0$, $\sum_{j=1}^N w_{ij} = 1$.

The global variables are evaluated in a separate dominant unit model. It is $\text{VAR}(p_\theta)$:

$$\theta_t = \mu_0 + \mu_1t + \Phi_1\theta_{t-1} + \dots + \Phi_{p_\theta}\theta_{t-p_\theta} + \eta_t, \quad (3)$$

where p_θ is the order of the model, Φ is the $k \times 1$ vector of coefficients, and η_t is the random error of the model.

With regard to the random components u_{it} of individual equations (1), it is assumed that the idiosyncratic shocks are independent and identically distributed random variables: $u_{it} \sim i.i.d.(0, \Sigma_{ii})$, where Σ_{ii} is a non-degenerate variance-covariance matrix.

The individual models are estimated separately, and their external and global variables are assumed to be weakly exogenous with respect to the regions, which is on the whole reasonable given the small sizes of the regional economies compared to the overall economic system under consideration. For obtaining the correct estimates of the coefficients, all model variables must be stationary $I(0)$ time series. The estimation of the final individual equations, including the dominant unit model, is performed using the ordinary least squares (OLS).

After the separate estimations, the individual equations are sequentially combined to obtain a single GVAR model and solve it relative to the system as a

whole, i.e. for the vector of all indicators for all regions: y_t with a dimensionality $(k + k_\theta) \times 1$, where $k = \sum_{i=1}^N k_i$. This vector includes all unique variables, both domestic and global, and when solving the model, they are all already regarded as endogenous to the system. At the first stage, they are combined by using connecting $(k_i \times k_i^*) \times k$ matrices W_i . They are based on the weights w_{ij} and make it possible to get rid of external variables in the individual equations.

We study the behaviour of the simulated economic system on the forecast horizon taking into account various possible scenarios by using IRFs of all model indicators to shocks of domestic variables at the level of the selected region, as well as to shocks of global variables in the equation where they are determined. Within the GVAR framework, it is necessary to take into account that the shocks within one region, as well as shocks across regions may be correlated. Construction of generalised IRFs (GIRFs) is a method which is suitable for GVAR and allows for and takes into account possible correlation between errors, while at the same time being invariant to the order of variables and regions in the model (Koop et al., 1996; Pesaran and Shin, 1998).

The following features of the model are worth noting separately.

Identification of monetary policy shocks. When modelling central bank policy by using interest rates in VAR models, a common problem is the problem of correct inflation response. This problem is known in the literature as the ‘price puzzle’ (Jung and Ryu, 2020): inflation can accelerate with policy tightening, i.e. respond positively to a positive rate shock, despite the correct response of other variables (for example, a decrease in the output or supply of money). Sims (1992) was one of the first to address this problem and suggested that it may be related to the endogenous nature of monetary policy. If the monetary authorities expect an acceleration of inflation not explained by the dynamics of the model variables, they will pre-emptively raise the interest rate, after which inflation will accelerate, although less than it could have had without the use of monetary policy measures. Such unforeseen acceleration may be caused, for example, by negative supply shocks, which are difficult to introduce into a non-structural time series model.

Sims (1992) and subsequent studies on the price puzzle suggest a number of solutions, mostly involving additional data. They include models using stock market indices of commodity prices, proxy indicators of inflation expectations (for example, from various surveys), or FAVAR models with a whole wide range of variables that central banks can take into account when making decisions. However, there is no single solution: in different countries, the problem can be manifested to different degrees and caused by different reasons. For example, Florio (2018) shows that, in countries with inflation as a clearly marked nominal anchor (Canada, Australia, New Zealand, euro area countries, and a number of other European countries), the problem is not observed, in contrast to the USA and Japan; this may be related to the effectiveness of inflation expectation management.

In this paper, we identify monetary policy shocks based on the fact that policy has a substantial transmission lag. According to the historical data on the Russian economy, the impact of changes in the interest rate on the real sector and inflation can begin to manifest in a few months and continue for a period of up to one and a half years (Bank of Russia, 2019, p. 89). As a consequence, in the short term central bank measures may have little effect on pro-inflationary shocks, regardless of how they are determined in the model. Accordingly, if this is not taken into account, a model with normal dimensionality, including up to 2–3 lags, can underestimate the effect of monetary policy shocks or identify them as insignificant or incorrect in sign. Therefore, in this paper, the monetary policy variable is used in the baseline model with a two-month lag. In combination with the inherent lags of the VAR model, this allows us to get the right response: inflation slowdown in response to an increase in the key rate. Loan rates, which respond more quickly to the given shock, are used with a similar lag.

Weight matrices for external variables. One of the key aspects of GVAR is taking spatial effects into account, and selection of the appropriate principle for constructing external variables is important for their correct modelling. Weights used for this should reflect, as fully as possible, the prior knowledge on the nature of spatial relationships. Using inappropriate weights may result in lower significance or misinterpretation of spatial effects.

Trade matrix. In this paper, we chose weights based on the volume of mutual interregional trade in consumer goods as the base weights for inflation. Firstly, the use of information on trade flows is the most common practice in GVAR modelling, and secondly, it better reflects the economic interaction of regions. It may depend not only on geographic factors but also on a number of others: presence of historically stable economic and political relationships, presence of large vertically integrated companies, a trade-friendly sectoral structure, etc. The combination of these factors largely determines the magnitude of trade flows between regions; therefore, using them as the basis for weights is more informative for the model.

To calculate the matrices, we had to overcome the limitations of the available data: only the trade statistics for 11 regions of the Volga Federal District with all other regions of Russia were available.¹⁵ The data have the following characteristics: given as of the end of 2016; separately for export and import; in monetary terms; for individual products and product groups (both industrial and consumer goods).

The complete weight matrix was built from the available data in three steps. First, we selected and aggregated data on trade in those consumer products and product groups that correlate to the inflation components observed by Rosstat. In total, we used statistics for 72 goods corresponding to 216 components of the CPI

¹⁵ We found no publicly available statistics on trade volumes between Russian regions. The available data were obtained in cooperation between the territorial bodies of the Bank of Russia and Rosstat for the following regions: Kirov, Nizhny Novgorod, Penza, Samara, Saratov and Ulyanovsk Regions, the Republics of Mari El, Mordovia and Tatarstan, and the Udmurt and Chuvash Republics.

(65.5% by weight in the CPI for all goods). Second, data on exports and imports were summed up to obtain indicators of foreign trade turnover (value of trade flows). Third, the final trade data for 11 regions were extrapolated to the rest of Russia using a gravity model estimation.

The gravity model provides econometric assessment of the dependence of interregional trade volume on key indicators similar in principle to Newton's law of gravity:

$$F = G \frac{m_1 m_2}{d^2}, \quad (4)$$

where F is the force of gravitation between two objects; G is a gravity constant; m_1 , m_2 is the mass of objects; and d is the distance between objects.

Jan Tinbergen (Tinbergen, 1962) was the first to propose the idea of using the size of regional economies and the distance between them as the mass and distance to build such models. Later, gravity models were developed in the studies of various researchers with the use of additional factors that determine the volume of interregional trade. In this paper, we use the specification proposed by Baier and Bergstrand (2009) and assume the following general relationship:

$$\text{Trade}_{ij} = f(\text{GRP}_{ij}, \text{Distance}_{ij}, \text{Multilateral resistance}_{ij}). \quad (5)$$

The total GRP of two regions reflects their size, and distance means both the direct distance between the regions and their adjacency. Multilateral resistance (MR) is an additional factor reflecting how far each of the two regions is from all other regions (the distance is weighted by the GRP of the regions and can be similarly estimated both by the adjacency of the regions and by the distance between them).

Without dwelling on the properties of the model used as an intermediate instrument, we characterise the estimated equation for extrapolating trade volume ($R^2 = 0.67$):

$$\begin{aligned} \ln(\text{Trade}_{ij}) = & -20.9 + 2 \times \ln(\text{GRP}_{ij}) + 0.8 \times \text{Common border}_{ij} - 1.3 \\ & \times \ln(\text{Distance}_{ij}) + 1.7 \times \text{MR for borders}_{ij} + 0.3 \times \text{MR for distance}_{ij}. \end{aligned} \quad (6)$$

All coefficients of the equation are statistically significant and correspond in sign to the theoretical assumptions. The trade volume depends positively on the size of the regional economies and negatively on the distance between them. More active trade is typical for neighbouring regions and for pairs of regions that are remote from all other regions.

Using coefficients of the estimated models, geographic data and GRP statistics, we calculated the values of trade turnover between all 80 regions. Therefore, the

final estimate of trade flows correctly takes into account the spatial mutual position of the regions. The normalisation to 1 necessary for any weight matrix provides the following interpretation for the obtained weights: w_{ij} reflects the share of region j in the interregional trade turnover of region i . Thus, we assume a spatial relationship between the economies of the trading partner regions, and the more active the trade with one partner relative to others, the greater the potential impact of shocks in its economic indicators.¹⁶

Financial matrix. The spatial relationship of loan interest rates is largely due to the fact that most banks operate in different regions of Russia and can both simultaneously and sequentially introduce changes in their policies in each of the regions. In addition, due to the competitive environment and the development of online banking, borrowers from one region can seek more favourable conditions with banks from other regions, in particular, lower interest rates. To account for such spatial relationships, we used bank reporting data on the volume of household lending in two dimensions simultaneously: by regions of location of lenders (banks) and by regions of borrowers' residence.¹⁷ Building the matrix of such credit flows with normalisation to 1 for the regions of borrowers gives the following interpretation to the weights: w_{ij} reflects the share of banks of region j in the volume of lending to the borrowers of region i . It is assumed that regional rates are more influenced by the rates of those other regions where banks are more active in lending to borrowers of the first region. Due to the high concentration of federal banks in the Russian credit market, the distribution of weights in this matrix is much less even than in others: rates in Moscow have a decisive influence (for an average region, the weight of the Moscow banks in the loans to the regional borrowers reaches 85%), rates in the regions with large regional banks have a small effect, and all other regions in aggregate have minimal to no effect.

Geographic matrices. In the course of this study, in addition to the basic trade and financial matrices, the models were additionally estimated using various matrices based on both the geographical and territorial location of regions. The alternative approach to weighting made it possible, among other things, to analyse the degree of influence of the weights on the results of GVAR modelling, as well as to check the robustness of the estimates obtained using the primary weights.

Three matrices were formed according to the location of regions.

1. Adjacency (proximity) matrix. The weight w_{ij} is one if the regions share a common border, and zero otherwise.
2. Inverse distance matrix. The weight w_{ij} is the inverse of the distance between regions. Distance was calculated as the distance between the administrative centres of the regions based on their geographic coordinates.

¹⁶ We note the dominant position of Moscow in the trade turnover of other regions (on average, the share is 38.9% for all goods).

¹⁷ Source: Bank of Russia. Information on lending in the context of the regions of registration of credit institutions is for intra-bank use only and is not publicly available. For data on lending to regional borrowers by all banks, see https://www.cbr.ru/statistics/bank_sector/sors/#a_63196 [In Russian].

3. Federal district matrix. The weight w_{ij} is one if the regions belong to the same federal district, and zero otherwise.

These weighting options assume the dependence of the regional economies either equally on the indicators of its neighbours along the border or in the federal district, or, to varying degrees, on the indicators of all other regions (the influence is stronger for closer regions). Despite their relative simplicity, preliminary analysis of models with geographic matrices showed the presence of significant spatial effects on inflation and loan interest rates in Russian regions.

To illustrate the structure of all resulting matrices, Appendix A shows the average weights of each region for each weighing option: they reflect the average impact of the dynamics and shocks of each region's indicators on the rest of Russia.

2.2. Model data and estimation

Monthly time series for the period from June 2004 to March 2020 (190 observations for each indicator) were used to estimate the model. The model includes data for all regions of Russia except for the Republic of Crimea and the city of Sevastopol, excluded due to the lack of historical data. The Nenets, Khanty-Mansi and Yamalo-Nenets Autonomous Districts are included in the corresponding regions (Arkhangelsk and Tyumen). In total, we analyse 80 regions with complete (without gaps and errors) data for each period. All time series are checked for seasonality, with seasonal adjustment as necessary.¹⁸ Pre-processing, data analysis and auxiliary modelling were carried out in the R environment, and the final models were evaluated in the MatLab with the use of the GVAR Toolbox (Smith and Galesi, 2014).

All series were tested for stationarity, which is necessary for correct OLS estimation of VAR models. The results of the augmented Dickey-Fuller test with a constant showed that practically all inflation indicators, as well as the rate of change of exchange rate and oil price, are stationary. The null hypothesis about the presence of a unit root is rejected at the 5% significance level for 160 out of 162 series (taking into account external variables), so we do not use additional transformations to preserve the correct interpretation. For interpretation reasons, lending rates and MIACR are also left unchanged, although most of them test as having unit roots. It is important to control the final stability of the model, the eigenvalues of which must lie within the unit circle; the estimation showed that this condition is fulfilled in the baseline model. This means that the model produces correct IRFs for subsequent analysis.

Given the high dimensionality of the model, the number of lags was limited to two. Thus, each of the regional equations includes two lags of domestic variables, as well as the current value and one lag each of the domestic and global variables.

¹⁸ Seasonality was found for all regional indicators. The X-13 ARIMA-SEATS method was used for seasonal adjustment.

In the dominant unit model, the equations for the exchange rate and oil price both include one lag of all global variables, and the equation for the interest rate includes two lags each of the global variables, as well as two lags of nationwide inflation. The final GVAR model consists of 81 VAR models and 163 equations and requires the estimation of 2,417 coefficients (including constants).

Identifying monetary policy shocks

Figure 2 shows the actual and model dynamics of MIACR, as well as the residuals of this series, which we interpret as monetary policy shocks. While doing a good job of describing the MIACR adjustment during relatively stable periods, the model predictably attributes most of the sharp jumps in the rate to the shocks. Thus, the sharp MIACR hike in early 2009 and late 2014 designed to stabilise the foreign exchange rate is mainly attributed to (tight) monetary policy shocks. The model also does not see the factors behind the rapid return of MIACR to its previous values in February 2009 and attributes it to a (loose) monetary policy shock. The 2019 MIACR hike in response to the expected acceleration of inflation resulting from the VAT hike was not in line with the model, which assumed a gradual rate cut. The latter example demonstrates certain disadvantages of the VAR approach when modelling a forward-looking monetary policy rule, such as an inflation forecast targeting rule. In this paper, we did not consider possible changes in the monetary policy rule or the inflation response to MIACR shock after the transition to inflation targeting in 2015. The issue appears interesting, but it is outside the scope of our study, which focuses on regional aspects.¹⁹

Figure 2. Monetary policy shocks, %

Source: authors' estimates

¹⁹ For this reason, we believe that possible inaccuracies in assessing both the monetary policy rule and monetary policy shocks should not be decisive for the issues of regional heterogeneity.

Results of the estimation of the regional inflation response to monetary policy shocks and their robustness

After a separate estimation of all equations and solving the general model, we calculated generalised cumulative IRFs of all system variables to a positive MIACR shock of one standard deviation over a 5-year horizon. To analyse their significance, the median responses and 10% confidence intervals were estimated using a bootstrap (1,000 iterations). Then we used the calculated values of the response to characterise its magnitude and the bootstrapped confidence intervals to determine its significance. All values are proportionally normalised so as to correspond to a 1 p.p. monetary policy shock. The characteristics of the estimated responses averaged over all 80 regions are shown in Figure 3.

Figure 3. Main parameters of cumulative price responses to a MIACR shock of 1 p.p. and their confidence intervals

Source: authors' estimates

First, virtually all regions (77 out of 80) are characterised by a significant price reaction to monetary policy shocks. The insignificance of the response in Moscow, the Moscow Region, and the Chukotka Autonomous District is primarily due to the model's inherent wide confidence intervals with a relatively low response magnitude, while the response dynamics are similar to other regions. Due to correct identification, all responses are correct in sign, i.e. prices decrease in response to key rate hikes.

Cumulative inflation decreases continuously, first at an accelerated rate, then at a decreasing rate, and in the long run (after five years), the average response converges to -0.74. Compared to its final value, on average, the price response is half realised within a year and almost completely within three years (Table 2).

Table 2. Dynamics of average cumulative response of prices to a MIACR shock of 1 p.p.

Response horizon	6 months	1 year	2 years	3 years	4 years	5 years
Response value, p.p.	-0.18	-0.39	-0.62	-0.70	-0.73	-0.74
Long-term response ratio, %	24	53	83	94	98	100

Source: authors' estimates

Such cumulative dynamics correspond to the monthly change in price growth rate presented in Figure 4.

Figure 4. Response of the price growth rate in each month to a MIACR shock of 1 p.p., p.p.

Source: authors' estimates

Monetary policy shocks reach maximum impact (about -0.04 p.p.) on monthly inflation on average 5–6 months after a change in the key rate. In the regions, this lag generally varies from two to six months.

In order to check the robustness of the results to the selected specification, we estimated a number of additional models that differ from the baseline model by one or several parameters. Each of them retains the correct nature of the inflation response, but the number of significant responses varies due to the sensitivity of the confidence intervals.

1. Model without spatial effects. The exclusion of external variables from the GVAR model reduced both the number of regions with a significant response (to 69) and the average response value (to -0.62). This indicates the influence of spatial relationships and confirms the need to take them into account in order to obtain correct model estimates, since otherwise, the response of the variables can be underestimated. This is illustrated by the situation with the Chukotka Autonomous District, where inflation reacts in approximately the same way as in other regions (but is insignificant only because of the wide confidence intervals) in the baseline model, but when the spillovers are excluded, its trajectory changes sharply and remains near zero. This shows that, for remote regions, spatial relationships play a special role and failure to recognise this can lead to errors in identifying the response of regional indicators.

In addition, the importance of the spillover effects is evidenced by the significance of the coefficients characterising instantaneous responses of the domestic variables (inflation or rates) to similar external variables. Analysis of t-statistics shows that such effects are significant for inflation in almost all regions, and for loan interest rates, in half of the regions.

2. Alternative weight matrices. Three additional specifications were similar to the baseline one, but the external variables for inflation and rates were derived from different geographic matrices. Results for the model with an adjacency matrix practically coincide with the baseline model both in the number of significant responses and in their average value. At the same time, specifications with the other two geographic matrices proved unstable (eigenvalues of the model were over 1). After applying additional transformations (reducing the number of lags, applying an alternative matrix only to inflation), it was possible to obtain response functions, but they remained unstable. The inflation response in these two models is correct in sign, but it is impractical to assess its magnitude and significance.

3. Estimation for another period. The model was alternatively estimated on the data from February 2009, which made it possible to assess the stability of the results over a shorter interval, as well as to include additional variables that became available from this period (in particular, retail trade turnover as a factor approximating consumer activity). The inflation response in these specifications is similar in sign, but at the same time, the number of significant regions has noticeably decreased (to 14 out of 80), which may be mainly associated with a decrease in the number of degrees of freedom (fewer observations, more estimated coefficients).

4. Automated selection of lags. Two specifications were estimated with the number of lags not manually specified but selected for each of the 81 VAR models automatically using the Akaike information criterion (AIC) and Bayesian information criterion (BIC). However, the maximum allowable number of lags was limited to three in order to avoid problems with the estimation of the model (each lag involves the estimation of 7 additional coefficients in the equations of regional models and 3–4 coefficients in the dominant unit equations). As a result, in both variants the nature of the response remained the same but with a smaller number and lower value of significant responses. This could be due to the fact that the statistically optimal choice of lag for each region does not take into account the theoretical premises for modelling the transmission of monetary policy shocks. For example, if only one lag is selected according to the criterion for the variables in the regional equations, this may not be enough to identify the impact of the shock, as the actual lag is more significant.

Table 3 summarises the main results of estimating the seven alternative models compared to the baseline model.

As the general results demonstrate robustness to individual specification issues, we proceed to the analysis of the heterogeneity of the responses obtained in the baseline model.

Table 3. Comparing the results of the baseline and alternative models

Model	Number of significant responses	Average long-term response value, %
Baseline	77	0.74
Without spillovers	69	0.62
Weights according to adjacency matrix	78	0.75
Weights according to inverse distance matrix	Unstable models; functions correct in sign but unstable in dynamics	
Weights according to federal district matrix		
Based on data from 2009 with retail turnover	14	0.65
With number of lags selected based on the AIC criterion	65	0.54
With number of lags selected based on the BIC criterion	61	0.48

Source: authors' estimates

3. Empirical analysis of differences in regional effects of monetary policy

3.1. Analysing the scale of heterogeneity

Statistical characteristics of inflation responses for each region according to the baseline model are given in Appendix B. Figure 5 shows a map of Russia demonstrating the 5-year cumulative response of regional core inflation to monetary policy shocks. Taking into account the fact that the response of all regions is correct in sign, from here on, we will consider absolute values of the response.

Figure 5. Map of regional inflation responses to a MIACR shock of 1 p.p.

Note: A darker shade of violet means a stronger regional inflation response. Regions with insignificant inflation response are marked in yellow.

Source: authors' estimates

We can draw the conclusion on the heterogeneous nature of the effects of monetary policy on inflation in Russian regions: the magnitude of the final responses ranges from 0.35 in Chukotka to 1.1 in Ingushetia (Figure 6).

If we discard the four regions with the highest and lowest response, truncating the sample by 10% and at the same time exclude three statistically insignificant responses, the range will still be substantial: from 0.55 to 0.93 (1.7 times). The standard deviation is 0.12, which means that the 95% confidence interval is a range of $\pm 32\%$ of the average response ($\pm 24\%$ for the trimmed sample). At the same time, it should be noted that, if bootstrapped confidence intervals are used to assess the significance of differences between responses, there will not be a single pair of regions with statistically significantly differing responses. Confidence intervals of all regions intersect, including the regions with the highest lower limit and the lowest upper limit, Chukotka and the Penza Region (see Figure 7).

Figure 6. Dynamics of regional inflation responses to a MIACR shock of 1 p.p.

Source: authors' estimates

Figure 7. Responses with the most differing confidence intervals

Source: authors' estimates

However, we know this to be common from previous research, which often analyses non-significant responses due to the problem of wide confidence intervals. Due to the wide range of the estimates of the responses, we consider the possible reasons for their heterogeneity.

3.2. Decomposition of cumulative regional inflation into shocks

Our methodology makes it possible to decompose the dynamics of regional inflation into shocks, providing a picture of the role of regional and general shocks affecting inflation, and the contribution of various interregional effects. The results of such decomposition are summarised in Table C1 in Appendix C which contains averaged values for 80 regions of Russia.

The contribution of the three general shocks to the inflation dynamics of an average region ranges from 8% (zero months) to 56% (five years). This result does not generally contradict Deryugina et al. (2019), who estimate the general inflation factor at 40%.²⁰ Notably, the contribution of oil price and exchange rate shocks decreases over time, while the contribution of monetary policy shocks grows (from 3% for six months to 32% for five years). The main reason for this is related to the fact that, first, significant lags in the monetary transmission mechanism reduce the contribution of monetary policy shocks to inflation dynamics in the initial periods; second, in the case of a monetary policy shock, the properties of the return of prices to the average level are weak. This may indirectly indicate that discretionary monetary policy can significantly affect the long-term difference in regional prices.²¹ However, most of this heterogeneity is probably not associated with the losses of agents, as they have enough time to adjust to the specifics of the region and monetary policy in all of their economic decisions.

The contribution of domestic inflation shocks decreases gradually: from 28% for zero months to 5% for five years. The idiosyncratic component of inflation is estimated by Deryugina et al. (2019) at approximately 40%. It is difficult to compare these estimates, since in our paper, part of the idiosyncratic component identified by Deryugina et al. (2019) is attributed to the influence of variables from other regions, while domestic interest rate shocks classified as 'Contribution of all other regional shocks'.

3.3. Heterogeneity in the response of regional inflation to general shocks: the stabilising role of monetary policy shocks

Table C2 in Appendix C shows the main properties of responses of regional inflation, MIACR and foreign exchange rate to general shocks: monetary policy,

²⁰ The results cannot be fully comparable, due to rather significant differences in the methodologies of the papers and because some of the general shocks associated with the dynamics of average inflation are included in the 'Contribution of all other regional shocks' aggregate.

²¹ This section deals with the contribution to dynamics. To understand how this might affect regional price dispersion, it is necessary to take into account the regional dispersion of price responses to monetary policy shocks in the long run, which is discussed in the next section.

foreign exchange rate, and oil price shocks. The dynamic properties of these shocks are quite different: monetary policy (MIACR) shocks have no significant long-term impact on the MIACR itself or on the foreign exchange rate and oil prices. An exchange rate shock (a 10% weakening of the rouble) leads to a long-term significant weakening of the rouble (about 5%), while an oil price shock (a 10% drop) in the long run intensifies to a decrease of 15% and leads to a long-term depreciation of the rouble by 4.8% (long-term oil price elasticity of the exchange rate is -0.32).

In Figures 8 and 9, the magnitude of the regional inflation response to monetary policy shocks (vertical axis) is compared with the magnitude of the regional inflation response to general foreign exchange rate shocks (horizontal axis in Figure 8) and to oil price shocks (horizontal axis in Figure 9). This comparison allows us to understand whether the unequal inflation response to monetary policy shocks can reduce regional heterogeneity created by general shocks in the exchange rate and oil prices. We plotted regional responses for three time intervals: six months (blue), one year (green) and five years (black). If all values for a time interval were on the same straight line, this would mean that the strong response of regional inflation to general shocks is compensated by the strong response to monetary policy shocks. This would help to reduce regional price dispersion resulting from external shocks that forms the basis for losses from imperfect adjustment. Due to the specifics of external shocks used in the study (weakening of the rouble and decline in oil prices), such a straight line should have a negative slope for both Figures. We see that the strongest correlation between responses is observed for the 6-month inflation response to exchange rate and monetary policy shocks, which is -0.43 . The longer the time elapsed since the shock, the less correlation of these responses is observed. A similar trend is observed for the pair of oil price and monetary policy shocks, with a lower correlation of the 6-month response at -0.2 . This means that, on a monetary policy horizon (up to a year), an unequal response to monetary policy shocks can moderately reduce the heterogeneity of inflation response to exchange rate shocks. Thus, discretionary monetary policy can to some extent reduce regional heterogeneity resulting from general external shocks.

In the long term, the picture becomes fundamentally different. It is no longer possible to smooth out the long-term heterogeneity of price growth resulting from external shocks through the response to monetary policy shocks. Moreover, as shown in the previous section, the contribution of monetary policy shocks to inflation in an average region begins to exceed the contribution of exchange rate and oil price shocks. However, in the long term, we are no longer dealing with losses arising in the regional business cycles. Differences in CPI between regions have the potential to become a source (or indicator) of income inequality, which will require longer-term regional fiscal policy measures.²²

²² This topic is beyond the scope of our study and should be considered within a more extensive analysis which would allow to draw conclusions about the long-term dynamics of real income variables.

Figure 8. Cumulative regional inflation responses to monetary policy shocks (1 p.p.) and foreign exchange rate shocks (10% depreciation of the rouble)

Source: authors' estimates

Figure 9. Cumulative regional inflation responses to monetary policy shocks (1 p.p.) and oil price shocks (10% decrease)

Source: authors' estimates

3.4. Econometric analysis of heterogeneity factors

A study of the factors of regional heterogeneity of the response of macroeconomic variables to monetary policy shocks is usually associated with the discussion of monetary transmission channels: each variable is associated with a certain channel, which makes it possible to structure the factor analysis to some extent. In this section, we adhere to this widely used analytical framework, which allows us to add extra information to the analysis of the heterogeneity of the impact of monetary policy on inflation and also to compare the obtained results with findings of similar studies.

To identify and analyse the factors influencing the regional differences in the response, cross section estimates for the model were used for all 80 regions. However, the analysis of a wide range of models with the inclusion of factors that characterise either one potential source of heterogeneity or several of them at once made it possible to determine the indicators that have a stable significant impact on the magnitude of monetary policy effects. Given the already demonstrated significance of spillover effects for the dynamics of regional macroeconomic indicators, we can assume that the magnitude of the response to monetary policy shocks may also be spatially interrelated (for example, see Bertanha and Haddad, 2008; Duran and Erdem, 2014). Therefore, the analysis of the heterogeneity factors involved an estimation of both conventional linear regressions and several specifications of spatial autoregressions (LeSage and Pace, 2009).

1. Model with spatial autoregressive lag (SAR): $y = \rho W y + X\beta + \varepsilon$.

The dependent variable is influenced by its spatial lag ρ .

2. Model with spatial interaction in errors (SEM): $y = X\beta + u, u = \lambda W u + \varepsilon$.

The dependent variable is spatially related to unobservable factors in other regions through the model error by the parameter λ .

Table 4. Indicators used and possible heterogeneity factors

Source of heterogeneity	Indicator
'Interest rate channel'	Share of the manufacturing industry in GRP
	Share of primary industries in GRP
	Share of loans to manufacturing enterprises in the total loans to firms
'Narrow credit channel'	Share of loans to firms and households of the region issued by regional banks;
	Share of funds of individuals deposited in the top five banks
'Broad credit channel'	Share of those employed in micro and small enterprises
	Share of household loans in GRP
'Currency channel'	Share of imports in GRP
	Share of exports in GRP
	Share of net exports in GRP
	Share of foreign trade turnover in GRP
Other factors	Unemployment rate, %
	Ratio of the region's public debt to GRP

The dependent variable y is the cumulative response of core inflation from the baseline model, W is a matrix of spatial weights, and various characteristics of the region's economy are used as X regressors. They are selected in relation to the heterogeneity factors attributed to different monetary transmission channels (for example, see Carlino and Defina, 1998, Carlino and Defina, 1999, etc.) and are detailed in Section 1. Table 4 shows a list of the indicators used. Descriptive statistics for variables are provided in Appendix D. Table 5 provides specifications of the model that better explain regional heterogeneity. Some alternative specifications are shown in Appendix E.

Table 5. Results of estimating models with heterogeneity factors

Heterogeneity factor	Response in one year		Response in two years		Long-term response	
	SAR	SEM	SAR	SEM	SAR	SEM
Share of primary industries ^a in GRP	0.195+ (0.132)	0.208+ (0.131)	0.169 (0.182)	0.228 (0.192)	0.0638 (0.206)	0.171 (0.224)
Share of loans to manufacturing enterprises	0.074* (0.046)	0.080* (0.048)	0.089 (0.065)	0.101+ (0.067)	0.067 (0.074)	0.082 (0.078)
Share of those employed in micro and small enterprises	0.638*** (0.190)	0.634*** (0.189)	0.933*** (0.269)	0.922*** (0.265)	0.953*** (0.309)	0.934*** (0.302)
Share of loans issued by regional banks	-0.072 (0.064)	-0.053 (0.070)	-0.084 (0.090)	-0.041 (0.088)	-0.077 (0.103)	-0.026 (0.096)
Share of imports in GRP	-0.022 (0.042)	-0.017 (0.044)	-0.059 (0.060)	-0.044 (0.061)	-0.077 (0.068)	-0.057 (0.069)
Unemployment rate	0.011*** (0.002)	0.011*** (0.002)	0.015*** (0.003)	0.016*** (0.003)	0.016*** (0.003)	0.017*** (0.003)
_cons	0.106 (0.147)	0.152*** (0.044)	0.055 (0.206)	0.286*** (0.064)	0.001 (0.214)	0.418*** (0.080)
ρ	0.128 (0.362)		0.387 (0.321)		0.569** (0.271)	
λ		0.292 (0.505)		0.587* (0.328)		0.743*** (0.224)
pseudo R^2	0.391	0.390	0.363	0.362	0.312	0.313

Note: ^a – primary industries comprise of agriculture and extractive industry. +, *, ** and *** mean that the estimate is significant at the 15%, 10%, 5%, or 1% level, respectively. Standard errors are given in round brackets.

Source: authors' estimates

The estimation of the spatial autoregressions showed the significance of the spatial lag of the response of other regions and the spatial autocorrelation of random components for the long-term response. This means that the long-term response of regional inflation is determined, among other things, by spillover effects. SAR and SEM models based on the inverse distance matrix were found to be optimal for identifying spillover effects. To further test the robustness of the results, the model was estimated with two types of spatial effects, and for the inflation response in one year (when half of the long-term value is realised) and two years. The models have satisfactory explanatory power in comparison to the findings of other

empirical studies. A review by Dominguez-Torres and Hierro (2019) shows that the proportion of explained variance is on average about 41% for all models considered and about 40% for the emerging economies models. In this paper, the identified factors provide for R^2 at the level of 30–40%, which is a good result but, as in all other cases, indicates the existence of a number of factors with unidentifiable influence.

The obtained results allow us to draw the following conclusions on the causes of heterogeneity.

1. The regional effect of monetary policy is influenced by spatial interaction.

For short-term responses, spillovers may have no impact, since the degree of heterogeneity and the degree of the structural factors' influence on it are lower; however, in the long-term, the magnitude of the cumulative inflation response positively depends on the corresponding magnitude of the response in the nearest regions. For the 1-year cumulative inflation response, no spatial connectedness manifests: this means that the spatial correlation arises due to the factors explaining the spatial heterogeneity. However, for the 5-year cumulative inflation response, we have a statistically significant spatial correlation. This may indicate that some of the differences in the price responses of the regions are smoothed out over time due to the price convergence mechanism. This price adjustment mechanism has been known for several centuries as the Hume mechanism, or the so-called price-specie flow mechanism, and is capable of amplifying regional fluctuations in output caused by idiosyncratic supply shocks, as well as of creating a contagion effect in the case of idiosyncratic demand shocks.

2. Influence of 'the interest rate channel' is confirmed by the factor of industry structure. As in most empirical works on the analysis of the causes of heterogeneity, it was possible to reveal a significant impact of the differences in efficiency of the 'interest rate transmission channel' (but with respect to core inflation). According to the results of the model estimation, primary industries (agriculture and mining) can be called more interest rate elastic in the short run, and the more important part they play in a region's economy, the more strongly prices react to monetary policy shocks.

The situation with the manufacturing industries is somewhat more complicated: the share of these industries in itself is not a statistically significant factor in the inflation response to monetary policy shocks, possibly due to the fact that the manufacturing sector represents a fairly wide range of activities not necessarily associated with investments. It was possible to identify their effect by adjusting the initial indicator for the share of loans issued to regional firms in this particular industry. As a result, the regressor reflects both the share of manufacturing enterprises in the regional economy and their propensity to borrow.

3. Effectiveness of the 'credit channel' is confirmed only on the demand side.

According to our theoretical assumption, the effect of the 'broad credit channel' is indicated by the significant positive impact of the share of small business in the regional economy: small firms have a more limited ability to raise borrowed funds

and incur more transaction costs, and therefore react more strongly to monetary policy shocks. In addition, it may be of importance that interest rates on loans to small businesses are consistently higher and more volatile than those for large companies (Figure 10). As a result, small firms are more sensitive to loan servicing costs and may to a larger extent shift those onto the price of their products.

Figure 10. Dynamics of weighted average rates on rouble loans to Russian businesses

Source: authors' estimates

However, the analysed specifications did not reveal any robust supply side effects. The role of 'narrow credit channel' factors may be minimal due to the specifics of the Russian banking sector, which is dominated by several federal banks. In this regard, the regions are quite homogeneous: only 7% of loans are issued by regional banks (with the exception of Moscow).

4. None of the variables that approximate the impact of the effectiveness of the 'currency transmission channel' were statistically significant. However, the insignificance of foreign trade indicators may be caused by imperfections of the data available. To match the inflation indicator, it would be optimal to use the share of imports in the consumption or the prime costs of consumer goods and services, but the available statistics reflect only the overall figure, which includes many industrial and intermediate goods.²³

5. Out of additional factors, the regional unemployment rate showed a significant positive impact. This is consistent with the effects of economic shock absorbers investigated in some studies: a persistently high unemployment rate reflects low labour mobility, which could mitigate monetary policy shocks (Anagnostou and Papadamou, 2014). Another subchannel of the impact of the unemployment rate is associated with the 'broad credit channel': a higher regional unemployment rate can have a stronger influence on aggregate demand through the income effect in the context of financial market imperfections.

²³ The insignificance of imports can also be explained by the fact that the available data are largely related to the procedure for registering regional imports with the Federal Customs Service.

4. Conclusion

In this paper, we identified the response of core inflation in the Russian regions to the shocks of a single monetary policy and analysed the impact of various factors on the intensity of this response. In order to obtain the IRFs of the core inflation to monetary policy shocks, we estimated a GVAR model where the global variables of MIACR, foreign exchange rate and oil prices were included in the dominant unit VAR, and the regional core inflation and interest rate on rouble loans to households in the region were included in the regional VAR. To assess spillover effects, we used a trade matrix obtained by estimating a gravity model. For 77 out of 80 regions, the estimation of the 5-year cumulative core inflation response was statistically significant: the average response to a MIACR shock of 1 p.p. is -0.74 p.p. If we exclude three statistically insignificant responses and discard the four regions with the highest and lowest responses, we get a range of -0.55 to -0.93 p.p. with a standard deviation of 0.12.

Following the widespread practice of analysing the heterogeneity of the response of regional economic activity variables to monetary policy shocks, we grouped the heterogeneity factors according to the three major monetary transmission channels. The variables traditionally attributed to the ‘interest rate’ and ‘broad credit channels’ explain some of the observed regional heterogeneity in the core inflation response to monetary policy shocks. The higher is the share of extractive industries in the GRP, the higher is the proportion of loans issued to enterprises in the manufacturing sector, the higher is the share of those employed by small enterprises of a region, and the higher is the unemployment rate in the region, the stronger is the regional core inflation response to monetary policy shocks. However, we did not discover any statistically significant relationship between the core inflation response and the variables characterising the ‘currency’ and the ‘narrow credit’ channels; the share of imports in GRP, the share of exports in GRP, the share of net exports in GRP, the share of foreign trade turnover in GRP, the share of loans to firms and households of the region issued by regional banks, the share of funds of individuals deposited in the top five banks, and the ratio of the region’s public debt to GRP turned out to be statistically insignificant. The set of factors which we identified allowed us to explain 30–40% (depending on the model specification) of the heterogeneity of the core inflation response to monetary policy shocks in the Russian regions.

We found a certain correlation between the regional inflation response to monetary and exchange rate shocks, which means that a stabilising discretionary monetary policy has a positive external effect: it can moderately reduce the range of regional inflation caused by the heterogeneous response to foreign exchange rate shocks. At the same time, this effect does not manifest for oil price shocks or for any long-term shocks.

Analysis of the decomposition of regional inflation into shocks showed that in the long term, the contribution of monetary policy shocks to the CPI dynamics

of the average region is quite noticeable (32% for five years), which may cause regional differences in the CPI. On the one hand, these differences probably will not be associated with any losses of economic agents, since they manifest over a long interval, during which the agents have enough time to adjust to the specifics of the region and monetary policy in all of their economic decisions. On the other hand, understanding whether these long-term differences are subject to regulation for regional fiscal policy requires further research into regional income inequality.

References

- Anagnostou, A. and Papadamou, S.** (2014). The Impact of Monetary Shocks on Regional Output: Evidence from Four South Eurozone Countries. *Region et Developpement*, 39, pp. 105–130.
- Baier, S. L. and Bergstrand, J. H.** (2009). Bonus Vetus OLS: A Simple Method for Approximating International Trade-Cost Effects Using the Gravity Equation. *Journal of International Economics*, 77(1), pp. 77–85.
<https://doi.org/10.1016/j.jinteco.2008.10.004>
- Bank of Russia** (2019). Monetary Policy Guidelines for 2020–2022. Moscow: Bank of Russia.
- Barran, F., Coudert, V. and Mojon, B.** (1996). *The Transmission of Monetary Policy in the European Countries*. CEPII Research Center Working Papers, N 3.
- Beare, J.** (1976). A Monetarist Model of Regional Business Cycles. *Journal of Regional Science*, 16(1), pp. 57–64. <https://doi.org/10.1111/j.1467-9787.1976.tb00947.x>
- Beckworth, D.** (2010). One Nation Under the Fed? the Asymmetric Effects of US Monetary Policy and Its Implications for the United States as an Optimal Currency Area. *Journal of Macroeconomics*, 32(3), pp. 732–746.
<https://doi.org/10.1016/j.jmacro.2009.12.001>
- Bernanke, B. S. and Gertler, M.** (1995). Inside the Black Box: The Credit Channel of Monetary Policy Transmission. *Journal of Economic Perspectives*, 9(4), pp. 27–48.
<https://doi.org/10.1257/jep.9.4.27>
- Bertanha, M. and Haddad, E. A.** (2008). Efeitos Regionais da Pol´itica Monet´aria no Brasil: Impactos e Transbordamentos Espaciais. *Revista Brasileira de Economia*, 62(1), pp. 3–29.
- Burriel, P. and Galesi, A.** (2018). Uncovering the Heterogeneous Effects of ECB Unconventional Monetary Policies Across Euro Area Countries. *European Economic Review*, 101(C), pp. 210–229. <https://doi.org/10.1016/j.eurocorev.2017.10.007>
- Carlino, G. and Defina, R.** (1998). The Differential Regional Effects of Monetary Policy. *Review of Economics and Statistics*, 80(4), pp. 572–587.
- Carlino, G. and DeFina, R.** (1999). The Differential Regional Effects of Monetary Policy: Evidence from the U.S. States. *Journal of Regional Science*, 39(2), pp. 339–358.
<https://doi.org/10.1111/1467-9787.00137>
- Céspedes, L. F., Chang, R. and Velasco, A.** (2004). Balance Sheets and Exchange Rate Policy. *American Economic Review*, 94(4), pp. 1183–1193.
<https://doi.org/10.1257/0002828042002589>

- Clements, B. J., Kontolemis, Z. and Levy, J.** (2001). Monetary Policy Under EMU: *Differences in the Transmission Mechanism?* IMF Working Paper, N 102.
- Dementiev, A. and Bessonov, I.** (2012). Indeksy bazovoy inflyatsii v Rossii [The Indices of Core Inflation in Russia]. *HSE Economic Journal*, 16(1), pp. 58–87. [In Russian].
- Deryugina, E., Karlova, N., Ponomarenko, A. and Tsvetkova, A.** (2019). The Role of Regional and Sectoral Factors in Russian Inflation Developments. *Economic Change and Restructuring*, 52(4), pp. 453–474. <https://doi.org/10.1007/s10644-018-9232-y>
- Deryugina, E., Ponomarenko, A., Sinyakov, A. and Sorokin, K.** (2015). *Evaluating the Underlying Inflation Measures for Russia*. Bank of Russia Working Paper Series, N 4.
- Dominguez-Torres, H. and Hierro, L. A.** (2019). The Regional Effects of Monetary Policy: A Survey of the Empirical Literature. *Journal of Economic Surveys*, 33(2), pp. 604–638. <https://doi.org/10.1111/joes.12288>
- Duran, H. E. and Erdem, U.** (2014). Regional Effects of Monetary Policy: Turkey Case. *Regional and Sectoral Economic Studies*, 14(1), pp. 133–144.
- Eichengreen, B.** (1993). European Monetary Unification. *Journal of Economic Literature*, 31(3), pp. 1321–57.
- Florio, A.** (2018). Nominal Anchors and the Price Puzzle. *Journal of Macroeconomics*, 58(C), pp. 224–237. <https://doi.org/10.1016/j.jmacro.2018.09.004>
- Georgiadis, G.** (2015). Examining Asymmetries in the Transmission of Monetary Policy in the Euro Area: Evidence from a Mixed Cross-Section Global VAR Model. *European Economic Review*, 75(C), pp. 195–215. <https://doi.org/10.1016/j.eurocorev.2014.12.007>
- Georgopoulos, G.** (2009). Measuring Regional Effects of Monetary Policy in Canada. *Applied Economics*, 41(16), pp. 2093–2113. <https://doi.org/10.1080/00036840701604362>
- Gluschenko, K.** (2010). Zakon yedinoi tseny v rossiyskom ekonomicheskom prostranstve [The Law of One Price in the Russian Economic Space]. *Applied Econometrics*, 17(1), pp. 3–19. [In Russian].
- Guo, X. and Masron, T. A.** (2017). Regional Effects of Monetary Policy in China: Evidence from China's Provinces. *Bulletin of Economic Research*, 69(2), pp. 178–208. <https://doi.org/10.1111/boer.12095>
- Jung, C. and Ryu, J. E.** (2020). The Price Puzzle Revisited. *Applied Economics Letters*, 27(6), pp. 441–446. <https://doi.org/10.1080/13504851.2019.1630705>
- Kashyap, A. K. and Stein, J. C.** (2000). What Do a Million Observations on Banks Say About the Transmission of Monetary Policy? *American Economic Review*, 90(3), pp. 407–428. <https://doi.org/10.1257/aer.90.3.407>
- Kenen, P.** (1969). The Theory of Optimum Currency Areas: An Eclectic View. In: R. Mundell and A. Swoboda, eds. *Monetary Problems of the International Economy*. Chicago: The University of Chicago Press, pp. 41–60.
- Kirillov A. M.** (2017). *Inflyatsiya tsen na prodovol'stvennyye tovary v regionakh Rossii: prostranstvennyy analiz* [Spatial Analysis of Food Inflation in Russian Regions]. *Prostranstvennaya Ekonomika = Spatial Economics*, 4, pp. 41–58. [In Russian]. <https://doi.org/10.14530/se.2017.4.041-058>
- Koop, G., Pesaran, M. and Potter, S.** (1996). Impulse Response Analysis in Nonlinear Multivariate Models. *Journal of Econometrics*, 74(1), pp. 119–147. [https://doi.org/10.1016/0304-4076\(95\)01753-4](https://doi.org/10.1016/0304-4076(95)01753-4)

- Kwon, G. and Spilimbergo, A.** (2005). *Russia's Regions: Income Volatility, Labor Mobility, and Fiscal Policy*. IMF Working Paper, N 185.
- LeSage, J. and Pace, R. K.** (2009). *Introduction to Spatial Econometrics*. Boca Raton: CRC Press.
- Malkin, I. and Nechio, F.** (2012). *U.S. and Euro-Area Monetary Policy by Regions*. FRBSF Economic Letter, N 6.
- Mandalinci, Z.** (2015). *Effects of Monetary Policy Shocks on UK Regional Activity: A Constrained MFVAR Approach*. Queen Mary University of London, School of Economics and Finance Working Paper, N 758.
- McKinnon, R.** (1963). Optimum Currency Areas. *American Economic Review*, 53(4), pp. 717–725.
- Mundell, R.** (1961). A Theory of Optimum Currency Areas. *American Economic Review*, 51(4), pp. 657–665.
- Nachane, D. M., Ray, P. and Ghosh, S.** (2002). Does Monetary Policy Have Differential State-Level Effects? An Empirical Evaluation. *Economic and Political Weekly*, 37(47), pp. 4723–4728.
- Nechio, F.** (2011). *Monetary Policy When One Size Does Not Fit All*. FRBSF Economic Letter, N 18.
- Nessén, M. and Söderström, U.** (2001). Core Inflation and Monetary Policy. *International Finance*, 4(3), pp. 401–439. <https://doi.org/10.1111/1468-2362.00080>
- Oliner, S. and Rudebusch, G.** (1996). Is There a Broad Credit Channel for Monetary Policy? *FRBSF Economic Review*, 1, pp. 3–13.
- Owyang, M. and Wall, H.** (2009). Regional VARs and the Channels of Monetary Policy. *Applied Economics Letters*, 16(12), pp. 1191–1194. <https://doi.org/10.1080/13504850701367247>
- Perevyshin, Y. and Egorov, D.** (2016). Vliyaniye obshcherossiyskikh faktorov na regional'nyu inflyatsiyu [Influence of Common Factors on Russian Regional Inflation]. *Russian Economic Development*, 23(10), pp. 44–50.
- Perevyshin, Y., Sinelnikov-Murylev, S. and Trunin, P.** (2017). Faktory differentsiatsii tsen v rossiyskikh regionakh [Determinants of Price Differentiation across Russian Regions]. *HSE Economic Journal*, 2017, vol. 21, no 3, pp. 361–384.
- Pesaran, H. H. and Shin, Y.** (1998). Generalized Impulse Response Analysis in Linear Multivariate Models. *Economics Letters*, 58(1), pp. 17–29. [https://doi.org/10.1016/S0165-1765\(97\)00214-0](https://doi.org/10.1016/S0165-1765(97)00214-0)
- Pesaran, M., Schuermann, T. and Weiner, S.** (2004). Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model. *Journal of Business Economic Statistics*, 22(2), pp. 129–162. <https://doi.org/10.1198/073500104000000019>
- Reis, R. and Watson, M.** (2010). Relative Goods' Prices, Pure Inflation, and the Phillips Correlation. *American Economic Journal: Macroeconomics*, 2(3), pp. 128–57. <https://doi.org/10.1257/mac.2.3.128>
- Ridhwan, M. M., Groot, H., Rietveld, P. and Nijkamp, P.** (2014). The Regional Impact of Monetary Policy in Indonesia. *Growth and Change*, 45(2), pp. 240–262. <https://doi.org/10.1111/grow.12045>

- Rocha, R. M., Silva, M. and Gomes, S. M.** (2011). Por Que Os Estados Brasileiros Têm Reações Assimétricas a Choques na Política Monetária? *Revista Brasileira de Economia*, 65(4), pp. 413–441.
- Sims, C.** (1980). Macroeconomics and Reality. *Econometrica*, 48(1), pp. 1–48.
<https://doi.org/10.2307/1912017>
- Sims, C.** (1992). Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy. *European Economic Review*, 36(5), pp. 975–1000.
[https://doi.org/10.1016/0014-2921\(92\)90041-T](https://doi.org/10.1016/0014-2921(92)90041-T)
- Smith, L. V. and Galesi, A.** (2014). *GVAR Toolbox 2.0*.
<https://sites.google.com/site/gvarmodelling/gvar-toolbox>
- Suardi, M.** (2001). *EMU and Asymmetries in Monetary Policy Transmission*. European Communities Economic Paper, N 157.
- Tinbergen, J.** (1962). *Shaping the World Economy: Suggestions for an International Economic Policy*. New York: The Twentieth Century Fund.
- Vespignani, J.** (2015). On the Differential Impact of Monetary Policy Across States/Territories and Its Determinants in Australia: Evidence and New Methodology from a Small Open Economy. *Journal of International Financial Markets, Institutions and Money*, 34(C), pp. 1–13. <https://doi.org/10.1016/j.intfin.2014.10.001>
- Zhemkov, M. I.** (2019). Regional Effects of Inflation Targeting in Russia: Factors of Heterogeneity and Structural Inflation Rates. *Voprosy Ekonomiki*, 9, pp. 70–89. [In Russian]. <https://doi.org/10.32609/0042-8736-2019-9-70-89>

Appendices

Appendix A

Table A1 shows the average weights of each region for all other regions in terms of weighting matrices: trade, financial (*fin*), neighbourhood (*neigh*), and inverse distances (*dist*).

Table A1. Average weights of regions for different matrices

Region	tag	trade	fin	neigh	dist
Altai Territory	ALT	0.6	0.0	0.8	1.2
Amur Region	AMU	0.4	1.5	1.3	0.8
Arkhangelsk Region	ARK	0.3	0.0	1.0	1.0
Astrakhan Region	AST	0.2	0.0	0.5	1.1
Belgorod Region	BEL	0.7	0.0	0.4	1.3
Bryansk Region	BRY	0.3	0.0	1.0	1.4
Vladimir Region	VLA	0.5	0.0	1.0	1.7
Volgograd Region	VGG	0.5	0.0	1.5	1.2
Vologda Region	VLG	0.3	0.4	1.9	1.4
Voronezh Region	VOR	0.9	0.0	2.0	1.5
Moscow	MOW	38.9	84.7	0.4	2.0
Saint Petersburg	SPE	4.0	8.4	1.5	1.3
Jewish Autonomous Region	YEV	0.5	0.0	0.5	1.0
Trans-Baikal Territory	ZAB	0.2	0.0	1.2	0.8
Ivanovo Region	IVA	0.3	0.0	0.9	1.7
Irkutsk Region	IRK	1.1	0.1	1.3	0.9
Kabardino-Balkar Republic	KB	0.2	0.0	0.9	1.3
Kaliningrad Region	KGD	0.2	0.0	0.6	0.7
Kaluga Region	KLU	0.5	0.0	1.8	1.6
Kamchatka Territory	KAM	0.0	0.0	1.4	0.5
Karachai-Cherkess Republic	KC	0.2	0.0	0.9	1.4
Kemerovo Region	KEM	1.3	0.0	1.8	1.2
Kirov Region	KIR	0.3	0.0	2.1	1.3
Kostroma Region	KOS	0.3	0.5	1.0	1.7
Krasnodar Territory	KDA	2.6	0.1	2.1	1.2
Krasnoyarsk Territory	KYA	2.5	0.0	1.6	1.0
Kurgan Region	KGN	0.5	0.0	0.7	1.1
Kursk Region	KRS	0.4	0.0	1.6	1.4
Leningrad Region	LEN	0.4	0.0	1.7	1.3
Lipetsk Region	LIP	0.6	0.0	1.3	1.6
Magadan Region	MAG	0.1	0.0	1.2	0.6

Table A1 continued on p. 39

Continuation, Table A1 starts on p. 38

Region	tag	trade	fin	neigh	dist
Moscow Region	MOS	3.2	0.2	2.2	2.0
Murmansk Region	MUR	0.1	0.0	0.3	0.7
Nizhny Novgorod Region	NIZ	1.0	0.1	1.9	1.5
Novgorod Region	NGR	0.4	0.0	0.9	1.3
Novosibirsk Region	NVS	1.7	1.2	1.3	1.2
Omsk Region	OMS	0.4	0.0	0.7	0.9
Orenburg Region	ORE	0.5	0.0	1.2	1.1
Orel Region	ORL	0.3	0.0	1.2	1.5
Penza Region	PNZ	0.4	0.0	1.0	1.5
Perm Territory	PER	0.9	0.0	1.1	1.2
Primorye Territory	PRI	0.7	0.3	0.2	0.6
Pskov Region	PSK	0.3	0.0	1.0	1.1
Republic of Adygea	AD	0.4	0.0	0.3	1.3
Republic of Altai	AL	0.2	0.0	1.2	1.0
Republic of Bashkortostan	BA	1.2	0.0	1.5	1.2
Republic of Buryatia	BU	0.3	0.0	0.8	0.9
Republic of Dagestan	DA	0.5	0.0	0.7	1.0
Republic of Ingushetia	IN	0.2	0.0	0.6	1.8
Republic of Kalmykia	KL	0.2	0.0	1.7	1.3
Republic of Karelia	KR	0.2	0.0	1.9	1.1
Republic of Komi	KO	0.3	0.0	1.0	1.1
Republic of Mari El	ME	0.4	0.0	0.7	1.6
Republic of Mordovia	MO	0.3	0.0	1.0	1.6
Republic of Sakha	SA	0.6	0.0	2.0	0.6
Republic of North Ossetia	SE	0.3	0.0	1.5	1.7
Republic of Tatarstan	TA	2.8	0.4	2.0	1.6
Republic of Tyva	TY	0.2	0.0	1.5	0.9
Republic of Khakassia	KK	0.3	0.0	0.9	1.1
Rostov Region	ROS	1.1	0.1	1.1	1.2
Ryazan Region	RYA	0.5	0.0	1.8	1.6
Samara Region	SAM	1.2	0.7	0.8	1.4
Saratov Region	SAR	0.5	0.1	1.7	1.4
Sakhalin Region	SAK	0.4	0.0	0.6	0.6
Sverdlovsk Region	SVE	1.9	0.4	1.6	1.2
Smolensk Region	SMO	0.3	0.0	1.2	1.2
Stavropol Territory	STA	0.7	0.0	2.7	1.4
Tambov Region	TAM	0.4	0.0	1.0	1.5
Tver Region	TVE	0.5	0.0	1.4	1.4
Tomsk Region	TOM	0.7	0.0	1.3	1.2

Table A1 continued on p. 40

Continuation, Table A1 starts on p. 38

Region	tag	trade	fin	neigh	dist
Tula Region	TUL	0.7	0.0	1.0	1.7
Tyumen Region	TYU	7.5	0.2	2.0	1.1
Udmurt Republic	UD	0.5	0.0	0.8	1.3
Ulyanovsk Region	ULY	0.4	0.0	1.4	1.5
Khabarovsk Territory	KHA	1.4	0.1	3.3	1.0
Chelyabinsk Region	CHE	1.1	0.0	1.1	1.2
Chechen Republic	CE	0.3	0.0	1.5	1.3
Chuvash Republic	CU	0.4	0.0	1.1	1.7
Chukotka Autonomous District	CHU	0.0	0.0	0.9	0.4
Yaroslavl Region	YAR	0.5	0.0	1.3	1.7

Source: authors' estimates

Appendix B

Table B1 shows the properties of inflation responses (in absolute value) to monetary policy shocks in Russian regions according to the baseline model: *sign* means the significance of response; *cum irf* means the limit value of the cumulative response (p.p.); *max irf* means the maximum response of monthly price growth (p.p.); *max lag* means the period in which the maximum response is achieved.

Table B1. Properties of inflation responses by regions

Region	sign	cum irf	max irf	max lag
Altai Territory	yes	0.92	0.05	6
Amur Region	yes	0.77	0.04	7
Arkhangelsk Region	yes	0.70	0.04	5
Astrakhan Region	yes	0.74	0.05	5
Belgorod Region	yes	0.80	0.05	5
Bryansk Region	yes	0.65	0.04	5
Vladimir Region	yes	0.70	0.05	4
Volgograd Region	yes	0.72	0.04	5
Vologda Region	yes	0.66	0.04	5
Voronezh Region	yes	0.73	0.04	5
Moscow	no	0.51	0.03	6
Saint Petersburg	yes	0.74	0.05	5
Jewish Autonomous Region	yes	0.82	0.04	6
Trans-Baikal Territory	yes	0.84	0.06	2
Ivanovo Region	yes	0.79	0.05	5
Irkutsk Region	yes	0.69	0.04	6
Kabardino-Balkar Republic	yes	0.77	0.05	6

Table B1 continued on p. 41

Continuation, Table B1 starts on p. 40

Region	sign	cum irf	max irf	max lag
Kaliningrad Region	yes	0.77	0.07	2
Kaluga Region	yes	0.69	0.04	6
Kamchatka Territory	yes	0.72	0.04	6
Karachay-Cherkess Republic	yes	0.93	0.06	5
Kemerovo Region	yes	0.71	0.05	2
Kirov Region	yes	0.82	0.05	5
Kostroma Region	yes	0.63	0.04	5
Krasnodar Territory	yes	0.68	0.04	6
Krasnoyarsk Territory	yes	0.68	0.04	4
Kurgan Region	yes	0.90	0.05	5
Kursk Region	yes	0.78	0.05	6
Leningrad Region	yes	0.79	0.05	5
Lipetsk Region	yes	0.79	0.05	6
Magadan Region	yes	0.71	0.04	5
Moscow Region	no	0.47	0.02	8
Murmansk Region	yes	0.55	0.03	6
Nizhny Novgorod Region	yes	0.87	0.06	3
Novgorod Region	yes	0.61	0.04	6
Novosibirsk Region	yes	0.85	0.05	6
Omsk Region	yes	0.76	0.04	6
Orenburg Region	yes	0.72	0.04	2
Orel Region	yes	0.55	0.03	5
Penza Region	yes	0.90	0.07	2
Perm Territory	yes	0.93	0.05	6
Primorye Territory	yes	0.74	0.05	2
Pskov Region	yes	0.62	0.04	5
Republic of Adygeya	yes	0.70	0.04	6
Republic of Altai	yes	0.84	0.05	4
Republic of Bashkortostan	yes	0.74	0.04	5
Republic of Buryatiya	yes	0.79	0.05	5
Republic of Dagestan	yes	0.86	0.05	5
Republic of Ingushetia	yes	1.10	0.06	5
Republic of Kalmykiya	yes	0.74	0.09	2
Republic of Karelia	yes	0.59	0.03	6
Republic of Komi	yes	0.73	0.04	6
Republic of Mari El	yes	0.68	0.04	6
Republic of Mordoviya	yes	0.75	0.06	2
Republic of Sakha	yes	0.53	0.03	7
Republic of North Ossetia	yes	0.72	0.04	6

Table B1 continued on p. 42

Continuation, Table B1 starts on p. 40

Region	sign	cum irf	max irf	max lag
Republic of Tatarstan	yes	0.55	0.03	6
Republic of Tyva	yes	0.82	0.05	6
Republic of Khakassia	yes	0.77	0.05	4
Rostov Region	yes	0.73	0.04	6
Ryazan Region	yes	0.77	0.05	5
Samara Region	yes	0.64	0.04	6
Saratov Region	yes	0.57	0.03	6
Sakhalin Region	yes	0.90	0.05	2
Sverdlovsk Region	yes	0.94	0.05	2
Smolensk Region	yes	0.87	0.06	2
Stavropol Territory	yes	0.70	0.04	5
Tambov Region	yes	0.75	0.07	2
Tver Region	yes	0.66	0.04	5
Tomsk Region	yes	0.70	0.04	4
Tula Region	yes	0.79	0.05	2
Tyumen Region	yes	0.84	0.04	6
Udmurt Republic	yes	0.93	0.04	10
Ulyanovsk Region	yes	0.77	0.05	5
Khabarovsk Territory	yes	0.78	0.04	6
Chelyabinsk Region	yes	0.92	0.05	6
Chechen Republic	yes	0.90	0.07	2
Chuvash Republic	yes	0.76	0.05	5
Chukotka Autonomous District	no	0.35	0.03	2
Yaroslavl Region	yes	0.67	0.04	6

Source: authors' estimates

Appendix C

Table C1. Decomposition of regional inflation into shocks (averaging over 80 regions)

	0 months	6 months	1 year	2 years	3 years	4 years	5 years
Contribution of domestic inflation shocks, %	28	8	6	5	5	5	5
Contribution of monetary policy shocks, %	1	3	8	18	25	30	32
Contribution of foreign exchange rate shocks, %	5	27	29	25	22	20	19
Contribution of oil price shocks, %	2	12	13	10	8	6	5
Contribution of all other regional shocks, %	64	50	45	42	40	39	39
Total, %	100	100	100	100	100	100	100

Source: authors' estimates

Table C2. Properties of the responses of variables to general shocks (monetary policy, foreign exchange rate and oil prices)

Response	Shock	6 months	1 year	2 years	3 years	4 years	5 years
MIACR	Monetary policy	0.64	0.36	0.09	0.02	0.00	-0.01
Foreign exchange rate	Monetary policy	-0.22	-0.30	-0.36	-0.37	-0.38	-0.37
Oil price	Monetary policy	-0.22	-0.48	-0.71	-0.77	-0.77	-0.76
Cumulative inflation (average)	Monetary policy	-0.17	-0.39	-0.63	-0.73	-0.76	-0.77
MIACR	Exchange rate	0.50	0.36	0.14	0.05	0.02	0.02
Foreign exchange rate	Exchange rate	5.10	5.08	5.02	4.99	4.98	4.97
Oil price	Exchange rate	-2.06	-2.35	-2.62	-2.72	-2.76	-2.78
Cumulative inflation (average)	Exchange rate	0.59	0.59	0.47	0.42	0.41	0.42
MIACR	Oil price	0.56	0.40	0.14	0.05	0.02	0.01
Foreign exchange rate	Oil price	4.94	4.95	4.87	4.85	4.84	4.83
Oil price	Oil price	-14.26	-14.61	-14.90	-14.99	-15.03	-15.04
Cumulative inflation (average)	Oil price	0.41	0.39	0.23	0.16	0.14	0.14

Note: Statistically significant (95%) responses are highlighted in bold.

Source: authors' estimates

Appendix D

Table D1. Descriptive statistics of variables

	Mean	Median	Standard deviation	Max.	Min.	Number of observations
Response in 1 year (irf12)	0.394	0.391	0.077	0.605	0.150	80
Response in 2 years (irf24)	0.619	0.617	0.108	0.913	0.245	80
Long-term response (irf60)	0.745	0.743	0.122	1.097	0.345	80
Share of primary sector in GRP	0.084	0.066	0.056	0.302	0.001	80
Share of manufacturing industry in lending	0.303	0.292	0.164	0.733	0.020	80
Loans issued by regional banks	0.083	0.045	0.112	0.809	0.000	80
Deposits of individuals in the top five banks	0.725	0.733	0.099	0.955	0.445	80
Share of those employed in small enterprises	0.205	0.215	0.052	0.326	0.048	80
Share of imports in GRP	0.118	0.065	0.185	1.382	0.009	80
Share of exports in GRP	0.184	0.125	0.172	0.846	0.001	80
Unemployment rate, %	6.974	6.053	4.501	36.030	1.473	80
Region's public debt to GRP	0.056	0.053	0.036	0.227	0.000	80

Source: authors' estimates

Appendix E

Table E1. Estimation results for various specifications of the model

	irf12	irf12	irf12	irf12	irf12	irf12
Share of primary sector in GRP	0.306** (0.153)	0.321** (0.149)	0.202+ (0.136)	0.239+ (0.129)	0.217+ (0.131)	0.208+ (0.132)
Share of manufacturing industry in lending		0.122** (0.051)	0.142*** (0.045)	0.082+ (0.047)	0.074+ (0.048)	0.075+ (0.048)
Unemployment rate			0.006*** (0.002)	0.011*** (0.002)	0.011*** (0.002)	0.011*** (0.002)
Share of those employed in small enterprises				0.543*** (0.178)	0.593*** (0.183)	0.635*** (0.199)
Share of loans issued by regional banks					-0.074 (0.066)	-0.074 (0.067)
Share of imports in GRP						-0.024 (0.044)
_cons	0.368*** (0.015)	0.330*** (0.022)	0.281*** (0.022)	0.162*** (0.044)	0.161*** (0.044)	0.155*** (0.046)
Number of observations	80	80	80	80	80	80
Adjusted R^2	0.037	0.093	0.274	0.346	0.348	0.342
	irf24	irf24	irf24	irf24	irf24	irf24
Share of primary sector in GRP	0.365+ (0.216)	0.384+ (0.212)	0.216 (0.193)	0.266 (0.186)	0.238 (0.188)	0.213 (0.189)
Share of manufacturing industry in lending		0.151** (0.072)	0.179*** (0.065)	0.098 (0.068)	0.089 (0.068)	0.0904 (0.069)
Unemployment rate			0.011*** (0.002)	0.015*** (0.003)	0.015*** (0.003)	0.015*** (0.003)
Share of those employed in small enterprises				0.734*** (0.256)	0.795*** (0.264)	0.919*** (0.284)
Share of loans issued by regional banks					-0.091 (0.095)	-0.092 (0.095)
Share of imports in GRP						-0.071 (0.062)
_cons	0.588*** (0.022)	0.541*** (0.031)	0.472*** (0.032)	0.311*** (0.064)	0.310*** (0.064)	0.293*** (0.065)
Number of observations	80	80	80	80	80	80
Adjusted R^2	0.023	0.064	0.248	0.314	0.313	0.316
	irf60	irf60	irf60	irf60	irf60	irf60
Share of primary sector in GRP	0.308 (0.246)	0.321 (0.245)	0.122 (0.222)	0.170 (0.217)	0.143 (0.220)	0.107 (0.221)

Table E1 continued on p. 45

Continuation, Table E1 starts on p. 44

	irf60	irf60	irf60	irf60	irf60	irf60
Share of manufacturing industry in lending		0.111 (0.083)	0.144+ (0.074)	0.067 (0.080)	0.059 (0.081)	0.061 (0.080)
Unemployment rate			0.013*** (0.003)	0.017*** (0.003)	0.017*** (0.003)	0.017*** (0.003)
Share of those employed in small enterprises				0.693** (0.299)	0.752** (0.309)	0.919*** (0.284)
Share of loans issued by regional banks					-0.088 (0.112)	-0.089 (0.111)
Share of imports in GRP						-0.100 (0.073)
_cons	0.719*** (0.025)	0.684*** (0.036)	0.602*** (0.037)	0.451*** (0.075)	0.450*** (0.075)	0.426*** (0.076)
Number of observations	80	80	80	80	80	80
Adjusted R^2	0.007	0.017	0.220	0.263	0.259	0.268

Note: Standard errors are given in round brackets. +, *, ** and *** mean that the estimate is significant at the 15%, 10%, 5%, or 1% level, respectively.

Source: authors' estimates