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D. Krylov

Denis Krylov

Economic Division, Far Eastern Main Branch, Bank of Russia

E-mail: KrylovDV02@cbr.ru

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12 Neglinnaya Street, Moscow, 107016

Tel.: +7 499 300 30 00, +7 495 621 64 65 (fax)

Bank of Russia website: www.cbr.ru

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Abstract

Movements in food prices have a major input in consumer price index and, thus, a significant impact on the living standards. Given the increased volatility of world food prices, it is essential that we understand the impact of this external driver of inflation on domestic price trends in order to produce a more accurate forecast of inflation and conduct a more efficient monetary policy.

This work presents a VARX model applied to data from 2003 to 2021. Statistically significant impact of world food prices on domestic consumer and producer food prices in Russia was observed in 2003-2014, both at nation level and across its regions. After 2014, when there was a transition to a floating exchange rate, inflation targeting policy, accelerated development of import-substituting agricultural production and the Russian government employment of a more active trade policy in agriculture and food products, the average pass-through effect declined materially and is no longer statistically significant.

The overall pass-through effect is greater in the case of rising world prices compared to decreasing world prices, while no statistically significant differences are found among regions. Meanwhile, the pass-through effect of world food prices on internal producer prices exhibits a significant regional heterogeneity.

Keywords: world food prices, pass-through effect, Russian regions, consumer prices, producer prices, vector autoregression

JEL Codes: C32, E31, F42, R11

1. Introduction

External factors such as exchange rates and world prices are significant determinants shaping the dynamics of domestic prices. The impact of exchange rates on inflation on a country level is studied thoroughly both by international economic profession (Burstein, Gopinath, 2014; Jašová et al., 2019; Ha et al., 2020), and in Russia (Ponomarev et al., 2014; Kartayev, Yakimova, 2018; Andreev, 2019). The dynamics of world prices also represent a significant factor influencing inflation (Kiselev, Zhivaykina, 2020).

Within the realm of research on world prices, there is a substantial body of literature focused on studying the impact of world prices of food products on internal inflation (Ferrucci et al., 2012; Cachia, 2014). The research interest in this topic is fueled by two substantial points. Firstly, the proportion of household expenditure on food products is significant in many developing countries, meaning that the price increase of food items carries relatively large weight in overall inflation (Meyimdjui, Combes, 2021). Secondly, most grocery products serve as markers shaping households' inflation expectations (D'Acunto et al., 2019; Grishchenko et al., 2023).

Russia has a relatively high weight (averaging 38% between 2004 and 2022) of food in household consumer expenditure. However, the impact of world food prices on food and overall inflation in Russia remains unstudied. This issue is of particular interest for Russia due to its significant regional diversity in terms of inflation rates. Researchers link this diversity to regional discrepancies in the growth rates of the tradable and non-tradable sectors (Balassa-Samuelson effect), dynamics of effective exchange rates, real monetary incomes, the degree of convergence in regional price levels, and other differences (Zhemkov, 2019; Sinelnikov-Murylev et al., 2020; Zhurakovsky et al., 2021). These factors might contribute to varying regional inflation responses to external shocks. There is a research gap in studying the pass-through effect of world food prices into internal food inflation in Russia, both at national and regional levels. This particular relevance arises for periods when world food prices exhibit a significant upward or downward trend lasting for at least a year, falling within the timeframe of monetary policy. Quantifying the contribution of world price changes to inflation is an option to consider in an effort to make monetary policy within the framework of inflation targeting more efficient by fine-tuning the forecast for inflation.

This study aims to address this gap following similar hypotheses examined in literature regarding the pass-through effect of exchange rates and global inflation. The following hypotheses are tested in this study:

1. Changes in world prices of food products lead to corresponding changes in consumer and producer food prices in Russia.

2. The pass-through effect of world prices of food products into internal food inflation in the Russian Federation differs significantly across regions.

The following key findings emerged from the study. The pass-through effect of world food prices in domestic food inflation of consumers and producers is statistically significant at the 10% significance level when assessed over the period 2003-2014. At the same time, after 2014, when there was a transition to a floating exchange rate, inflation targeting policy, accelerated development of import-substituting agricultural production and the Russian government employment of a more active trade policy in agriculture and food products, the annual pass-through effect became statistically insignificant. No significant heterogeneity of the influence of world prices on consumer prices by regions is revealed, some heterogeneity is observed for producer prices only.

The structure of this work is as follows: The second section provides a review of research on factors influencing world prices internally and approaches to assessing this influence. The third section presents an analysis of Russia's main trade indicators in the agro-industrial complex. The fourth section describes the research methodology and data. The fifth section presents the research findings, followed by their discussion. Subsequently, an assessment of result stability is conducted. The conclusion outlines the main conclusions drawn from the entire study.

2. Literature review

Let us define some terms this study operates. Researchers studying the effects of foreign exchange rates, of price levels in other countries or of commodity prices on domestic prices, may operate different designations of these phenomena. Zhurakovsky (Zhurakovsky et al., 2021) defines the exchange rate as an external factor of inflation of Russia; at the same time, Kiselev and Zhivaykina (Kiselev, Zhivaykina, 2020), define world inflation as the global factor of inflation for Russia. In this work, food prices in world commodity markets are global by definition since they affect inflation in most countries of the world; at the same time, they are external to Russia in the sense that Russia’s influence over price-setting in world food markets is limited. For this reason, the two terms are almost interchangeable in analysing world food prices.

In this study, the analysis of the pass-through of world prices to domestic prices often cites works exploring the pass-through of ruble exchange rate dynamics to domestic inflation, since the latter subject was given broader coverage in Russian literature. Although the pass-through effects of the exchange rate are not the same as of world prices, the approach seems reasonable considering that both the exchange rate and world prices are external factors of inflation.

Let us identify the key factors of the relationship between world and domestic prices:

1) **The law of one price.** In an open market economy, firms can independently choose the markets for their products. If prices in the world market (less the costs of entering it) are higher than domestic market prices, then economically rational agents will sell their products not in the domestic market, but in international markets at the world price because of higher profits. In this case, domestic prices will be approaching world prices less the costs of entering the world market (Burstein, Gopinath, 2014). In this study, the law of one price is understood in its dynamic form. In the real world, the law of one price does not hold in its strict sense, with price levels across regions, given currency rates and trade costs, varying significantly under the influence of such barriers as customs tariffs and domestic taxes. However, it is thought that the law of one price holds dynamically. Accordingly, empirical studies show that price relationships between most goods and services across different regions remain approximately the same over a long-term horizon (Rogoff, 1996; Ceglowski, 2004).

2) **The share of imports in consumption.** Changes in the prices of imported goods are directly dependent on exchange rate dynamics and the prices of these goods in trading partner countries. These factors determine producer costs of imported raw materials and components, as well as trading firms' costs of imported goods. In a competitive market, changes in the costs of goods production or distribution are expected to translate into their retail prices. At the same time, the higher the share of imported goods in consumption, the stronger the pass-through, all other things being equal. For a change in world prices and in the exchange rate of the local currency is primarily reflected in the retail prices of imports (Burstein, Gopinath, 2014).

3) **The market power of sellers and buyers.** If a firm has market power, then it can set a product price other than the equilibrium price (the one that would have been formed under conditions of perfect competition) (Weldegebriel, 2004).

4) Transportation costs, transaction costs including the costs of distribution, and others may change independently of the dynamics of world prices for certain goods. This can lead to non-linearity of the pass-through of world prices to domestic prices, especially with a large proportion of transport or transaction costs in the retail price structure (Burstein, Gopinath, 2014).

5) **External trade barriers.** Customs tariffs and non-tariff regulation (e.g. quotas and import bans), taxes and subsidies – protectionist policies which countries may resort to – weigh on the equilibrium market price. Incidentally, the imposition of an import tax triggers an increase in the prices of imports and so decreases demand for such goods, pushing demand for domestic equivalents higher. This results in a drop in the proportion of imported goods in consumption, reducing pass-through effects (Cachia, 2014).

Having specified the key theoretical aspects of pass-through effects and identified the drivers of their value, let us discuss the current approaches to their quantification based on empirical data. Kiselev and Zhivaykina (Kiselev and Zhivaykina, 2020) build a dynamic hierarchical factor model (DHFM) to break down inflation into factors, to highlight, among other things, the contribution of global inflation (the model's 'global factor') to the dynamics of domestic prices for food products. The data are the panel of monthly consumer price indices by product and service group in member countries of the Organisation for Economic Cooperation and Development, the US, Russia and Brazil between 2003 and 2018. For Russia, the global factor accounts for about 12.5% of the variance of consumer food price indices. This work provides quantified evidence to the importance of the global factor in the dynamics of inflation in Russia.

Cachia (2014) estimates the pass-through of world food prices to domestic inflation in several regions: North America, Europe, South Asia, and others. The author uses monthly data on the food CPI, broken down by country groups, and the FAO World Food Price Index. To assess the pass-through effects, the researcher builds an error correction model; its dependent variable is the consumer price index for food products, and the only factor is the FAO World Food Price Index. The author explains the limited set of variables by the fact that other important macroeconomic variables for a number of countries are not available as monthly data. To analyse the shocks, it is critical to use high-frequency data as the crisis shocks of world prices under study were historically rather quick to materialise. To quantify the pass-through effects, the work relies on impulse response functions, obtained from country group models. The author estimates the pass-through to regional inflation for Europe for 16 months at 1,3% with 10% shock of world prices, for 32 months at 1,9%, and in the long term at 2,7%. In conclusion, the author notes that one-dimensional models do not control the effects of other macroeconomic factors on inflation, which most likely suggests that the estimates in this work are overvalued since the whole range of consumer prices for food products in the model is driven only by world food prices.

Ferrucci et al. (2012) evaluate the pass-through of world food prices to a harmonised index of consumer prices of food products and the index of food producer prices in the euro area. The data from 1997 to 2009 are of a monthly frequency. The work operates several models to check the robustness of inferences: a linear VAR as the base model, a VAR model highlighting the asymmetry of pass-through when world prices rise and fall, and AR-GARCH and Net models, to highlight the effects of pass-through non-linearity in periods of high volatility. The values of impulse response functions for different models have no statistically significant differences (except for the asymmetry VAR model). On average, the pass-through of the 10% shock of international prices to the consumer price index for food products was 3,6% for the year, which is quite close to the estimates for Europe in Cachia (2014). The pass-through is significantly higher for producer price indices and averages 5,0% for one year. The authors attribute this to the proximity of producers and world markets in the production chain. The works focusing on Russia also note the stronger pass-through effects of the external inflation factor – of the exchange rate – to producer price indices relative to consumer prices (Ponomarev, 2015; Tiunova, 2018).

Ferrucci and many other authors highlight asymmetries as a special focus of research into price transmission. To analyse the explanatory variable, both foreign (e.g. Hamilton, 2003) and Russian authors (e.g. Andreyev, 2019) divide the explanatory variable x into two:

$$\begin{aligned} x_t^+ &= x_t \ if \ x_t > 0; \ else \ 0 \\ x_t^- &= x_t \ if \ x_t < 0; \ else \ 0 \end{aligned} \tag{1}$$

These two variables are then added to the model as factors. However, as Kilian and Vigfusson (Kilian and Vigfusson, 2009) show, the use of this method in conjunction with the conventional least squares method invalidates the estimates for the coefficients of regression equations. This leads to the authors using two approaches to estimate the asymmetry: 1) based on formula (1) for greater comparability with early studies and 2) the method which involves estimating structurally identical models on two subsamples that assume growing and falling world prices. The estimates show better characteristics in the second method; however, it fails to take into account all available data.

Therefore, the literature often relies on econometric approaches to time series analysis for estimating the pass-through of world food prices to domestic inflation. The models in use are vector autoregressions, defining the pass-through as the ratio between the impulse response of interest, for example the CPI, to the shock of world prices. In the current work, this is the approach used to estimate the pass-through effect.

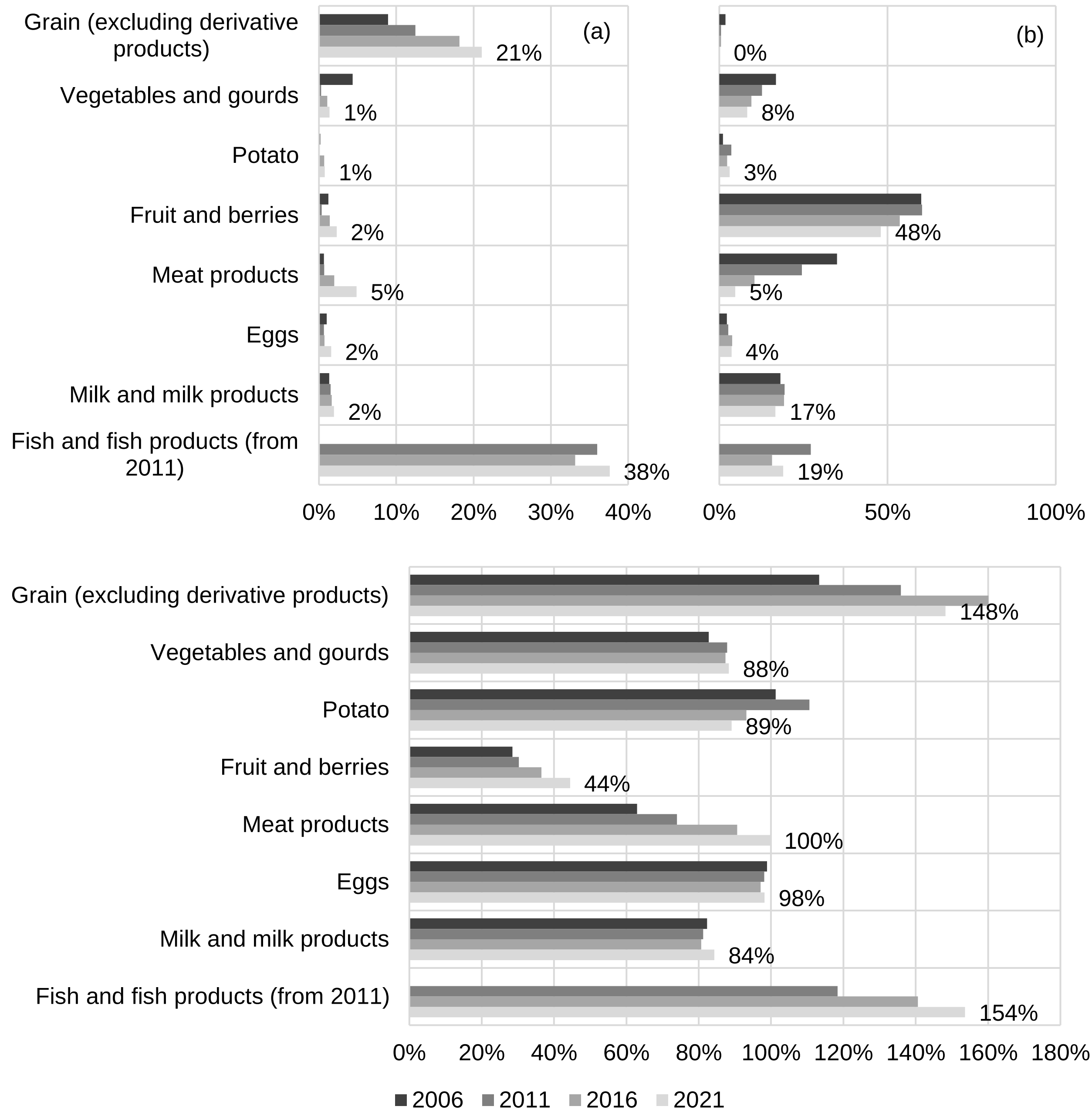
3. Analysis of trade dynamics of the Russian agro-industrial complex

The history of the Russian market of food products and agricultural raw materials is rich in various economic and political shocks. Taking this context into account when analyzing the dynamics of prices for food products is critical to take into account all the important factors of pricing.

The Russian food market has historically relied on imports of a number of staple foods, such as meat products, cheese, and fruit, to name but a few (Shagayda, Uzun, 2015). Meanwhile, sanctions pressure since 2014 has led to Russia rolling out additional import substitution incentives. The starting point of import substitution was Russia's imposition of an embargo on a significant portion of food imports from the European Union, the United States, and other countries on August 6, 2014. In their analysis of import substitution processes between 2014 and 2022, some researches (Kuzminov et al., 2023) highlight the agro-industrial complex as a success story of domestic production substituting imports. Intuitively, such development of the domestic agro-industrial complex could weaken the impact of the pass-through effect on domestic prices through the development of domestic production. But it is worth remembering that an expansion in domestic production and a rise in self-sufficiency level for food products do not weaken the pass-through of world prices to domestic ones by themselves. This is due to the workings of the law of one price and the strength of relationship between the domestic and world markets. Price pass-through can be set in motion by price trends in both imported and exported goods. With relatively high world prices, the low costs of entering the world market can likely enable domestic producers to sell their products in the world market; domestic prices will then tend to approach world prices to keep supply and demand in balance (Burstein, Gopinath, 2014). However, the costs of entering the world market in the conditions of sanctions, customs tariffs and quotas for Russia were probably relatively high (Kuzminov, etc., 2023). These could have combined with the saturation of the domestic market with domestic products to weaken the pass-through of world prices to domestic ones.

The effects of import substitution policies in the agro-industrial complex can be seen in detail in Rosstat’s data for the balances of food products (Figure 1). The self-sufficiency of food products varies across product groups. Meat products, grain, fish products, fruit and berries show a significant rise in the self-sufficiency ratio between 2006 and 2021. With imports accounted for 35% of all meat products in 2006, the self-sufficiency ratio was 63%. In 2021, this ratio went up to 100% for the first time. The initial self-sufficiency ratios for eggs, milk products, vegetables and gourds were high and little changed over the course of time; potatoes posted a downward change on the back of declining volumes of domestic production.

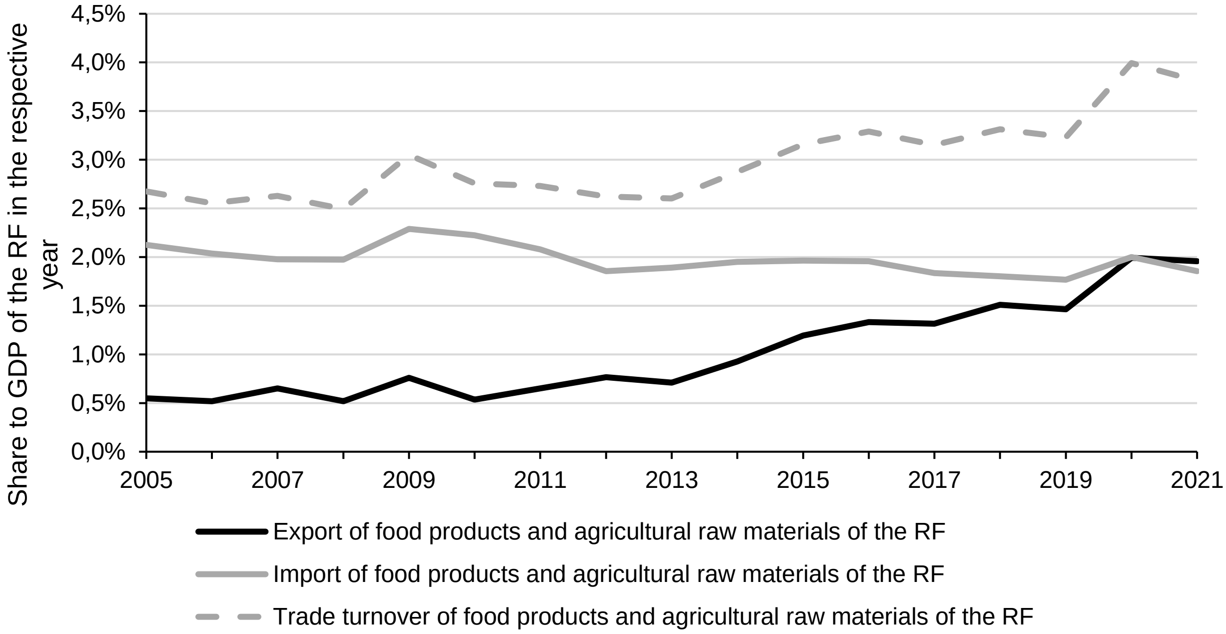
Figure 1. Share of exports (a) and of imports (b) in product resources, and self-sufficiency ratio (c) for selected food products in Russia



Note: The self-sufficiency ratio is calculated according to Rosstat's methodology as the domestic production to domestic consumption ratio for individual food products.
Source: Rosstat, Author's own calculations.

The greater dynamism of the Russian agro-industrial complex not only drove the self-sufficiency ratio higher for a number of food products, but also strengthened the country's positions in the world food market. These developments are evidenced by external trade statistics at a macro level (Figure 2).

Figure 2. External trade in food products and agricultural raw materials of the Russian Federation (RF)

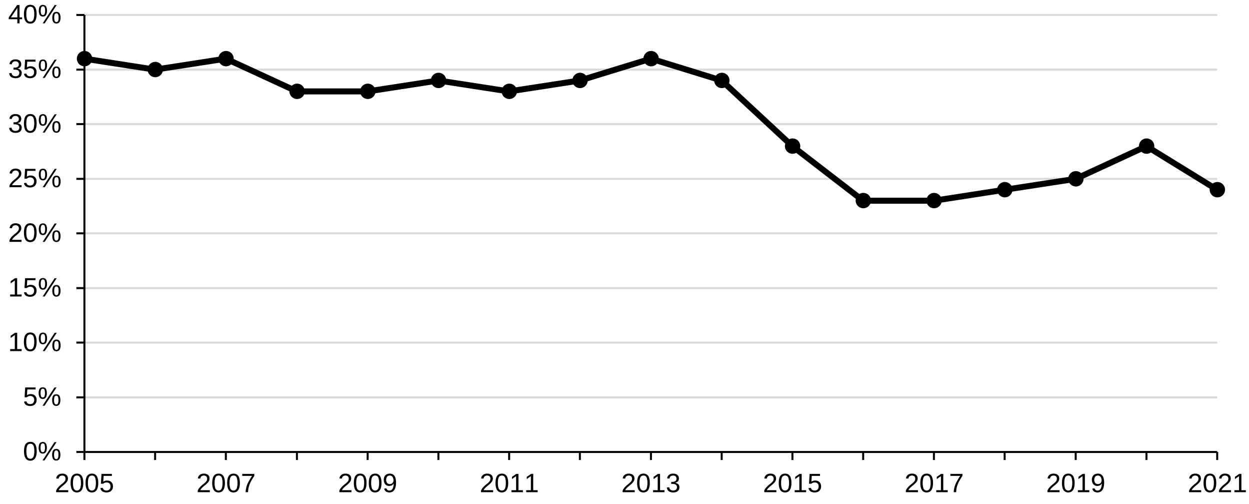


Source: Federal Customs Service, Rosstat, Bank of Russia, Author's own calculations.

Throughout almost the whole period under study, the share of imports of food products and agricultural raw materials in GDP hovered within 2%. At the same time, the share of exports grew throughout almost the entire period in question, having risen 3.6 times from 2010 to 2021 and 2.1 times from 2014 to 2021. In 2014, Russia encountered a large package of sanctions, entailing an 8% drop in the average annual volume of imports in physical terms in 2015–2021 relative to 2004–2014. Imports did not recover to the 2014 mark until 2021. This notwithstanding, total trade turnover since 2014 has increased on the back of rising exports, both in physical terms (18% for the 2014–2021 period), and as a share of GDP (33% for the same period). The dynamics observed in Figure 2 indirectly points out the growing importance of the export channel in transferring world prices to domestic prices. At the same time, it also points out the growing role of the restrictions practiced by the Russian government on food exports, which periodically significantly weakens the effect of this channel (Makhotina et al. 2022).

The development of the agro-industrial complex and import substitution policies also had an impact on macroeconomic indicators of the domestic market. This can be traced by the data on shares of food imports in retail products, available from Rosstat (Figure 3). Up to 2014, this indicator had been persistently close to 34%; after the 2014 events, it went down to 25% on average.

Figure 3. Share of imports in food retail products in Russia as a whole



Source: Rosstat

In addition to significant changes in food supply, there have also been significant reforms in monetary policy since 2014. In November 2014, the Bank of Russia moved away from a fixed (currency corridor) to a floating exchange rate and began its inflation targeting policy. According to many researchers, this move helped ease the negative shocks of the external sector, reduce exchange rate volatility and inflation and boost public confidence in the national currency (Kartaev, Yakimova, 2018; Tiunova, 2018).

The pass-through effects must have been affected by the totality of those structural changes. Based on the presented assumptions, the pass-through effect of world food prices to domestic prices of consumers and food producers should have decreased after 2014. This is further tested through model analysis of subsamples of the data, pre-2014 and post-2014.

4. Methodology and data

Following the approaches to estimating the pass-through of world prices to domestic prices in previously described academic works, to estimate the pass-through of world food prices to food inflation for consumers and producers both countrywide and in regional terms, this work uses linear vector autoregressions with exogenous variables (VARX). VARX can be presented in vector-matrix form as follows:

$$y_t = a_0 + \sum_{m=1}^{p} A_m y_{t-m} + Bx + e_t, \quad (2)$$

where y_t is the vector of endogenous variables in period t, a_0 is the vector of constants, p is the order of the model, that is the number of lags of endogenous factors, A_m is the matrix of coefficients for endogenous variables in period $t-m$, y_{t-m} is the vector of endogenous variables in period $t-m$, B is the matrix of coefficients for exogenous variables, x is the vector of exogenous variables, and e_t is the residuals of the model.

We have the following endogenous variables:

1) The consumer price index for food products (without alcoholic beverages) – as the main variable under study and the end point of pass-through effects;

2) The weighted average of the agricultural producer price index and industrial producer price index for food and soft drinks – as a variable under study and an important intermediate point of pass-through effects;

3) The food retail volume index – as a variable reflecting demand in the economy;

4) The FAO World Food Price Index in US dollars – as a proxy for world food prices;

5) The index of the nominal effective ruble exchange rate – as the main variable reflecting external conditions;

6) The MIACR interest rate – as the variable of monetary conditions;

7) The volume of foreign exchange purchase or sale operations of Russia's Ministry of Finance in the domestic market, in line with the fiscal rule, from February 2017 – as a variable reflecting the impact of the fiscal rule on the ruble exchange rate dynamics and the change in the nature of its dependence on oil prices (Andreyev, 2022).

We have the following exogenous variables:

1) The freight tariff index, describing changes in transportation costs;

2) Brent, the oil price index – as a variable reflecting world economic activity;

3) The proxy of barriers to external food trade – as a variable reflecting the impact of economic sanctions and trade embargoes on domestic food prices for Russian consumers after 2014;

4) The weighted average of the agricultural producer price index for grain and legume crops and the industrial producer price index for sunflower oil – as a separate component in the model and the variable accounting for the influence of state regulation of markets for these goods.

The set of variables maps out the general pattern of transmission of world prices to consumer prices, consistent with the academic literature (Burstein, Gopinath, 2014; Cachia, 2014). First, a change in world prices affects import prices in a specific country and then producer prices; thereafter, this change feeds through to retail markets, ultimately translating into consumer prices. All the other variables are treated as control variables.

The model is estimated on monthly data from January 2003 to December 2021[1]. The analysis includes 80 constituent entities of the Russian Federation[2] and aggregate series for Russia as a whole. The description of the statistical indicators is presented in Table 1.

[1] Data analysis after 2022 is complicated by the unavailability of Federal Customs Service statistics on external trade.

[2] Data for the Chechen Republic begin from 2008. The relevant autonomous districts are reflected in statistics for the Arkhangelsk and Tyumen Regions. Other entities are outside the analysis due to the lack of adequate data.

Table 1.

Description of statistical indicators in the model

Name	Legend	Source	Transformation	Section	Notes
Consumer price index for food products (without alcoholic beverages)	prod_cpi	Rosstat	Month-on-month (MoM) ratio, seasonal adjustment (SA), in logarithms	By region	
The weighted average of the composite agricultural producer price index and the industrial food and soft drink producer price index	prod_ppi	Rosstat, calculations	MoM, SA, in logarithms	By region	Indices are weighted through amounts of sales by producers by activity, consistent with Rosstat's methodology
Food retail volume index	prod_rozn	Rosstat, until 2009, GMT of Rosstat	MoM, SA, in logarithms	By region	
Freight transportation tariff index (less pipeline transport)	tpi	Rosstat	MoM, SA, in logarithms	By region	For data up to 2009, the countrywide indicator is used due to the lack of regional data
FAO World Food Price Index (US dollars)	fao_prod_wpi	Food and Agriculture Organisation of the United Nations	MoM, in logarithms	Global	No seasonality found in the published data; the global indicator is used for all regions
The nominal effective ruble exchange rate index (growth = depreciation, decline = appreciation of the exchange rate)	neer	Bank of Russia	MoM, in logarithms	Global	Seasonality is absent; presented consistent with a pattern in which growth in the index corresponds to the weakening of the exchange rate, and decline corresponds to strengthening
Volumes of the Ministry of Finance's fiscal rule-based operations to buy (sell) foreign currency in the domestic currency market	fiscal_rule_fxi	Bank of Russia, Author's own calculations	in billions of rubles deflated by the average of total Russian CPI for 2019 (in constant 2019 prices)	Global	Seasonality is absent, the time series has values beginning from February 2017 and is zero until this time
Proxy of barriers to external trade in food	trade_barriers_proxy	Author's own calculations, Federal Customs Service, Rosstat	MoM, SA, in logarithms	Global	The calculation methodology is explained below.

Continuation of Table 1.

The weighted average of agricultural producer prices for cereals and legumes and the industrial producer price index for unrefined sunflower oil and its fractions	grains_sunoil	Rosstat, calculations	MoM, SA, in logarithms	Global	Indices are weighted through the amounts of sales by producers by product, consistent with Rosstat's methodology
Change in Brent oil price	brent	Investing.com	MoM, in logarithms	Global	Seasonality is absent
The average monthly actual lending rates for one day, based on data from Moscow banks (MIACR)	miacr	Bank of Russia	In absolute changes for the month, percentage points	Global	Seasonality is absent
The matrix of interregional trade volumes (import-export tables)	spillover	Rosstat, GMC of Rosstat	For 2016, % of the total	By region	---

Note: Seasonal smoothing (SA) is based on X-13ARIMA-SEATS.
Source: Author's own calculations.

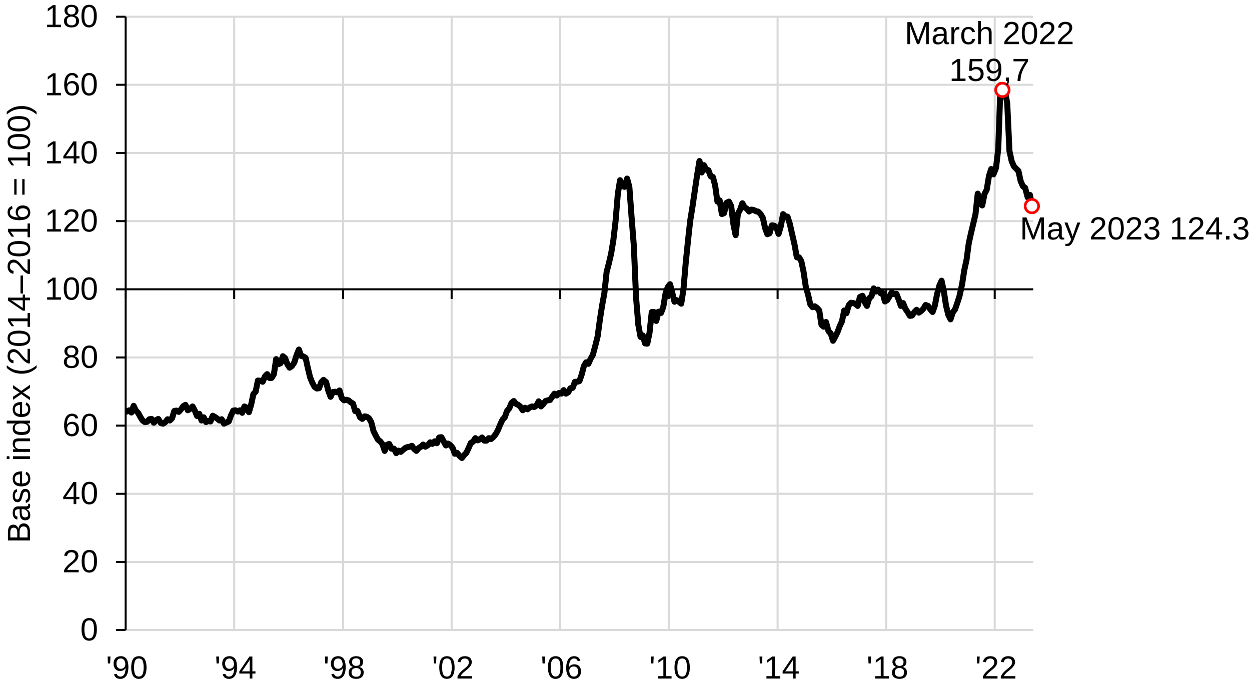
The analysis is based on the consumer food price index excluding alcoholic beverages[3]; the index of producer prices is based on the weighted sum[4] of industrial producer prices with OKVED2[5] activity codes 10, 11.07 (food products including soft drinks but excluding alcoholic beverages) and producers of agricultural products with OKVED2 code 01.02.AG (crop production and livestock, excluding support activities and services). For simplicity, this aggregate food price index is hereinafter referred to as the food producer price index (PPI). Prices for alcoholic beverages are stripped out due to their specificity; for example, in the UN COICOP[6] classification, alcoholic beverages are separated from the core group of food products and are combined with tobacco products and drugs.

The FAO World Food Price Index is used to describe the dynamics of world food prices (figure 4). In compiling the index, the FAO records prices for a wide range of commodities in five main groups: meat products (weight is 33%), milk products, cheese and butter (14%), cereals (29%), plant oils (17%), and sugar (7%). Key sources of price data are prices for commodity futures, and export prices, among others (Cluff, Mustafa, 2020). There are also other world price indices, for example, the S&P GSCI Agriculture Index, DJ-UBS Agriculture Sub-Index, and UBS Bloomberg CMCI Agriculture Index. However, the FAO Price Index seems more appropriate to analyse world food prices thanks to its more extensive geographical coverage and its inclusion of food export prices in addition to futures prices. It also enables better comparisons with Russia's domestic price indices, directly accounting for almost half of the consumer food basket for such groups as meat products

[3] All the components in the food price index are available on Rosstat's website, Folder 'Consumer spending pattern'.
[4] Producer price indices were aggregated in accordance with Rosstat's methodology for calculating producer price indices (Rosstat Order No. 729, dated 17.11.2016).
[5] The All-Russian Classifier of Economic Activities (KDES 2).
[6] The Classification of Individual Consumption According to Purpose.

(23% of weight of Russia's food products in 2023), milk products, cheese and butter (totalling 14%), grain and cereal products (8%), vegetable oils (1%), and sugar (1%). The rest of the basket is divided into two types of products. These are those that are almost directly produced from the above-mentioned products (weight 17%), for example confectionery (7%), and others products that are not clearly captured in the FAO index (36% weight), including fruit and vegetables (11%), fish products (6%) and others.

Figure 4. FAO World Food Price Index



Source: FAO.

As noted in the literature review, tariff and non-tariff customs regulation are a significant factor for pass-through effects. Such external trade barriers were of particular importance to the Russian food industry in the context of the introduction on 6 August 2014[7] of a trade embargo on most food imports from the EU, the US and other countries. By including barriers to external trade as a separate factor in the model, we may obtain a more accurate assessment of what is the net contribution of changes in world food prices to domestic prices and take into account the possible transformations of this relationship as current barriers to external trade changes.

The structure of external trade barriers can be extremely complex. The simplest case may be a single ad valorem customs duty for all goods, mandating the payment of a tariff as a percentage of the customs price. However, in most cases, external trade barriers are a complex combination of tariff and non-tariff (quotas, embargoes, etc.) measures of customs regulation. It is quite a challenge to quantify them in the form of an aggregate index of external trade barriers to be used in the model. In this area, some progress has been made by the United Nations Conference on Trade and Development (UNCTAD), which

[7] Executive Order of the President of the Russian Federation No. 560, dated 6 August 2014, 'On Additional Temporary Economic Measures to Ensure Russia's Financial Stability'.

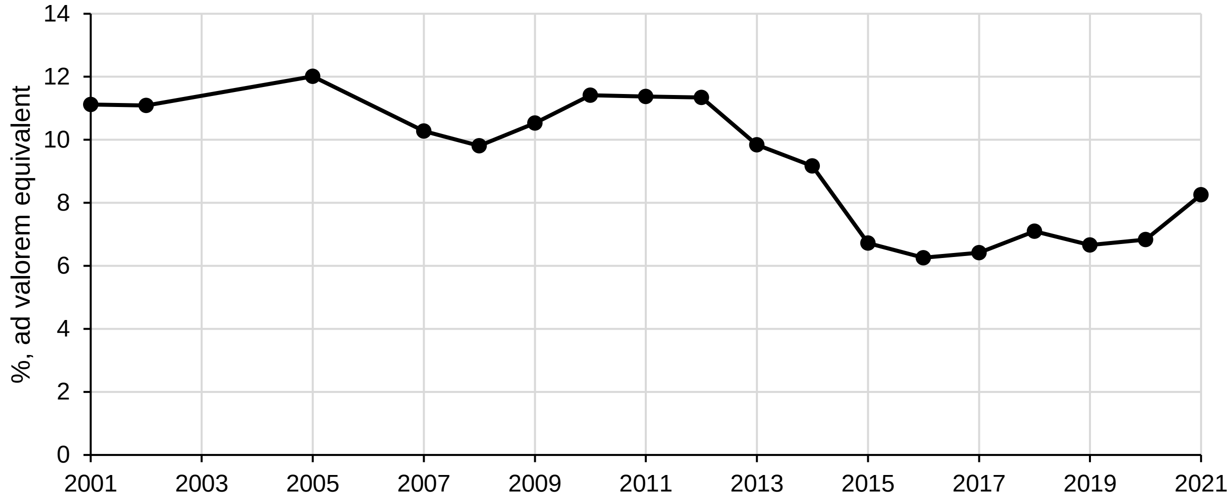
quantified the ad valorem equivalents of non-tariff measures (AVE) of customs regulation (Cadot, 2018). Quantifying all customs regulation measures through one unit of measurement (ad valorem equivalent) helps researchers build time series and assess the impact of customs restrictions on other macroeconomic variables. Such AVE estimates are available, for example, in the World Integrated Trade Solution (WITS) database (Barattieri et al., 2018).

In this study, I originally intended to take a time series of aggregate import tariffs for food products[8] accounting for AVE estimates in line with UNCTAD methodology from the WITS database and use it as a proxy for external trade in Russian food products. The assumption was that the AVE estimates would be able to accurately account for the introduction of significant barriers to external trade in food products after 2014. However, the construction of this time series showed a critical drawback of these data: after 2014, many tariff lines for food imports from the EU and other countries covered by Russia's food embargo simply disappeared, that is, the AVE models fail to simulate them. This technical problem leads to the effective[9] volume-weighted import tariff for Russian food products in the ad valorem equivalent totalling 6.7% in 2015, compared to 9.8% in 2013 (Figure 5). Therefore, WITS data show a significant drop in level of barriers to food trade in Russia after 2014. This finding runs counter to the economic logic of the Russian trade embargo and the conclusions many researchers arrived at (e.g. Obolensky, 2019).

[8] Commodity groups with codes 1–24 without 22 (drinks and alcohol) and 24 (tobacco) are in accordance with the commodity nomenclature of foreign economic activity of the Eurasian Economic Union.

[9] WITS uses the effectively applied tariff concept (AFN), which is defined as the lowest rate available. If there is a preferential tariff (PRF), it will be used as an effectively applied tariff; otherwise, the tariff applied within the most favoured (MFN) regime will be used.

Figure 5. Import volume-weighted effectively applied import customs tariff on food products in Russia



Note: Weighing is based on the average volumes of imports of commodity groups from corresponding countries in 2010–2013; fixed weights are used to highlight the changes in tariff rates, rather than import volumes; data for 2003, 2004 and 2006 are not available in WITS.

Source: Author's own calculations based on WITS, UNCTAD, Federal Customs Service of Russia data.

Russia joined the World Trade Organisation on 22 August 2012, marking an overall drop in import tariffs after they had sustainably held at 10–12% (in the ad valorem equivalent). After 2014, the overall level of food import tariffs significantly declined, following the cessation of imports from countries subject to the food embargo. The other reason for that is the fact that a significant part of trade flows affected by the embargo was increasingly imported into Russia through Eurasian Economic Union countries (Belarus, Armenia, Kazakhstan, and Kyrgyzstan) (Obolensky, 2019), which as a rule had zero import duties.

The dynamics of estimated aggregate import tariffs for Russian food products based on WITS data are overall in line with economic logic but fail to account for all the effects of the trade barriers introduced in 2014. With the dynamics of aggregate import duties inaccurately approximating the real barriers of external trade, owing to the limitations of the AVE estimation methodology, another approach was followed to assess the impact of the 2014 events on domestic food prices in Russia. It focuses on the assessment of shortfalls in food imports due to the introduction of external trade barriers by both Russia and Western countries. To see the dynamics of this indicator, it is necessary to simulate the volume of food imports in a hypothetical scenario providing for the absence of any new significant barriers to external trade between 2014 and 2015. This hypothetical path would enable the assessment of the degree to which external trade barriers influence domestic prices, based on analysis of the dynamics of the difference between the hypothetical and actual path of imports. This difference would reflect the actual magnitude and time evolution of the change in trade barriers.

As a rule, building this hypothetical trajectory involves creating a whole system of equations with many factors, to take into account all the significant economic relationships in the simulation scenario. In this particular case, however, we can obtain relatively accurate estimates of changes in trade barriers using only the relationship between Russia's GDP and food imports. Several conditions must be met to correctly build such a model:

1) GDP dynamics should be independent of changes in external food trade barriers after 2014. Otherwise, the hypothetical path of food imports, modelled only on actual GDP dynamics, in the no barrier scenario will be biased since it will not take into account the change in GDP itself as a result of sanctions and trade barriers;
2) There should be a strong relationship between GDP and food imports in Russia until 2014; it will help simulate import volumes accurately enough based on only GDP data.

The first condition is met to a fuller extent, since the actual impact of trade barriers on Russia's GDP between 2014 and 2018 was rather limited. This statement is supported by IMF experts in a report on the Russian economy (International Monetary Fund, 2019). According to the report, the introduction of trade and other sanctions resulted in actual GDP growth deviating from the 2013 IMF forecast by -0.2% a year on average between 2014 and 2018. For comparison, the oil price (-0.9%), fiscal (-1%) and monetary (-1.2%) factors in the expression cumulatively contributed much more (-3.1%) to the deviation from the IMF forecast, released before the economic crisis of 2014–2015 in Russia.

This issue is covered in further detail in a review of economic sanctions by Klinova and Sidorova (Klinova, Sidorova, 2019). The authors' calculations give a sense of the shares of all countries that imposed sanctions in total Russian exports. In 2013, this share was 51% and in 2017 remained almost the same at 50.1%. In this context, the food embargo of the Russian Government, in effect since its rollout in 2014 to this day, has been one of the few truly significant new barriers to external trade and has had an explicit effect on imports statistics (Figure 3).

Undoubtedly, the import and export of food products can be viewed as an integral part of GDP by the end-use method, which means that if some trade barriers affect the import and export volumes of food products, they also automatically affect GDP. However, the food imports to GDP ratio is relatively small; this effect can be neglected. It was approximately 1.9% in 2013 (unadjusted for CIF and FOB prices) and 1.8% in 2017 (Figure 3). For exports, this ratio is even lower at 0.7% in 2013 and 1.3% in 2017. At the same time, the export of Russian food products after 2014 was essentially unaffected by sanctions (Figure 3), for there was no massive food embargoes against Russia.

The second condition can be directly checked on the data – by constructing a one-dimensional linear regression of the following form:

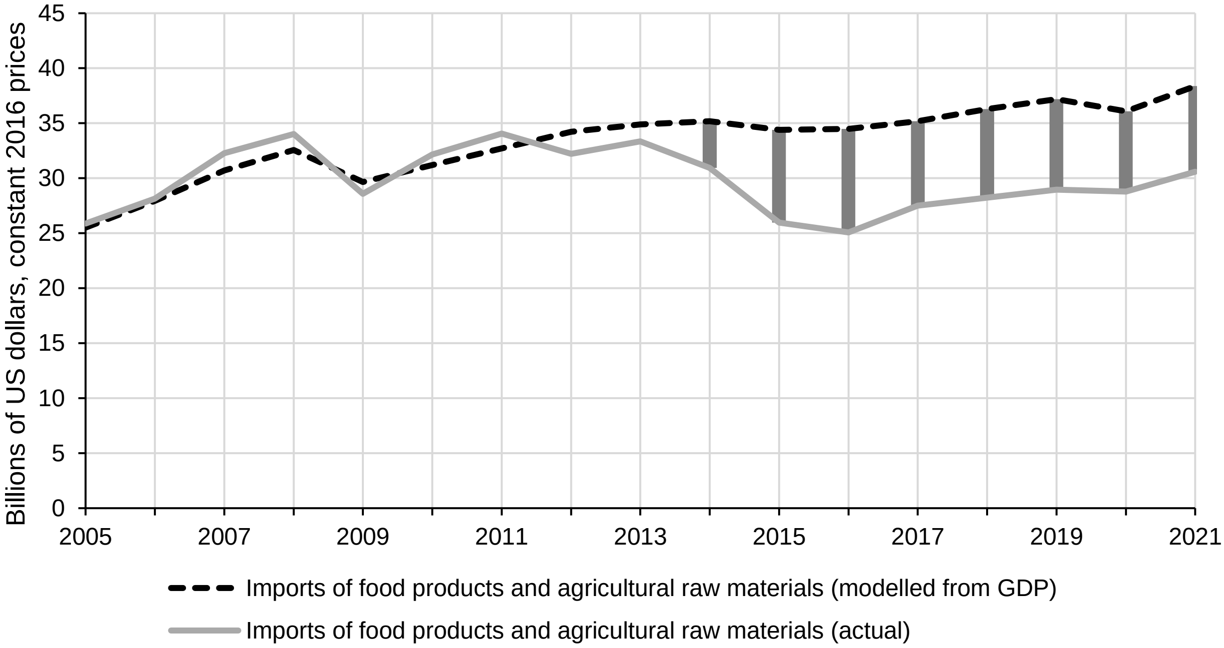
$$imp_{prod} = b_0 + b_1 GDP + e, \tag{3}$$

where imp_prod is the annual series of food and agricultural raw material imports of Russia in constant 2016 prices, b_0 is the constant, GDP is the annual series of Russia's GDP in constant 2016 prices, and e is the residuals of the model.

In estimating this relationship based on data from 2004 to 2013 through an OLS method, model fitting R^2 was 88%; in estimating for the 2014 to 2018 period it was 29%, and for the 2019 to 2021 period, 83%. Therefore, the relationship between physical imports and GDP was quite stable until 2014, negligible in 2014–2018 and stable again in 2019–2021.

Using the forecast import values from the model estimated for 2004–2013, a hypothetical import path can be obtained (Figure 7). It approximates the dynamics of imports that would come to pass in the no barrier scenario (in which no trade barriers for food products were introduced after 2014).

Figure 6. Proxy for the hypothetical dynamics of imports of food products of Russia in the scenario where barriers to external *trade in food products were not introduced after 2014*



Source: Author's own calculations, Federal Customs Service of Russia, Rosstat.

The proxy for external food trade barriers is the difference between the hypothetical and actual imports data. Thus, the greater the value of this proxy, the stronger the impact of external trade barriers on other economic indicators. The estimates suggest that the impact of trade barriers was strongest in 2016; thereafter, barriers to external trade in food products declined gradually, if immaterially.

However, the specific values of external trade barriers are less relevant to the purposes of this research than their time evolution and implications for domestic price trends. In order to fully incorporate this indicator into the model, it is subjected to temporal disaggregation, intended to switch from annual to monthly data. For this, I use the Federal Customs Service's high-frequency data on the import of food products and agricultural raw materials. It is assumed that the intra-year structure of the hypothetical path of food imports by month is the same as the actual structure. Prior to the disaggregation of the proxies for external trade barriers, the prices of imported food products are recalculated back from constant to current prices through the Federal Customs Service indices of average food prices. This unwanted transformation is driven by the lack of sufficient data on the physical volume indices of food imports in the monthly frequency. The price effects of imports are unlikely to have a major impact on the final estimates of pass-through effects, since external trade barriers are included in the model in the form of relative changes in US dollars over the relatively small time intervals of several months. Prior to the temporal disaggregation, the actual monthly volumes of imports are seasonally adjusted with the algorithm X13-ARIMA-SEATS. Since the proxy for external trade barriers is relevant only from 2014, the change in this series until 2014 is equal to zero so that all other data in the model before this period can be included. This factor is included in the model as an exogenous variable, with external trade barriers being an instance of politics rather than economics.

In addition to import tariffs and non-tariff measures, the Russian customs practice also provides for duties and other restrictions on export operations. Although most of them relate to petroleum products, they have been used in the case of basic cereals (wheat and meslin, barley, corn), sunflower seeds and, beginning in 2021, sunflower oil as a final product. The model should also take into account these restrictions, given that increased export duties or non-tariff policies – and the higher costs they involve – disincentivise producers from entering world markets. As a result, world prices are becoming increasingly decoupled from domestic prices, which ultimately lowers pass-through effects.

As with import tariff and non-tariff measures, it is a methodological challenge to include restrictions in the model. Among the multifaceted factors complicating the accounting of the impact of export duties on domestic prices is the single economic space of Russia and other countries. Russia's new export duties are often applied only to exports to countries outside the single economic space (e.g. EAEU[10]). At the same time, the countries within this space do not as a rule impose such export duties in sync with Russia, thereby offering a workaround to exporters. This means that they can export products that are subject to restrictions, for example to Kazakhstan, without paying any import duties and then export them from there without the obligation to pay export duties (Makhotina et al. 2022).

In addition to the problem of accounting for the actual implementation of export restrictions, there is a problem of quantifying non-tariff measures (such as quotas). These methodological difficulties explain the choice of a simpler method for the model to capture these effects. The proxy for this external trade barrier was the weighted average of the agricultural producer price index for cereals and legumes and the industrial producer prices for unrefined sunflower oil and its fractions.

The values of this time series are influenced by external trade barriers for export and all other food price factors. In the optimum case, it is necessary to identify price effects only from external trade barriers, with all the other price-setting factors being taken into account in the other variables of the model. However, the methodology to accurately conduct such a decomposition has yet to be finalised. This is why the dynamics of domestic producer prices for grain and sunflower oil are taken as the best available proxy for export barriers to

[10] This is often evident from the names of relevant resolutions, for example, Resolution of the Government of the Russian Federation No. 2068, dated 27.11.2021 (updated 30.08.2023), 'On Rates of Export customs Duties on Exports from the Russian Federation outside the Customs Territory of the Eurasian Economic Union'.

external trade in food products. This variable enters the model as an exogenous variable in the same logic as the proxy for external trade import barriers.

Many regions of Russia are integrated into interregional trade – a factor to take into account in analysing regional inflation trends given the operation of the law of one price and other convergence processes in regional economies (Glushchenko, 2010; Kirillov, 2017; Napalkov et al., 2021; Korneychenko et al., 2021). This research uses a matrix of interregional trade to take into account spatial relationships. For each region, the weighted average is calculated, reflecting spatial (spillover) effects. I follow Napalkov et al., 2021 in using use the matrix of volumes of interregional trade flows – Rosstat's imports-exports table – as weights. A special table is used in the calculation of weights, in which trade flows of all commodity groups are summated in monetary terms, while classified information complicates the use of data for individual commodity groups. Calculations are based on tables for only 2016. Tables in monetary terms for subsequent periods are not published according to the law whereby primary statistical data are classified. At the same time, some early tables may come without the table with totals, which cannot be calculated independently due to classified status of multiple essential items. It is assumed that the structure of interregional trade is relatively stable over time, but this limitation should be reflected in interpreting regional assessments.

Based on this matrix, two types of weights are calculated for each region i:

1) The share of trade turnover (imports and exports) of region *i* with other regions, excluding interregional turnover i (weight of region $i = 0$);

2) The share of trade turnover of region *i* with other regions, including interregional turnover i (weight of region $i \neq 0$).

The weights of the first type are used for indicators in which it is necessary to cut off the impact of spatial effects from the impact of internal variables of the region to obtain more insights into how world prices weigh on the indicators of a region. Each regional model uses two indicators of the price index: the regional price index and the weighted average price index of all other regions.

The weights of the latter are used for indicators that can dispense with the breakdown of factors as intra- and inter-regional, as long as they perform only a control function. These weights are used for freight tariff indices and physical retail volumes. For Russia as a whole, the indicators of spillover effects are not calculated, since Russia's series already represent aggregate values of all the regions.

All the time series were put to an extended Dickey-Fuller stationary test with a 5% significance. All the series are stationary but a number of food CPIs for Moscow and the Kirov Region; however, all the VARX models were stable, that is, their eigenvalues lay within the unit circle, so these series were not excluded from the analysis to ensure it is complete.

An important factor in the quantification of the model is the isolation of the impact of outliers on VARX coefficients. In this context, in estimating the model, the impact of the following periods on the ratios was eliminated by introducing dummy variables:

1) October 2007: the abnormal increase in food prices over the month in Russia on the back of the forthcoming administrative measures to limit price increases; sellers had adjusted prices in advance even before the restrictions were introduced;

2) Between September 2008 and March 2009: the acute phase of the 2008 financial crisis, with a strong drop in prices across almost all exchange markets;

3) Between December 2014 and June 2015: increased inflationary pressure amid falling oil prices, introduction of sanctions restrictions, high volatility of the ruble exchange rate and transition to a floating exchange rate;

4) Between April 2020 and June 2020: the world coronavirus lockdown;

5) The whole of 2022: a crisis triggered by sanctions pressure.

For each of the 80 regions in the analysis, the total number of observations for model estimation is 210. It is possible that the presented shocks affected the economy even earlier or later that the specified periods. However, for the purposes of evaluating the model, it was precisely those periods in which these shocks were clearly reflected in the statistical data and significantly influenced the coefficients of the model.

In addition to VARX, estimates of the vector error correction model with exogenous variables (VECMX) were also under study. This model uses information about the co-integration of time series – their long-term relationship. For the series of Russia as a whole, co-integration was established by the Johansen test, but finally VARX was chosen as the base model. This is explained by our specification, which simulates world prices as an autoregression process without including factors to account for the long-term equilibrium of food prices in world commodity markets. The inclusion of such factors would probably improve the accuracy of estimates, but would greatly complicate the model, especially in handling data of each individual region of Russia. From a methodological viewpoint, the use of VAR to simulate co-integrated series through taking the first differences is suboptimal, but acceptable and applied by many researchers. The VECMX models were only built for Russia as a whole, and the pass-through effects obtained through this method are slightly different from the base model estimates; the results of VECM modelling are available in the paragraph presenting robustness assessment.

Information on import and export prices, the volumes of food imports and exports for Russia and its regions would also be worth adding to the model to control for all stages of the pass-through of world prices to domestic ones. However, this is prevented by the poor quality of these data in regional terms and the insufficient length of time series for Russia as a whole. External Trade Statistics by the Federal Customs Service by region does not indicate the final point of destination for imports, but the region of registration of the importing entity. For example, Moscow accounted for 54.3% of consumer imports in 2018, and the share of the Central Federal District was 75.7% (Zhurakovsky et al., 2021). The same problem persists for exports data. In the area of statistics, there is very scant research into how some information could help determine where imports are ultimately consumed, making it impossible to accurately assess the impact of the external sector on regional economies based on customs statistics. These are the reasons why these factors are not presented in the model. External sector statistics for Russia as a whole look better, but the problem of the insufficient length of data series holds. Accordingly, food import and export price indices in Russia have been published on a quarterly basis only since 2010[11]. The switch to a quarterly frequency and inclusion of these data in the model will significantly limit the length

[11] According to the Unified Interdepartmental Statistical Information System (FEDSTAT)

of time series. This will prevent an accurate estimation of the model coefficients due to the small number of the degrees of freedom, deteriorating the comparability of the models at the regional and countrywide levels.

In this study, ‘quantifying the pass-through’ means finding the ratio of cumulative increase of the impulse response function (IRF) of producer and consumer price indices to the corresponding cumulative IRF of world prices after the shock of inflation factor, i.e. a 10% increase in world food prices (in US dollars). The calculation of the IRF relies on Cholesky’s recursive identification to isolate the pass-through of world to domestic prices from other factors of the model. The confidence intervals of impulse response functions are calculated by the bootstrap method in 2,000 iterations, to identify statistically significant differences in estimates of different models, including those of individual regions; the main method is analysing the overlapping of 90% confidence intervals. In other words, if the confidence intervals of two estimates overlap, these estimates are regarded as insignificantly different from each other statistically, and otherwise if the confidence intervals do not overlap. The procedure for quantifying the pass-through is run for each Russian region to gain further insights into regional heterogeneity. The optimal order of the VARX model is determined through information criteria minimisation by Akaike and Schwartz; a VARX with two lags was chosen for all specifications.

In the Cholesky decomposition, the impulse response functions depend on the order of endogenous variables in the model, and factors in general need to be located by the principle of primacy of one shock over another. The primacy of world over domestic food prices seems obvious and follows from reasoning (Cachia, 2014) as well as the production chain that almost always begins with raw materials which are traded in world food markets. Thus, all the models being estimated have the following order of variables:

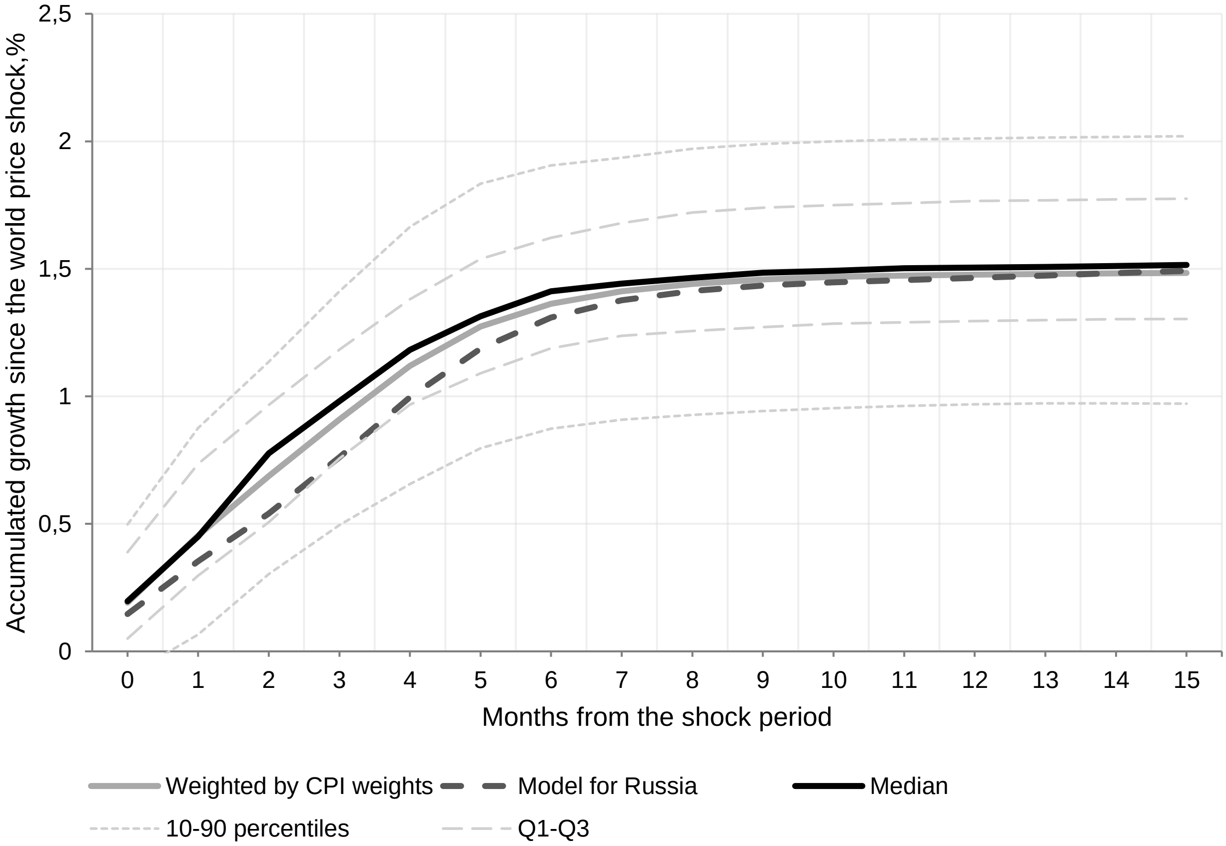
fao_prod_wpi → neer → fiscal_rule_fxi → miacr → prod_ppi → prod_rozn → prod_cpi

Since this work studies the impact of the shock of the variable fao_prod_wpi, which is always the first in the order of identification, the order of all other variables is not relevant to the final values of shocks according to the principle of recursive identification. This is why the study does not present the results of model calculations with other orders of variables, since they are not different in any way from the results obtained with the current order.

5. Findings

The dynamics of the cumulative impulse response of the food CPI to 10% shock of world food prices is presented in Figure 7. Regional values are aggregated in the form of statistics (median, average, etc.); weighted average values were calculated based on Rosstat data on the shares of regions in food consumption in 2018–2019. Additional materials of the work are available in the Appendix; all the calculations and other data are available at: https://doi.org/10.6084/m9.figshare.21875385.v4..

Figure 7. Cumulative increase in the food CPI impulse response function to 10% shock of world food prices, Russia as a whole and region statistics



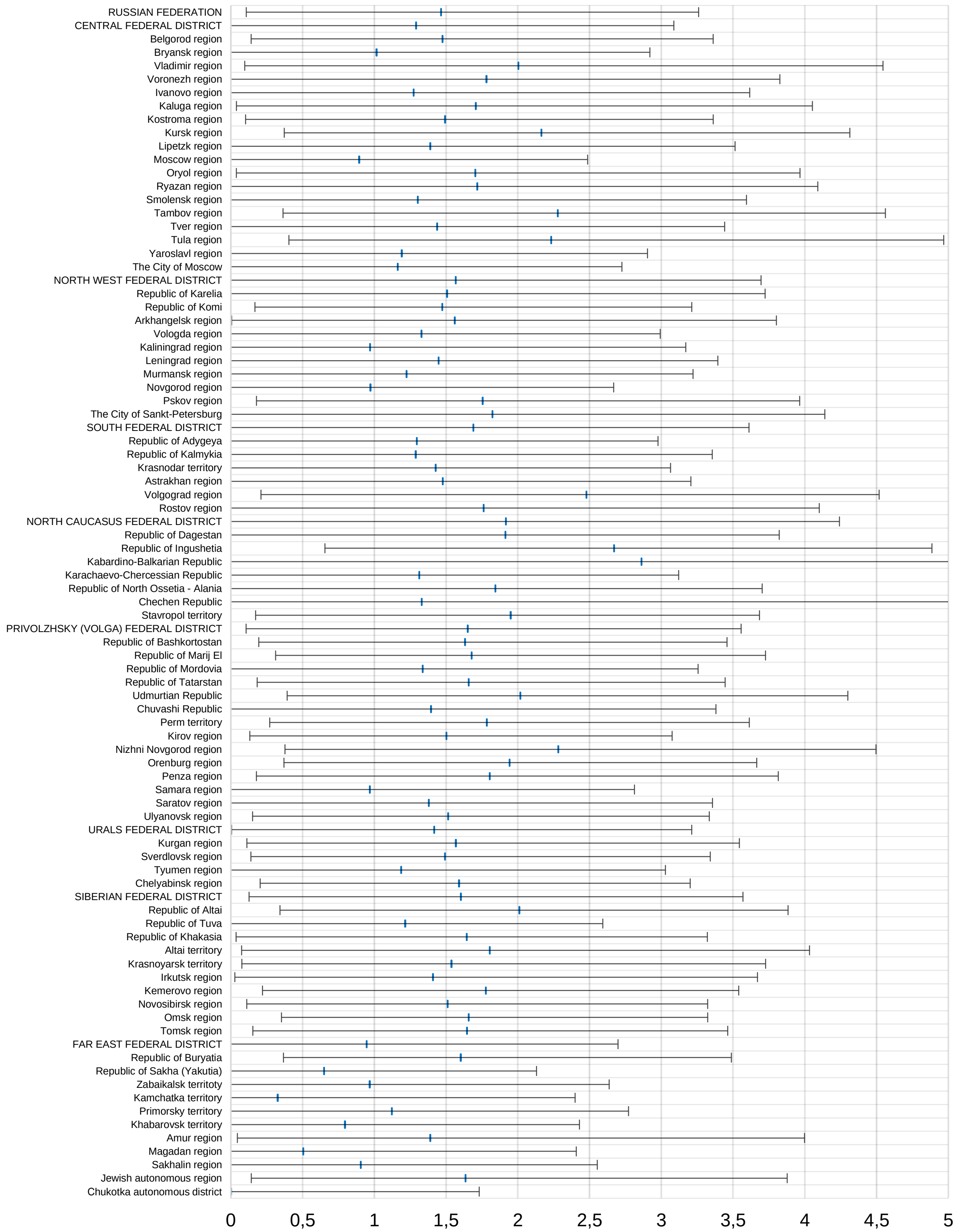
Source: Author's own calculations.

The impulse response functions of the model, which was estimated only on Russia's time series, are quite consistent with the weighted average values by region. This suggests the robustness of the results.

The pass-through effect almost fully materialises over the course of one year and is 1.5% for Russia as a whole (the 90% confidence interval is between 0.11% and 3.3%) and 1.5% for an average region. The main part of the pass-through materialises in the first quarter, with the cumulative increase in prices over the period totalling 52% of the annual increase, and 89% in the second quarter. The cumulative responses of the CPI in 12 months after the world price shock and their 90% confidence intervals for each region are presented in Figure 8; the estimates for federal districts are weighted average estimates for the regions they include.

Hereinafter, the medium-term pass-through is understood as annual, considering that it takes one year for almost all cumulative functions of the impulse response of domestic food inflation to the shock of world food prices to reach their maximum.

Figure 8. Medium-term cumulative increases in impulse response functions of food CPI to 10% world food price shocks in Russian regions with a 90% confidence interval, %



Source: Author's own calculations.

With the confidence intervals of point estimates of impulse responses of all regions overlapping with each other, there are no regions where the response of the food CPI to the shock of world prices was statistically significantly different from any other region. The average annual pass-through effect has a relatively small spread: half the regions show a pass-through effect between 1.3% and 1.8%.

Figure 9 shows the results of model estimation on separate periods accounting for pass-through changes over time: before the Bank of Russia's switch in November 2014 to a floating exchange rate, for the whole period, and in the post-2014 period.

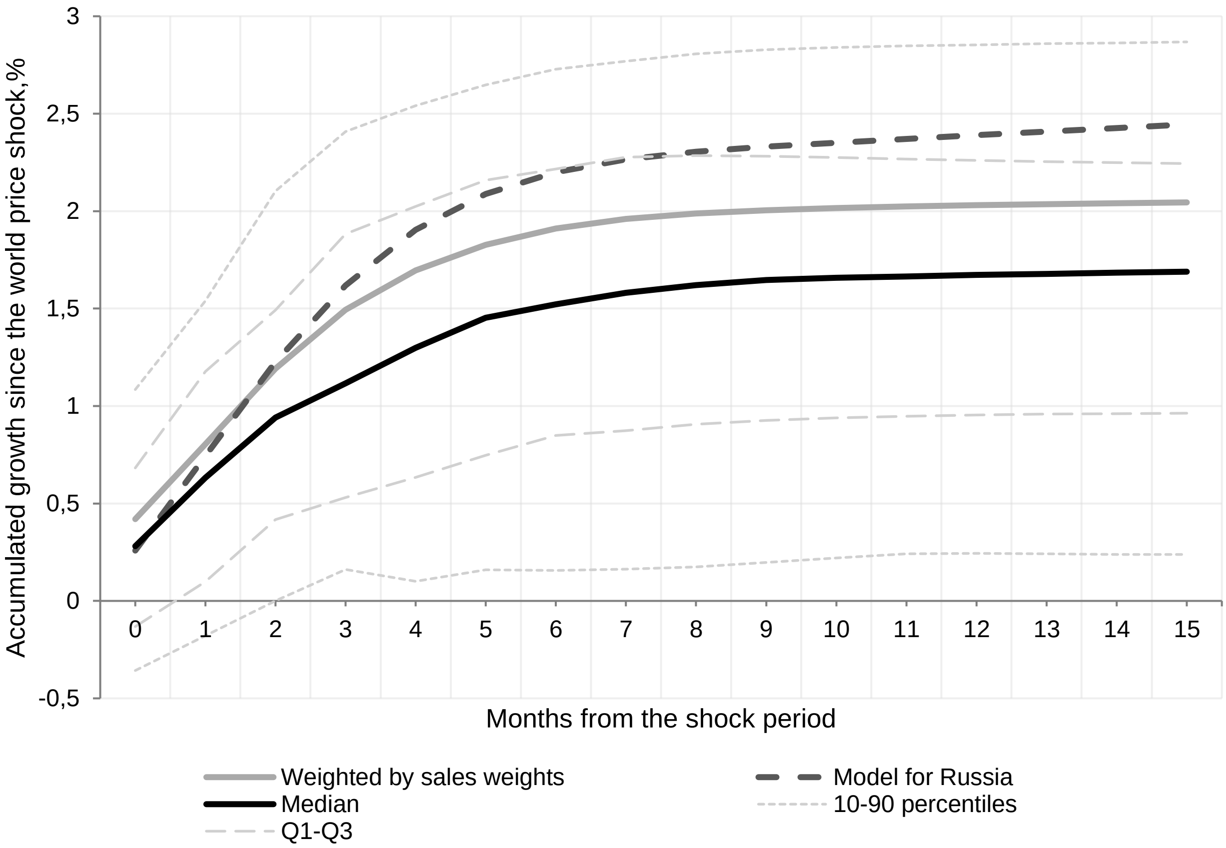
Figure 9. Cumulative increases in impulse response functions of the food CPI to 10% world food price shock by model estimation period

Source: Author's own calculations.

Based on the results of calculations, the average pass-through effect dropped after 2014, but the wide confidence intervals make this change formally insignificant. Accordingly, based on data before 2014, the estimated pass-through effect for Russia as a whole is 2.1% (the 90% confidence interval is from 0.3% to 5.7%); based on post-2014 data, -0.5% (the 90% confidence interval is between -12% and 7.1%).

Figure 10 shows the functions of impulse response of food producer price indices to 10% shock of world prices.

Figure 10. Cumulative increase of the food PPI impulse response function to 10% world food price shock, Russia as a whole and region statistics



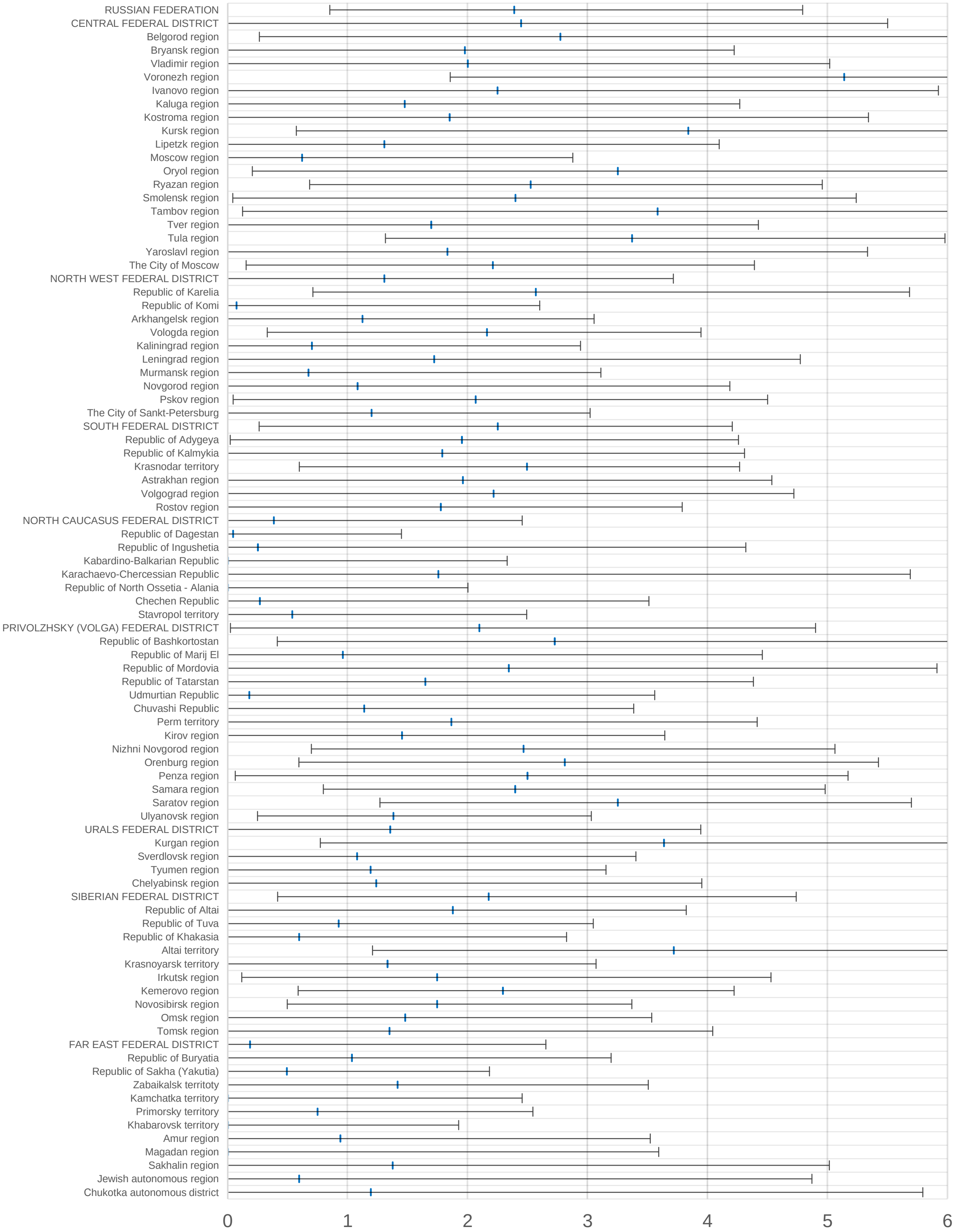
Source: Author's own calculations.

Based on the regional weights of cumulative impulse responses by the volume of food sales by producers, the performance of individual regions is overall consistent with Russia-wide results. The pass-through of world prices to the food PPI almost fully materialises over the year: in the first quarter, the index grows at the highest rate and accounts for 68% of the medium-term pass-through, and it takes two quarters for as much as 92% of the medium-term pass-through to materialise.

The pass-through for the food producer price index over the year is calculated at 2.4% (with the 90% confidence interval from 0.8% to 4.8%) for Russia-wide estimates, and 2% on average by region.

The variance of estimates by region for producer price indices is greater than that for the consumer price index. The medium-term pass-through in 50% of the regions is already within the 1–2.3% range. There are a number of regions whose impulse response functions are significantly different from the responses of other regions. The Voronezh, Kursk, Kurgan, Tambov, Tula, Saratov, Orel Regions and Altai Territory (Figure 11) stand out; the likely causes of the differences is presented in the findings paragraph.

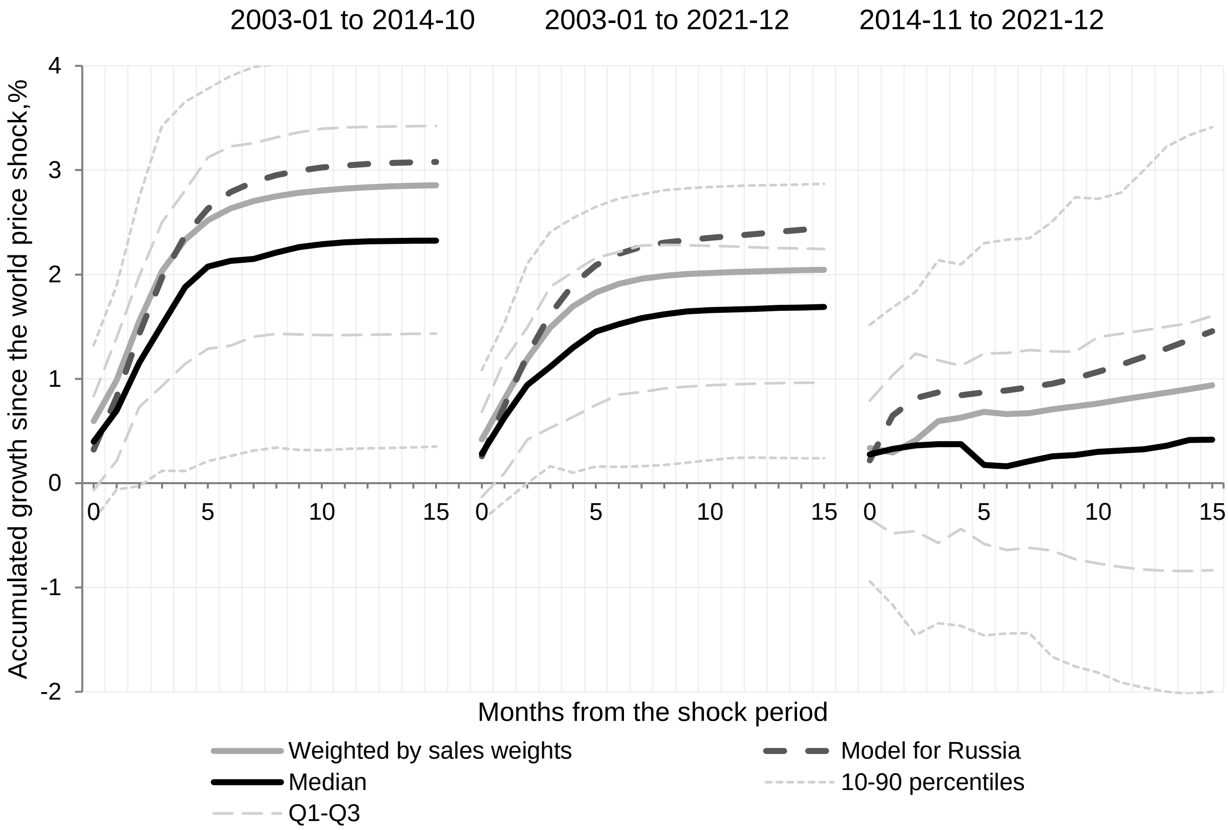
Figure 11. Medium-term cumulative increases in food PPI impulse response functions to 10% world food price shocks by region, 90% confidence intervals, %



Source: Author's own calculations.

Figure 12 shows pass-through estimates for world prices in PPIs in individual periods.

Figure 12. Cumulative increases in impulse response functions of the food PPI to 10% world food price shock by model estimation period

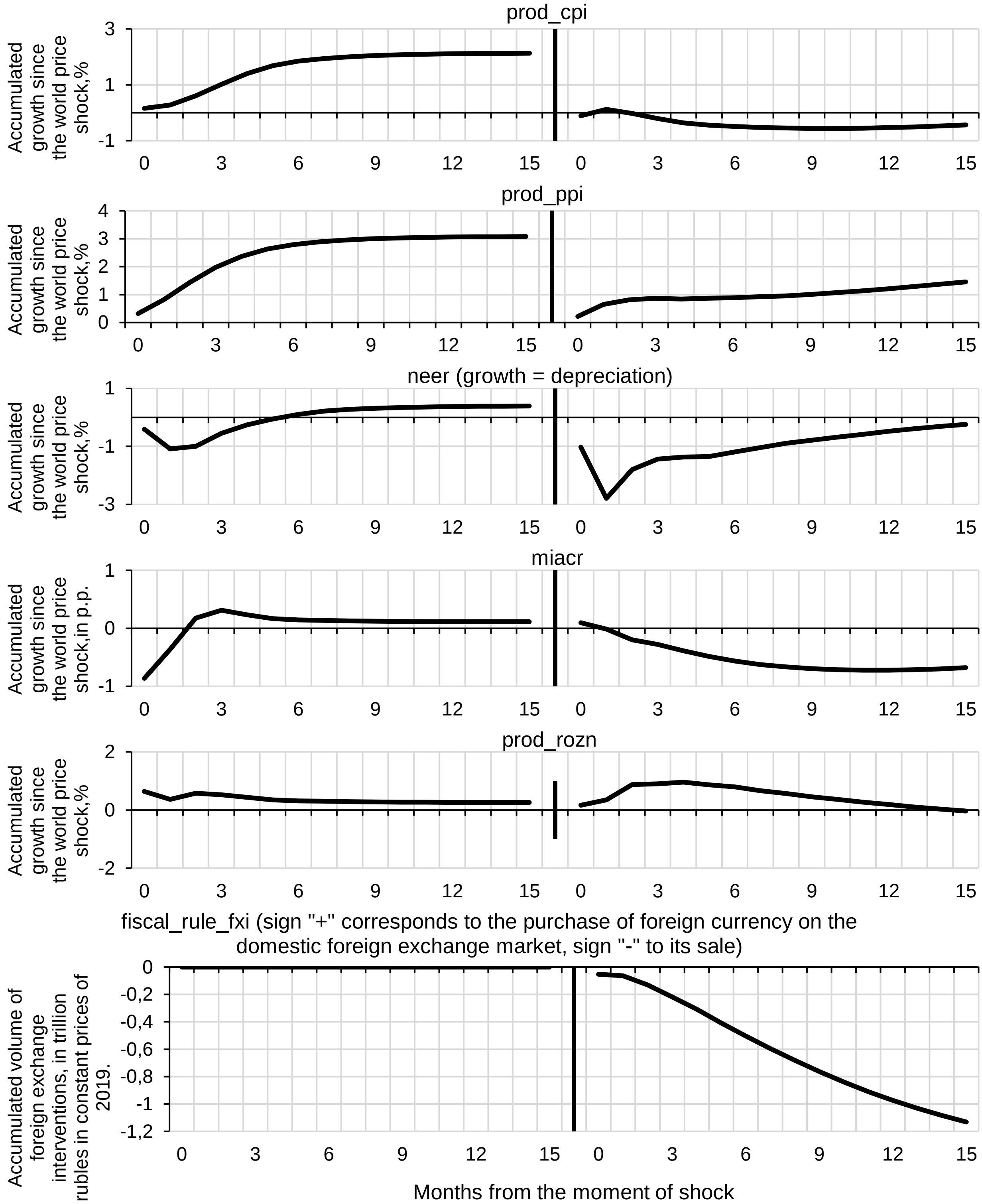


Source: Author's own calculations.

The pass-through effect trends down over time. Based on the data before 2014, the countrywide pass-through was 3.1% (the 90% confidence interval is from 1 to 7.5%) and 1.2% for the 2015–2021 data (the 90% confidence interval is from -13% to 13%).

In the estimates, changes in pass-through over time are of particular interest; to enable a detailed analysis of the possible causes of these changes, Figure 13 shows the responses of all endogenous factors of the system estimated on the data before and after 2014.

Figure 13. Cumulative increases in the impulse response functions of the endogenous variables of the VARX system to 10% world food price shock by model estimation period



Note: The separator separates the model estimates on the data before (on the left) and after (on the right) October 2014; the confidence intervals are stripped out due to their very wide ranges of values.

Source: Author’s own calculations.

After 2014, we have seen a strong decline in the pass-through of world food prices to domestic prices of consumers and producers. The largest contribution to this decline was the increase in the responsiveness of the nominal effective exchange rate after 2014. Based on post-2014 data calculations, the foreign exchange rate strengthens significantly in the first two quarters after the world price shock. Based on this analysis, it can be assumed that after 2014 the foreign exchange channel of price transmission worked to better offset the effects of changing world prices on domestic prices for Russian food products.

As the literature review mentions, the asymmetric character of the pass-through is highlighted in many studies. This explains the formulation of the initial hypothesis: the pass-through of world food prices to domestic inflation is asymmetric, and its value is higher than average in the case of growing world prices and lower in the case of world price downturn. The estimated asymmetry is presented in Table 2.

Table 2.

Estimated asymmetry of pass-through of world to domestic prices

	Method based on formulae (1)		**Method based on a split of sample into two parts**	
Countrywide pass-through over one year, %	Consumer price index	Producer price index	Consumer price index	Producer price index
↑ in world prices	2.4 (0,5; 4,8)	3.3 (1,1; 6,4)	2.7 (0,9; 5,6)	3.1 (0,9; 6,4)
↓ in world prices	-0.7 (-3,9; 2,3)	1.2 (-2,3; 4,8)	-0.1 (-4,4; 8,4)	-0.1 (-4,9; 9)

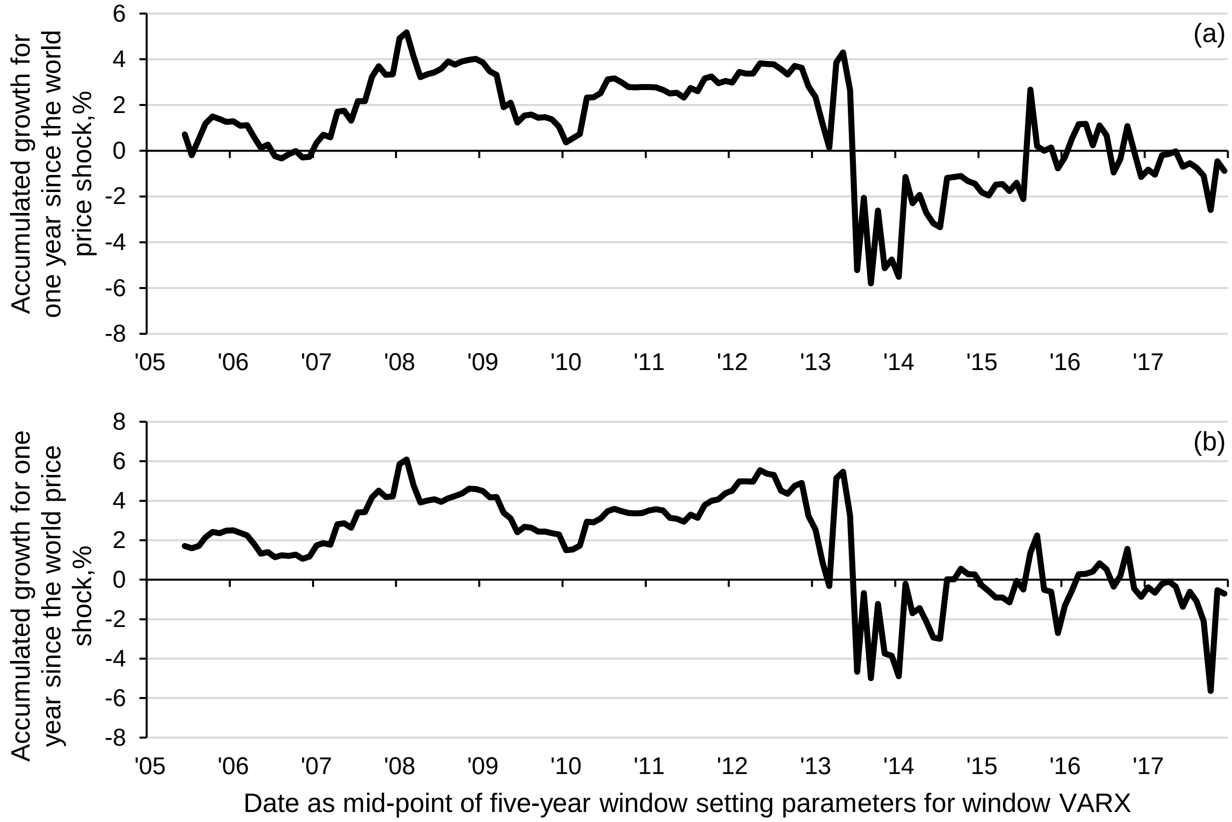
Note: 90% confidence intervals are in brackets.

Source: Author's own calculations.

Pass-through effects in the cases of growth and decrease in world prices have wide confidence intervals that overlap with base model estimates, so formally the asymmetry hypothesis is rejected for two different approaches to estimating the asymmetry. At the same time, the average pass-through values in the growth or decrease scenarios are different depending on the direction of trends in world food prices.

Asymmetry effects can also be related to volatility and specific time periods, such as crises. The pass-through effect will likely be stronger at times of crisis due to the effects of roaring demand and economic panic. To analyse these effects, we calculate window VARXs to identify, as far as possible with limited data volumes, the contribution of world prices to domestic prices in certain periods. A window VARX is a VARX estimate on a moving data window of five years, each such VARX calculating the annual pass-through of world to domestic prices. To fully capture the effects of economic crises, dummy variables were not introduced in outlier-based model estimation; otherwise the specifications of window VARXs fully correspond to the base model. The results of the calculations are presented in Figure 14.

Figure 14. Cumulative increases in the impulse response functions of consumer (a) and producer (b) food prices over one year to 10% world food price shocks in VARX, estimated over a five-year moving window of data, Russia as a whole



Note: in the outlier-based estimation of window VARXs, dummy variables were not introduced to capture the effects of economic crises; confidence intervals are stripped out due to their very wide ranges of values.

Source: Author's own calculations.

Based on the data presented in Figure 14, it is possible to draw several conclusions on the time evolution of the pass-through effect:

1) Two periods are clearly seen in the pass-through: before 2014 and after. The moving pass-through effect for one year in the models built on data before October 2014 averages 2.2% for consumer prices and 3.1% for producer prices. In the models based on past-October 2014 data, the moving pass-through effect for one year averages -0.3% for consumer prices and 0.2% for producer prices. These estimates are very close to the calculated pass-through effect from the non-moving models by period (Figure 9 and 12), which speaks to some comparability of moving estimates with the previously submitted pass-through calculations;

2) The pass-through effect even in these two periods is marked by a high level of time dispersion relative to its average. The standard deviation of moving estimates for consumer prices is 1.4% and 2.2% for the data before 2014 and after, respectively. For producer prices, it is 1.2% and 2.5% for the data before 2014 and after respectively;

3) While on the crisis effects, conclusions can be limited due to the relatively large window width of these moving estimates. The pass-through was telling in 2008, a time of

the world financial crisis marked by sharp fluctuations in world food prices. World food prices had risen ahead of the crisis, with their local peak in June 2008 showing a 45% increase year-on-year. Thereafter, by late 2008, the world crisis put world food prices on a downward trend. As soon as March 2009, they fell 36% year-on-year (Figure 4). According to our estimates, the maximum average window pass-through for 2008 was 5.2% for consumer and 6.1% for producer prices. Another illustrative period is the 2014–2015 currency crisis in Russia. The window estimates covering this period show that the average maximum pass-through for one year was 4.3% for consumer and 5.5% for producer prices. After the crisis of 2014–2015, the average window pass-through decreased to almost zero for both consumer and producer prices, but went up 1–2% at some points in time.

6. Discussion of findings

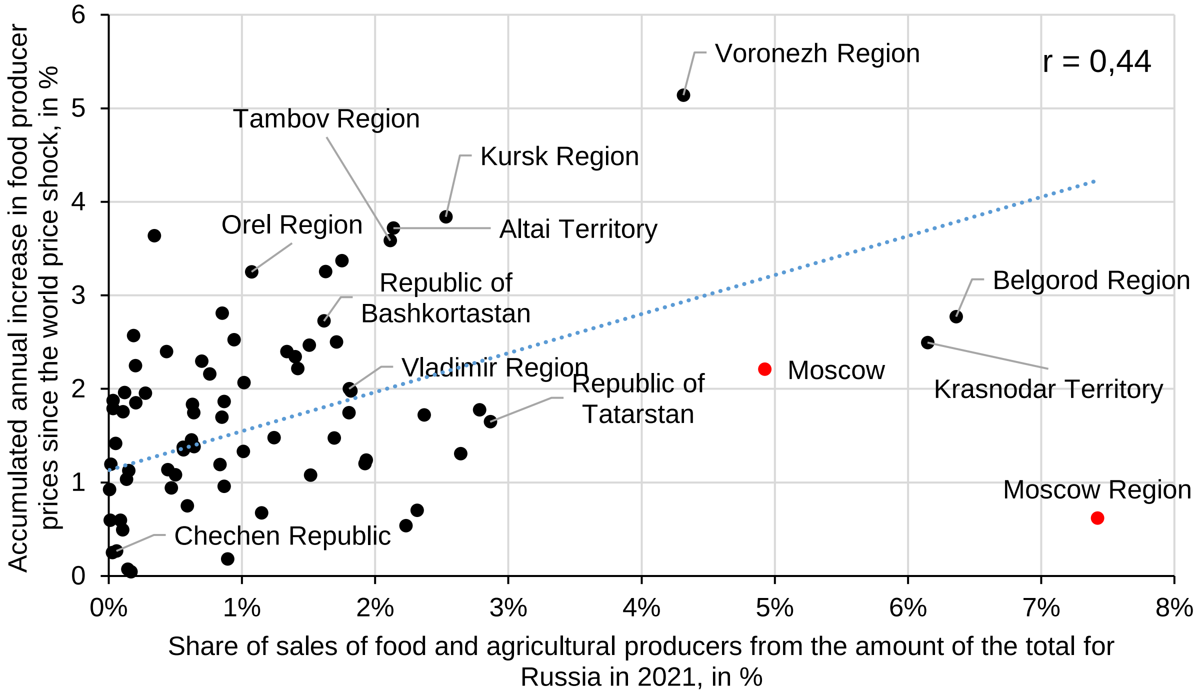
The pass-through of world food prices to food inflation in Russia is statistically significant (the level of significance is 10%) for the 2003–2014 data, but becomes almost zero for the post-2014 data on the back of strengthened exchange rate dynamics, which work to offset the shock of world prices. In general, the logic of this change is aligned with the findings of researchers who highlight the strengthening role of the exchange rate as a natural stabiliser for external shocks, after Russia's adoption of the floating exchange rate policy (Kartaev, Yakimova, 2018; Tiunova, 2018).

The pass-through of world food prices to food inflation, both countrywide and regional, is incomplete. This is consistent with Western and domestic studies on exchange rate pass-through and world price pass-through to domestic inflation (Ferrucci et al., 2012; Ha et al., 2019; Andreyev, 2019). While this is true for both consumer and producer prices, the effects for the PPI are stronger, which is also consistent with the conclusions in relevant works (Ferrucci et al., 2012; Ponomarev, 2015; Tiunova, 2018).

In order to gain deeper insights into regional differences in terms of the pass-through of world to domestic prices, it is worth considering the estimates in the context of other economic indicators of Russian regions. It is difficult to conduct this analysis for the food CPI due to the absence of regional heterogeneity of the pass-through of world prices to domestic consumer prices. In the case of the food PPI, the differences are more significant. These regional differences in the food PPI may be different due to the inner structures of agricultural and food industries that significantly vary by region. In this context, current estimates combine both structural and price effects.

Importantly, the pass-through of world food prices to domestic prices of food producers and the measure of regional involvement in the food production industry are in a co-directional relationship (Figure 15).

Figure 15. Relationship between the effect of world food price pass-through to producer prices and food production by region



Note: In calculating the linear function and the Pearson correlation coefficient, Moscow and the Moscow Region are removed from the sample (red-highlighted): this is a simple one-dimensional model that cannot capture the features of a capital city area.

Source: Rosstat, Author's own calculations.

On average, the greater involvement of the region in food production, the stronger the pass-through of world prices to food producer prices in this region. The positions of some regions in this simple linear model significantly deviate from their simulated positions. While the deviation of the capital city areas is down to their special status, the significant deviation in the Krasnodar Territory and the Belgorod Region is more difficult to understand. The two regions are quite close to each other in this simple two-dimensional space; they are among key food producers in Russia. It is possible that the pass-through to the PPI is lower in these regions due to a higher level of monopolisation: monopolist firms' prices deviate from market equilibrium, and the deviations can be large and long-lasting.

This relationship does not exist in consumer prices. It can be assumed that regional price differences translating from producer to consumer prices are smoothed by the law of one price thanks to the countrywide economic space and the operations of developed federal retailers.

The hypothesis about the asymmetry of the response of domestic consumer and producer prices depending on the direction of change in world prices was not confirmed by statistical tests; however, the average pass-through effects are noticeably different. The differences in models simulating symmetric and asymmetric exchange rate pass-through and world price pass-through to domestic prices have also been established in many other studies (Ferrucci et al., 2012; Ha et al., 2019; Andreyev, 2019; Zhurakovsky, etc., 2021).

Having said that, there is no evidence that this asymmetry exists in the long term. For example, Andreyev (Andreyev, 2019) finds the asymmetry of the exchange rate pass-through in Russia in the short term, but in the long term the asymmetry proved statistically insignificant.

The pass-through effect is characterised by a high time spread relative to its average values. As a rule, pass-through effects are higher at a time when world food prices are soaring and markets are highly volatile, and lower at a time when price movements in world food commodity markets are slow. Similar results were obtained in Jašovà et al., 2019 for the exchange rate pass-through to domestic inflation. In this study, window models with a five-year window on average show a higher pass-through effect than in the 2008 crisis.

7. Robustness of findings

To assess the robustness of findings, we estimate the vector error correction model with exogenous variables (VECMX) for Russia as a whole. The set of endogenous and exogenous variables is the same as in VARX, but the month-on-month growth indicators are in the form of the base index, i.e. in levels. All the variables have first-order integration, that is, they are non-stationary in levels, but become stationary when the first differences are taken. The Johansen co-integration test with trace statistics shows that there are at least two co-integration equations of a 5% significance level for the model estimated on all data, as well as for the model estimated on post-2014 data. The pass-through of world to domestic prices has the same algorithm of calculation according to Cholesky’s recursive identification as the base model. The results of pass-through estimates in the model are presented in Table 3.

Table 3.

Estimated pass-through of world to domestic prices in the vector error correction model

Pass-through for Russia as a whole for one year, %	Consumer price index	Producer price index
Estimates based on data between 2003–01 and 2021–12	1 (-0.4; 1.9)	2.6 (0.9; 3.8)
Estimates based on data between 2014–11 and 2021–12	0.3 (-1.3; 1.4)	1.3 (-1.1; 2.7)

Note: 90% confidence intervals are presented in brackets.
Source: Author’s own calculations.

The difference of the pass-through effect in VECMX from baseline estimates are statistically insignificant since the 90% confidence intervals of estimates overlap. Some differences in results are most likely the consequence of VECMX integrating information about the long-term equilibrium of the model. However, as observed in the methodology paragraph, the study prefers VARX-based estimates, given that the model does not include world food price equilibrium determinants, such as world GDP, a world trade indicator, and other world variables.

8. Concluding remarks

The results obtained in this study indicate a significant influence of shocks in global food prices on domestic food inflation in Russia, corroborating findings from studies conducted in various countries. However, in Russia, this impact decreased after 2014 when the economy underwent significant structural changes, including the transition to a floating exchange rate, inflation targeting policy, active development in the agro-industrial complex, and the implementation of import substitution policies amid the Russian government's imposition of various external trade barriers on food. Prior to 2014, a 10% increase in world food prices corresponded to an average 2.1% rise in domestic consumer food prices within one year across Russia. Post-2014, this impact decreased practically to zero.

Furthermore, the results also indicate that shocks in world food prices exert a stronger influence on producer price dynamics than on consumer prices. Before 2014, a 10% change in world food prices, on average, led to a 3.1% change in Russian food producers' prices. After 2014, this effect also became statistically indistinguishable from zero. The discrepancy in reactions between producer and consumer prices to shocks in world prices might be due to producers' closer ties to global food markets compared to retail sellers.

Despite the significant heterogeneity among Russia's regions in terms of price levels and inflation, no substantial differences were found in the response of consumer food prices to shocks in world prices. However, some heterogeneity in the response of producer prices to these shocks was identified. The strongest reaction was observed in regions specializing in food production.

Moreover, the obtained results demonstrate that the response of internal food prices for both consumers and producers to shocks in world food prices is asymmetric. On average, the pass-through effect is higher in the case of rising world food prices and lower during decreases in prices in global food markets. Over time, the pass-through effect exhibits considerable variability. On average, the effect is greater during sharp increases in world food prices and significant market volatility and lower during periods of slow changes in prices on global food markets.

A significant limitation of the results is the model excluding some important pricing factors, such as the industrial production index, the import and export price indices, the external trade volumes, the share of imports in consumption, and the market power of firms. This is primarily due to the availability and quality of such statistics at the regional level.

Further studies may seek to make more accurate estimates of the pass-through of world food prices to domestic food inflation after 2014 as new data enter the time series and import price indices are considered among other pricing factors.

Additionally, a separate avenue for further work could involve investigating the role of the Russian economy in shaping prices in global food commodity markets. It's possible that the substantial growth in the Russian agro-industrial complex partially shifted Russia from a price-taker position to a price-setter position. Accounting for these economic interrelationships potentially impacts the pass-through effect by secondary effects within the global economic system.

Value can also be created by a study of the structure of interregional relations and trade in the context of regional heterogeneity in the response of producer price indices to world food price shocks, provided that consumer prices are not marked by such heterogeneity. To address this task, efforts may focus on a mechanism in which price shocks at higher levels of production and distribution are more or less evenly distributed across Russian regions as they feed through to consumer food prices.

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Appendix A. Intensity of interregional trade relations in 2016 based on imports and exports data (thermal map)

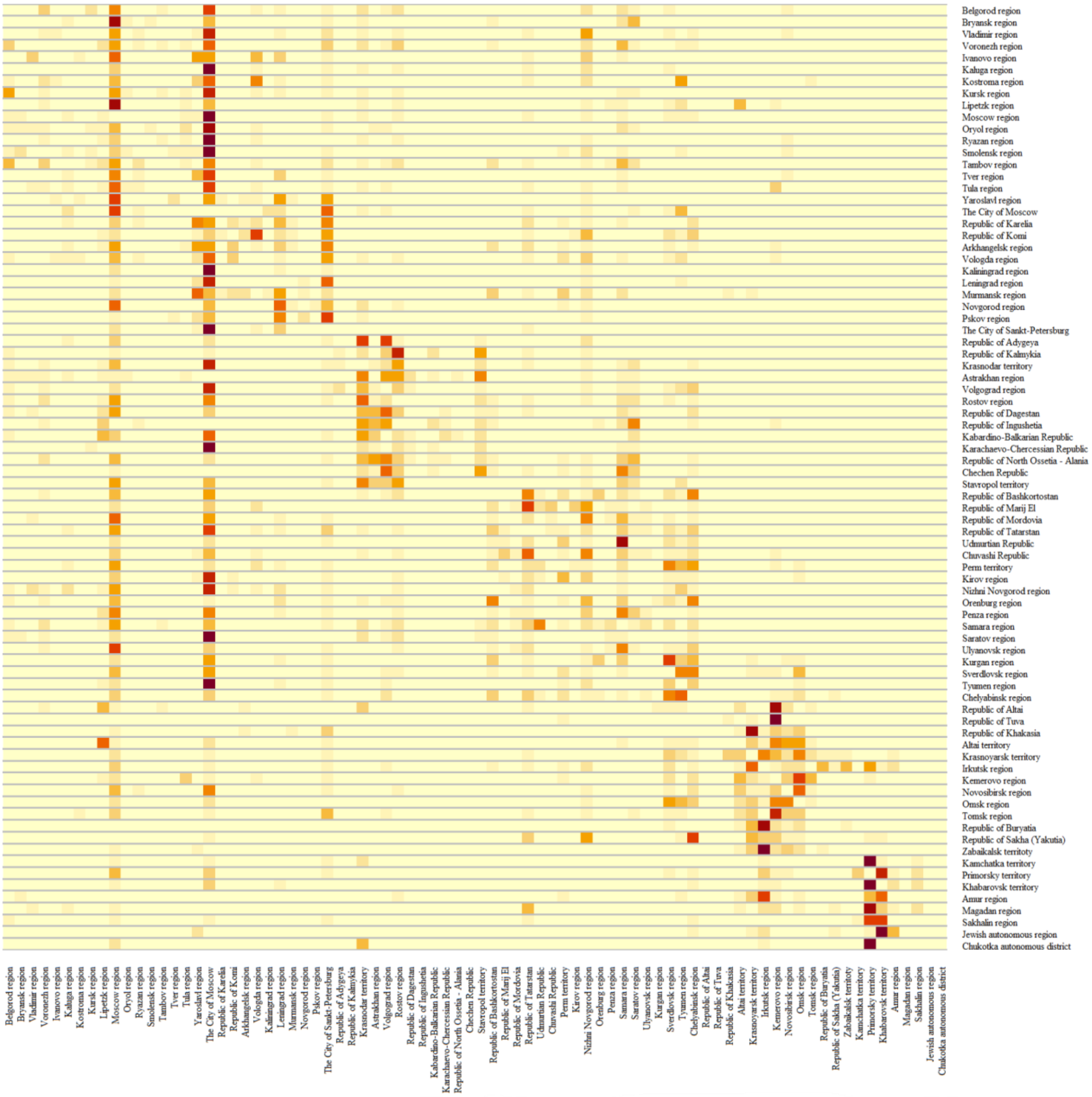

Figure A1. Intensity of interregional trade relations in 2016 (thermal map)

Note: Each cell stands for the regional share of trade turnover (exports and imports) in the columns of total trade of the regions by row, excluding trade within the region; the sum of shares in the rows is equal to one; these weights are used to calculate the spillover indicators; individual spillover indicators are based on the weights taking into account interregional trade.

Source: Rosstat, Author's own calculations.

Appendix B. Estimated pass-through effects in the base model and the aggregate weights of Russian regions

Table B-1.

Estimated pass-through effects in the base model and the aggregate weights of Russian regions

in percentage terms

Region	Pass-through for one year according to food CPI	CPI weights	Pass-through for one year according to food PPI	PPI weights
Belgorod Region	1.5 (0.1; 3.4)	1.03	2.8 (0.3; 6.4)	6.36
Bryansk Region	1 (-0.4; 2.9)	0.73	2 (-0.2; 4.2)	1.82
Vladimir Region	2 (0.1; 4.5)	0.86	2 (-0.5; 5)	1.8
Voronezh Region	1.8 (-0.1; 3.8)	1.31	5.1 (1.9; 9.2)	4.31
Ivanovo Region	1.3 (-0.5; 3.6)	0.65	2.2 (-0.4; 5.9)	0.2
Kaluga Region	1.7 (0; 4.1)	0.65	1.5 (-0.4; 4.3)	1.69
Kostroma Region	1.5 (0.1; 3.4)	0.41	1.9 (-0.5; 5.3)	0.2
Kursk Region	2.2 (0.4; 4.3)	0.66	3.8 (0.6; 8.2)	2.53
Lipetsk Region	1.4 (-0.2; 3.5)	0.71	1.3 (-1; 4.1)	2.64
Moscow Region	0.9 (-0.5; 2.5)	5.93	0.6 (-2.4; 2.9)	7.43
Orel Region	1.7 (0; 4)	0.39	3.3 (0.2; 6.9)	1.07
Ryazan Region	1.7 (-0.1; 4.1)	0.56	2.5 (0.7; 5)	0.94
Smolensk Region	1.3 (-0.3; 3.6)	0.65	2.4 (0; 5.2)	0.43
Tambov Region	2.3 (0.4; 4.6)	0.46	3.6 (0.1; 7.6)	2.11
Tver Region	1.4 (0; 3.4)	0.82	1.7 (-0.4; 4.4)	0.85
Tula Region	2.2 (0.4; 5)	1.04	3.4 (1.3; 6)	1.75
Yaroslavl Region	1.2 (-0.5; 2.9)	0.73	1.8 (-0.7; 5.3)	0.63
Moscow	1.2 (-0.1; 2.7)	13.97	2.2 (0.2; 4.4)	4.92
Republic of Karelia	1.5 (-0.1; 3.7)	0.41	2.6 (0.7; 5.7)	0.18
Republic of Komi	1.5 (0.2; 3.2)	0.57	0.1 (-2; 2.6)	0.14
Arkhangelsk Region	1.6 (0; 3.8)	0.82	1.1 (-0.5; 3.1)	0.15
Vologda Region	1.3 (-0.3; 3)	0.83	2.2 (0.3; 3.9)	0.76
Kaliningrad Region	1 (-0.7; 3.2)	0.65	0.7 (-1.3; 2.9)	2.32
Leningrad Region	1.4 (-0.1; 3.4)	1.33	1.7 (-0.9; 4.8)	2.37
Murmansk Region	1.2 (-0.3; 3.2)	0.62	0.7 (-1.5; 3.1)	1.15
Novgorod Region	1 (-0.4; 2.7)	0.37	1.1 (-1.1; 4.2)	0.5
Pskov Region	1.8 (0.2; 4)	0.34	2.1 (0; 4.5)	1.01
St Petersburg	1.8 (0; 4.1)	4.69	1.2 (-0.7; 3)	1.92
Republic of Adygea	1.3 (-0.5; 3)	0.26	2 (0; 4.3)	0.27
Republic of Kalmykia	1.3 (-0.4; 3.4)	0.15	1.8 (-0.4; 4.3)	0.03
Krasnodar Territory	1.4 (-0.4; 3.1)	4.01	2.5 (0.6; 4.3)	6.15
Astrakhan Region	1.5 (-0.2; 3.2)	0.69	2 (-0.7; 4.5)	0.12
Volgograd Region	2.5 (0.2; 4.5)	1.48	2.2 (-0.2; 4.7)	1.42

Continuation of Table B-1.

Rostov Region	1.8 (-0.1; 4.1)	2.74	1.8 (-0.2; 3.8)	2.78
Republic of Dagestan	1.9 (-0.4; 3.8)	2.18	0 (-1.5; 1.4)	0.17
Republic of Ingushetia	2.7 (0.7; 4.9)	0.22	0.3 (-4.3; 4.3)	0.03
Kabardino-Balkar Republic	2.9 (-0.8; 7)	0.43	-1.5 (-4.4; 0.8)	0.21
Karachay-Cherkess Republic	1.3 (-0.4; 3.1)	0.2	1.8 (-1.8; 5.7)	0.11
Republic of North Ossetia-Alania	1.8 (-0.1; 3.7)	0.36	-0.1 (-2.4; 1.9)	0.06
Chechen Republic	1.3 (-1.2; 5.2)	0.78	0.3 (-1.7; 3.5)	0.06
Stavropol Territory	2 (0.2; 3.7)	1.31	0.5 (-1.1; 2.5)	2.23
Republic of Bashkortostan	1.6 (0.2; 3.5)	2.64	2.7 (0.4; 6.2)	1.62
Mari El Republic	1.7 (0.3; 3.7)	0.31	1 (-1.4; 4.5)	0.87
Republic of Mordovia	1.3 (-0.3; 3.3)	0.42	2.3 (-0.2; 5.9)	1.4
Republic of Tatarstan	1.7 (0.2; 3.4)	2.43	1.6 (-0.5; 4.4)	2.86
Udmurt Republic	2 (0.4; 4.3)	0.91	0.2 (-2.3; 3.6)	0.89
Chuvash Republic	1.4 (-0.2; 3.4)	0.54	1.1 (-0.5; 3.4)	0.44
Perm Territory	1.8 (0.3; 3.6)	1.56	1.9 (-0.1; 4.4)	0.87
Kirov Region	1.5 (0.1; 3.1)	0.74	1.5 (-0.1; 3.6)	0.62
Nizhny Novgorod Region	2.3 (0.4; 4.5)	2.01	2.5 (0.7; 5.1)	1.5
Orenburg Region	1.9 (0.4; 3.7)	1.02	2.8 (0.6; 5.4)	0.85
Penza Region	1.8 (0.2; 3.8)	0.74	2.5 (0.1; 5.2)	1.71
Samara Region	1 (-0.5; 2.8)	1.98	2.4 (0.8; 5)	1.34
Saratov Region	1.4 (-0.1; 3.4)	1.38	3.3 (1.3; 5.7)	1.63
Ulyanovsk Region	1.5 (0.2; 3.3)	0.67	1.4 (0.2; 3)	0.64
Kurgan Region	1.6 (0.1; 3.5)	0.42	3.6 (0.8; 8.2)	0.34
Sverdlovsk Region	1.5 (0.1; 3.3)	2.93	1.1 (-0.5; 3.4)	1.51
Tyumen Region	1.2 (-0.3; 3)	2.72	1.2 (-0.4; 3.2)	0.84
Chelyabinsk Region	1.6 (0.2; 3.2)	1.99	1.2 (-0.8; 4)	1.93
Altai Republic	2 (0.3; 3.9)	0.09	1.9 (-0.4; 3.8)	0.03
Republic of Tyva	1.2 (-0.3; 2.6)	0.13	0.9 (-1.1; 3)	0
Republic of Khakassia	1.6 (0; 3.3)	0.3	0.6 (-1.5; 2.8)	0.09
Altai Territory	1.8 (0.1; 4)	1.16	3.7 (1.2; 7.9)	2.14
Krasnoyarsk Territory	1.5 (0.1; 3.7)	1.93	1.3 (-0.1; 3.1)	1.01
Irkutsk Region	1.4 (0; 3.7)	1.39	1.7 (0.1; 4.5)	0.64
Kemerovo Region	1.8 (0.2; 3.5)	1.42	2.3 (0.6; 4.2)	0.7
Novosibirsk Region	1.5 (0.1; 3.3)	1.76	1.7 (0.5; 3.4)	1.8
Omsk Region	1.7 (0.4; 3.3)	1.06	1.5 (0; 3.5)	1.24
Tomsk Region	1.6 (0.2; 3.5)	0.67	1.3 (-0.4; 4)	0.56
Republic of Buryatia	1.6 (0.4; 3.5)	0.48	1 (-0.5; 3.2)	0.13
Republic of Sakha (Yakutia)	0.6 (-0.4; 2.1)	0.84	0.5 (-1; 2.2)	0.1
Trans-Baikal Territory	1 (-0.1; 2.6)	0.65	1.4 (-0.2; 3.5)	0.05
Kamchatka Territory	0.3 (-1.6; 2.4)	0.35	-0.9 (-3.5; 1.6)	1.22
Primorye Territory	1.1 (-0.1; 2.8)	1.56	0.7 (-0.6; 2.5)	0.59

Continuation of Table B-1.

Khabarovsk Territory	0.8 (-0.3; 2.4)	0.96	-0.4 (-1.7; 1.5)	0.42
Amur Region	1.4 (0; 4)	0.42	0.9 (-0.8; 3.5)	0.47
Magadan Region	0.5 (-0.8; 2.4)	0.15	-1.4 (-4.6; 2.2)	0.02
Sakhalin Region	0.9 (-0.3; 2.6)	0.5	1.4 (-1.6; 5)	0.56
Jewish Autonomous Region	1.6 (0.1; 3.9)	0.09	0.6 (-3; 4.9)	0.01
Chukotka Autonomous Area	-1.5 (-3.3; 0.2)	0.06	1.2 (-2.3; 5.8)	0.01

Note: 90% confidence intervals are in brackets.

Source: Author’s own calculations, food CPI-based weights are calculated by the Volga-Vyatka Main Branch of the Bank of Russia based on public population data and Rosstat’s survey of household budgets; the PPI weights are Rosstat data.

Appendix C. Structure and values of VARX coefficients in the base model for Russia as a whole

Table C-1.

Structure and values of VARX coefficients in the base model for Russia as a whole

Dependent variables	Endogenous variables						
	fao_prod_wpi(-1)	neer(-1)	fiscal_rule_fxi(-1)	miacr(-1)	prod_ppi(-1)	prod_rozn(-1)	prod_cpi(-1)
fao_prod_wpi	0.3***	-0.0143	0.0028	-0.1018	0.2488	0.0545	0.0289
neer	-0.0686	0.3167***	-0.0012	0.0535	-0.2331	0.0931	0.7036**
fiscal_rule_fxi	2.1828	0.2717	1.1692***	1.6155	9.1529	-3.356	-2.9253
miacr	0.0108	-0.0626*	0.0015	-0.0151	0.2136	0.0168	-0.1335
prod_ppi	0.0517***	0.0255	7e-04	0.0335	0.6927***	0.0518	0.1932**
prod_rozn	-0.0159	-0.0207	-0.0011	0.0486	0.1085	-0.0197	-0.2026
prod_cpi	0.0145	0.0154	7e-04	-0.0136	0.1023	0.0969**	0.6085***
Dependent variables	**Endogenous variables**						
	fao_prod_wpi(-2)	neer(-2)	fiscal_rule_fxi(-2)	miacr(-2)	prod_ppi(-2)	prod_rozn(-2)	prod_cpi(-2)
fao_prod_wpi	-0.0191	-0.0621	-0.0038	-0.2331**	5e-04	-0.0309	-0.2341
neer	0.0829	-0.1698**	-1e-04	-0.0447	0.3428	-0.029	-0.371
fiscal_rule_fxi	-2.4164	-0.9242	-0.2286***	-0.0834	-17.335**	2.5681	8.1399
miacr	0.0198	-0.0221	-0.0017	-0.1077*	-0.0958	-7e-04	0.1473
prod_ppi	0.0087	-0.0052	-0.0011	-0.0198	-0.0882	-0.0146	-0.1269*
prod_rozn	0.0242	-0.0112	0.001	-0.0713	-0.1331	0.1639**	0.2314*
prod_cpi	0.0012	0.0075	-7e-04	0.0183	0.1416*	0.0174	-0.2258***
Dependent variables	**Constant**	**Exogenous variables**					
	const	tpi(0)	tpi(-1)	trade_barriers_proxy(0)	trade_barriers_proxy(-1)	brent(0)	brent(-1)
fao_prod_wpi	0.2911	0.0054	-0.0654	-2.8021	4.9798	8.1356***	-1.2465
neer	0.1304	0.0631	-0.0682	2.5473	0.9355	-14.248***	-1.5993
fiscal_rule_fxi	0.1727	2.7107	1.0095	52.3051	154.5865**	119.4913***	48.7782
miacr	-0.0754	0.1115**	-0.0489	-0.6572	0.5867	-1.2899	-1.5223*
prod_ppi	0.1116*	0.0107	-0.0041	0.0255	-0.0312	-0.197	-0.0601
prod_rozn	0.2274**	-0.0369	0.077**	-0.4255	-1.2157	-1.0245	0.2069
prod_cpi	0.2202***	0.0308	-0.0088	-0.9054	-0.0762	-0.3571	-0.2788
Dependent variables	**Exogenous variables**		**Outliers**				
	grains_sunoil(0)	grains_sunoil(-1)	10–2007; from 09–2008 to 03–2009; from 12–2014 to 06–2015; from 04–2020 to 06–2020				
fao_prod_wpi	0.2085***	-0.0036					
neer	0.0607	-0.0443					
fiscal_rule_fxi	-3.2806**	1.9014*					
miacr	0.0823**	-0.0466*					
prod_ppi	0.1039***	-0.0242**					
prod_rozn	-0.0351	0.0185					
prod_cpi	0.0256	-0.0322***					

Note: * $p < 0.1$; * * $p < 0.05$; * * * $p < 0.01$: the brackets are used to indicate the p-value of equation coefficients; other models for Russia as a whole have the same structure as the base model except for the asymmetry model (which includes the formula 1 design) and the VECMX model.

Source: Author's own calculations.

Appendix D. Structure and values of VARX coefficients in the base model by region

Table D-1.

Structure and values of VARX coefficients in the base model in the Republic of Tatarstan

Dependent variables	**Endogenous variables**						
	fao_prod_wpi(-1)	neer(-1)	fiscal_rule_fxi(-1)	miacr(-1)	prod_ppi(-1)	prod_ppi_spillover(-1)	prod_cpi_spillover(-1)
fao_prod_wpi	0.2896***	0.0027	0.0033	-0.1141	0.2743*	0.2121	0.6938*
neer	-0.0456	0.3172***	-0.0018	0.0314	0.1571	-0.5907	0.8012*
fiscal_rule_fxi	1.9789	0.2485	1.1537***	2.3592	-8.2183**	10.923	-3.6868
miacr	0.0479	-0.0403	0	0.0182	0.013	0.4779***	-0.283
prod_ppi	0.0143	0.0447	6e-04	0.0873	0.3526***	0.232	0.2402
prod_ppi_spillover	0.0198	0.0018	-9e-04	0.0442	0.1336***	0.2458***	0.3233***
prod_cpi_spillover	0.0198	0.0186	2e-04	-0.0166	0.0853*	0.0403	0.5663***
prod_rozn_spillover	-0.0111	0.0067	-0.0014	0.0686	0.0662	-0.161	-0.4666
prod_cpi	0.0337	0.0332	8e-04	-0.0063	0.17**	0.0376	0.6959***

Dependent variables	**Endogenous variables**						
	prod_rozn_spillover(-1)	prod_cpi(-1)	fao_prod_wpi(-2)	neer(-2)	fiscal_rule_fxi(-2)	miacr(-2)	prod_ppi(-2)
fao_prod_wpi	-0.0299	-0.7347***	0.005	-0.0505	-0.0044	-0.2466**	0.1206
neer	0.121	-0.0561	0.0696	-0.1739**	5e-04	-0.0088	-0.2256
fiscal_rule_fxi	-3.1917	4.1255	-1.802	-0.6464	-0.2245***	0.3667	5.6437
miacr	-0.0627	0.0847	0.0076	-0.018	-2e-04	-0.0986	-0.2824***
prod_ppi	0.0069	-0.0633	0.0097	0.001	-0.0015	0.0186	0.0195
prod_ppi_spillover	0.0353	-0.0513	0.0269	0.0023	7e-04	-0.0442	-0.0109
prod_cpi_spillover	0.064**	-0.0239	0.0076	0.0149	-2e-04	0.007	-0.0117
prod_rozn_spillover	-0.1362*	0.1626	0.0021	0.0036	-4e-04	-0.0704	-0.0311
prod_cpi	0.0534	-0.1443	0.027	0.0532*	-7e-04	0.0045	-0.0535

Dependent variables	**Endogenous variables**				**Exogenous variables**		
	prod_ppi_spillover(-2)	prod_cpi_spillover(-2)	prod_rozn_spillover(-2)	prod_cpi(-2)	const	tpi_spillover(0)	tpi_spillover(-1)
fao_prod_wpi	-0.3985	0.4969	-0.103	-0.5869**	0.3475	-0.0054	-0.1678*
neer	0.475	-0.3131	-0.0267	0.1631	0.0821	0.0624	-0.06
fiscal_rule_fxi	-12.697*	2.6482	1.9789	-1.5182	5.7709	2.8803	-2.5873
miacr	0.0306	-0.1518	0.0346	0.3243**	-0.0654	0.2259***	-0.1059**
prod_ppi	-0.0139	0.0253	-0.0225	-0.1248	0.2384*	0.0738	-0.1179**
prod_ppi_spillover	0.008	0.0396	-0.0099	-0.1207*	0.0834	0.0414	0.0462*
prod_cpi_spillover	0.1728**	-0.1842	-0.013	-0.0333	0.1939***	0.0459	0.0208
prod_rozn_spillover	0.0372	0.2104	-0.0582	0.0271	0.5346***	0.0331	0.098
prod_cpi	0.0956	-0.1115	-0.0491	-0.1372	0.1295	0.0686	0.0274

Dependent variables	**Exogenous variables**						
	trade_barriers_proxy(0)	trade_barriers_proxy(-1)	brent(0)	brent(-1)	grains_sunoil(0)	grains_sunoil(-1)	
fao_prod_wpi	-3.1201	4.0033	8.027***	-0.2732	0.1822**	0.0113	
neer	3.8968	0.9017	-14.5522***	-1.7698	0.0725	-0.0221	
fiscal_rule_fxi	11.1596	157.8521**	118.122***	42.6828	-2.8176	1.5223	
miacr	-0.639	0.2656	-1.4828	-1.7653**	0.0403	-0.0471*	
prod_ppi	2.443	0.3302	-1.8023**	1.3038*	0.131***	-0.0346	
prod_ppi_spillover	-0.6758	0.4789	-0.1252	0.0179	0.1189***	-0.0034	
prod_cpi_spillover	-0.0639	-0.2146	-0.4771	-0.065	0.03	-0.0416***	
prod_rozn_spillover	1.8192	-2.0193	-1.1047	2.1538*	-0.0282	0.0214	
prod_cpi	0.4384	-0.8048	0.1183	0.159	-0.0027	-0.0344*	
Dependent variables	**Outliers**						
fao_prod_wpi	10–2007; from 09–2008 to 03–2009; from 12–2014 to 06–2015; from 04–2020 to 06–2020						
neer							
fiscal_rule_fxi							
miacr							
prod_ppi							
prod_ppi_spillover							
prod_cpi_spillover							
prod_rozn_spillover							
prod_cpi							

Note: * p < 0.1; ** p < 0.05; *** p < 0.01: the brackets are used to indicate the p-value of equation coefficients; other models for regions have the same structure as the base model for Tatarstan, except for the asymmetry model (which includes the formula 1 design).

Source: Author’s own calculations.