Asymmetry and hysteresis in the Russian gasoline market: the rationale for green energy exports

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Asymmetry and hysteresis in the Russian gasoline market: the rationale for green energy exports

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Abstract

Using monthly data of 79 Russian regions from 2003 to 2017, we study the long-run relationship of the retail gasoline prices with the crude oil price and the nominal exchange rate. We find that models that were successfully applied to deal with asymmetries in other countries are not suitable for Russia without taking structural breaks into account. Once breaks are allowed, we find that there is no asymmetry in the long-run elasticities between the gasoline prices and the crude oil price, and no significant hysteresis. However, there is an asymmetric relation between the gasoline price and the exchange rate that has decreased over time. These results also hold after several robustness checks. The evidence reported in this work shows that the effects of the exchange rate on gasoline prices are much more difficult to control than the oil price, and they require a larger set of policy measures: the recent development of a plan to decrease the importance of hydrocarbons exports by producing clean hydrogen using electrolysis and pyrolysis and the potential future export of electricity generated using nuclear power and onshore wind farms may help to diversify the local economy and to shield it from new sanctions.

Keywords: Gasoline market, Russia, Asymmetric cointegration, Panel cointegration, Hysteresis, Structural breaks.

JEL classification: C32, C33, C54, Q28, Q38, Q43, Q48, L71.

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1 Introduction

Russia enjoys one of the cheapest gasoline prices in the world, but the average citizen spends a relatively large portion of his income on fuel in comparison with the expenses sustained in countries with higher fuel prices (Randall (2018)). Such misbalance can be attributed to different factors, such as the low purchasing power of wages in Russia, active use of vehicles, preferences for big car models to deal with poor road quality and climate specifics. Moreover, the problem becomes even more acute when the constantly growing fuel prices are considered. Even when the crude oil price fell, there were no considerable changes in petrol prices. This pricing phenomenon is known in the literature as the *rockets and feathers hypothesis* (Bacon (1991)): the gas price grows faster after an increase of the crude oil price than it falls after a decrease of crude oil prices. Despite heated discussions in the Russian media, there is still no comprehensive empirical analysis of the gasoline pricing asymmetry for the Russian market. The aim of this paper is to check the existence of asymmetric responses of Russian gasoline price changes to changes in crude oil prices and in the Dollar/Ruble exchange rate, taking into account the experience of other countries and the specific features of the Russian market. This research topic is both of great social and practical importance because pricing asymmetry can highlight market imperfections, such as oligopolies, information asymmetry, and sunk costs. Scrutinizing the pricing mechanism can reveal the underlying problems, and necessary measures to improve the regulation can be taken.

We employ two approaches to examine the Russian gasoline market: the first approach consists of the recently proposed nonlinear model by Shin, Yu, and Greenwood-Nimmo (2014). This approach has several characteristics which are useful when dealing with gasoline prices: it separately includes positive and negative cumulative sums of the control variables to capture asymmetry, and it can also accommodate the presence of an inaction band where price setters do not modify the markup to offset swings in the explanatory variables (that is, *hysteresis in prices*, see Fedoseeva and Werner (2016)). Moreover, this model allow the computation of long-run elasticities, which were found to be significant in several previous studies with gasoline prices, see Bagnai and Ospina (2015) and references therein. This approach can disantagle the effects on gasoline prices of the crude oil price and of the local exchange rate. In this regard, the exchange rate is assumed to have an indirect effect on gasoline prices through other oil products, the income of refining companies, the correlation with the economic climate and government budgeting. The second approach consists of the panel cointegration model with structural breaks proposed by Banerjee and Carrion-i-Silvestre (2015).

In this paper, the monthly gasoline prices in 79 Russian regions are considered. The analysis is

conducted at the regional level because of the strong regional heterogeneity. The empirical analysis shows that, despite a strong long-run cointegration relation between the gasoline prices, the crude oil price and the exchange rate in each region, the nonlinear model by Shin, Yu, and Greenwood-Nimmo (2014) fails to provide robust estimations: the models' parameters are unstable, while their residuals are strongly heteroskedastic. A panel version of this model is also considered, but it presents the same misspecification problems. Interestingly, all considered regional control variables (state population, car density, road quality, income level) are found to be insignificant across all alternative model specifications. The models allowing for structural breaks show better results, instead: the panel cointegration model with breaks by Banerjee and Carrion-i-Silvestre (2015) shows that, for almost all regions, a first break took place in 2007, while a second in 2010. This model improves considerably the data fit and suggests that the price asymmetry is present at the regional level but it has changed over time. The Wald tests fail to reject the null hypothesis of symmetric oil price effects on the gasoline price, but the null hypothesis is strongly rejected for the exchange rate. However, in this latter case, the degree of asymmetry has decreased since 2007, which can be interpreted as a signal of a more competitive gasoline market in Russia. A set of robustness checks is finally computed to verify that our results also hold with different model specifications, additional control variables and changes in the taxation regimes. In general, the empirical analysis indicates that the models which work well for gasoline pricing in Italy, the UK and in other foreign markets, cannot be used to explain the gasoline price dynamics in the Russian market and structural breaks must also be taken into account.
The paper is organized as follows: Section 2 provides a survey of the literature dealing with gasoline prices and describe the main aspects of the Russian gasoline market. The econometric methodologies used in this study are presented in Section 3, while the estimation results of the empirical analysis are discussed in Section 4. Robustness checks are reported in Section 5, while the main conclusions and policy implications are presented in Section 6.

2 Literature review and main features of the Russian gasoline market

2.1 Literature review

Bacon (1991) was the first to introduce the "rockets and feathers hypothesis" and to estimate this asymmetry effect for biweekly net-of-tax gasoline prices for the UK. During the last thirty years, this market asymmetry was estimated for the USA, the UK, Spain, Italy, France, and many other countries based on net-of-tax and gross-of-tax prices, see the surveys by Frey and Manera (2007), Perdiguero-Garcia (2013), and Fosten and Cook (2019) for more details.

This asymmetry was found to be present in almost all markets, but its size and sign vary considerably across studies. Grasso and Manera (2007) advanced several reasons to explain this variability: first, several studies omitted the exchange rate in their models, thus assuming that the elasticities of gasoline prices to crude oil prices and to the exchange rate are equal both in the long-run and in the short- run. This is rather unrealistic in practice, as Campa and Goldberg (2005), Delatte and Lopez-Villavicencio (2012) and Bagnai and Ospina (2015) showed. For this reason, both variables are used in this paper. Secondly, some studies do not consider long-run asymmetries, but long- and short-run asymmetries can be different, see e.g. Atil, Lahiani, and Nguyen (2014). Finally, the existence of sunk costs can cause hysteresis in pricing, that is prices will depend not only on the crude oil price and the exchange rate, but also on the size of the shocks to these variables (Bagnai and Ospina (2015)): in this case, it is possible to have a central "inaction price band," where retailers translate into the final gasoline price all the small changes in the explanatory variables, and an upper and lower price regimes where retailers modify the markup to compensate for the changes in the explanatory variables, thus determining smaller and asymmetric long-run elasticities. Neglecting this form of nonlinearity can lead to biased estimations, with underestimated coefficients for the outside regimes and overestimated coefficients for the central regime.

Recent theoretical studies provide additional insights into the causes of this price asymmetry. Lewis (2011) introduces a consumers search model, based on past observable information and costs for checking the gasoline price. More specifically, consumers develop their expectations about the price distribution based on a reference price given by the average price level from the previous period. In this case, if the oil price goes up putting upward pressure on gasoline prices, the consumers' expectations of the price distribution based on the previous period will be too low, and they will start searching more than they otherwise would: as a consequence, retailers' will get lower margins and the gasoline price dispersion will be lower. If the oil price goes down, the consumer will be less likely to look for lower prices because of the past experience. Therefore, the retailer's response to the oil price decrease will be slower than the reaction to an oil price increase and he/she will get higher profit margins. Moreover, the gasoline price dispersion will be much higher. The main novelty of this approach is the suggestion that consumers' imperfect knowledge of current price levels may significantly affect retail gasoline prices, and incorrect consumer expectations can lead to prices well above their full information competitive level.

2.2 Main features of the Russian gasoline market

The academic literature about the Russian gasoline market is very scanty and it is mostly based on the work by Balsevich and Podkolzina (2013), who examined the components of petrol prices in Russia. They show that the fuel pricing varies from one region to another and depends on the remoteness of the region from the central part of Russia, the degree of monopolization and the ratio of the number of gas stations to the region area. In general, Balsevich and Podkolzina (2013) characterize the Russian market as a vertical-integrated industry with a complex retail system, which makes the pricing process unobservable. Moreover, when the level of competition on the market decreases, the government averts prices growth thanks to the action of the largest companies in the industry.

In the financial professional literature, it is worth noting the article by Starinsky (2015), which collected the views and comments of several industry experts about the gasoline prices components and the reasons for its growth in Russia. They show that the oil price's share of retail gas price is about 7-10%, so that the petrol price in Russia is more sensitive to the exchange rate and to the world prices on oil products than to the crude oil price.

Finally, we remark that it is well known in the energy literature that both pre-tax and after-tax retail prices should be considered, because they may reveal rent-seeking behavior of oligopolistic companies, see Greenwood-Nimmo and Shin (2013) and references therein. Unfortunately, this kind of analysis cannot be made with Russia gasoline prices because only yearly pre-tax prices are available. Furthermore, the excise tax depends on the ecological class of the fuel, but all available retail statistics are classified by octane number, so it is difficult to compute after-tax gasoline prices without significant simplifications. We remark that the gasoline excise in Russia is a lump-sum tax which was changed only a couple of times during the time period considered in our empirical analysis. Therefore, the effects of gasoline excise on gasoline price dynamics may be lower in Russia compared to its effects in other countries. We will perform a robustness check in section 5 to verify this hypothesis.

3 Methodology

We present below the three approaches which were employed to model Russian gasoline prices. First, we describe the nonlinear auto-regressive distributed-lag (NARDL) model proposed by Shin, Yu, and Greenwood-Nimmo (2014), which allows for long-asymmetries, short-run asymmetries and hysteresis simultaneously. Secondly, the panel-NARDL model suggested by Apergis and Payne (2014) is introduced. Finally, the panel cointegration approach allowing for both structural breaks and cross-section dependence by Banerjee and Carrion-i-Silvestre (2015) is presented.

3.1 The NARDL model

The NARDL model by Shin, Yu, and Greenwood-Nimmo (2014) is based on the ARDL model by Pesaran, Shin, and Smith (2001) and the nonlinearity derives from the decomposition of the control variables in two partial sums, which correspond to the positive and negative changes of these variables. Given our dataset, we have the following nonlinear error correction model:

$$\Delta r_t = \rho\xi_{t-1} + \sum_{j=1}^{p-1}\gamma_j \Delta r_{t-j} + \sum_{j=1}^{q-1}(\pi_{1j}^{+}\Delta c_{t-j}^{+} + \pi_{1j}^{-}\Delta c_{t-j}^{-} + \pi_{2j}^{+}\Delta er_{t-j}^{+} + \pi_{2j}^{-}\Delta er_{t-j}^{-}) + \varepsilon_t \tag{1}$$

where r is the log of the gasoline price in rubles, c is the log of the crude oil price in USD, er is the log of the USD/RUB exchange rate, ρ is the feedback coefficient, $\pi_{ij}^{+/-}$ are the impact elasticities of the gasoline price to the oil price and the exchange rate for $i = 1$ and $i = 2$, respectively, while ξ_t is the cointegration residual:

$$\xi_t = r_t - \beta_1^{+} c_t^{+} - \beta_1^{-} c_t^{-} - \beta_2^{+} er_t^{+} - \beta_2^{-} er_t^{-}, \tag{2}$$

where $\beta_i^{+/-}$ are long-run elasticities, $x_t^{+} = \sum_{j=1}^{t}\max(\Delta x_j, 0)$ and $x_t^{-} = \sum_{j=1}^{t}\min(\Delta x_j, 0)$, such that $x_t = x_t^{+} + x_t^{-} + x_0$. The feedback coefficient ρ is expected to be negative to allow for a pricing correction mechanism where the gasoline price tends to the equilibrium level. To estimate the long- and short-run asymmetries simultaneously, the following unrestricted ARDL parameterization is used:

$$\Delta r_t = \rho r_{t-1} + \theta_1^{+} c_{t-1}^{+} + \theta_1^{-} c_{t-1}^{-} + \theta_2^{+} er_{t-1}^{+} + \theta_2^{-} er_{t-1}^{-} + \sum_{j=1}^{p-1}\gamma_j \Delta r_{t-j} + \\ + \sum_{j=1}^{q-1}(\pi_{1j}^{+}\Delta c_{t-j}^{+} + \pi_{1j}^{-}\Delta c_{t-j}^{-} + \pi_{2j}^{+}\Delta er_{t-j}^{+} + \pi_{2j}^{-}\Delta er_{t-j}^{-}) + \varepsilon_t \tag{3}$$

The asymmetric long-run elasticities can be found from (2) and (3) as follows:

$$\beta_i^{+} = -\frac{\theta_i^{+}}{\rho}, \quad \beta_i^{-} = -\frac{\theta_i^{-}}{\rho}.$$

Fedoseeva and Werner (2016) proposed an extension of the previous model, where the explanatory variables are splitted into three regimes to better reflect the hysteresis in prices. Therefore, equation

(3) is transformed into:

$$\Delta r_t = \rho r_{t-1} + \theta_1^+ c_{t-1}^+ + \theta_1^0 c_{t-1}^0 + \theta_1^- c_{t-1}^- + \theta_2^+ er_{t-1}^+ + \theta_2^0 er_{t-1}^0 + \theta_2^- er_{t-1}^- + \sum_{j=1}^{p-1} \gamma_j \Delta r_{t-j} + \\ + \sum_{j=1}^{q-1} \left(\pi_{1j}^+ \Delta c_{t-j}^+ + \pi_{1j}^0 \Delta c_{t-j}^0 + \pi_{1j}^- \Delta c_{t-j}^- + \pi_{2j}^+ \Delta er_{t-j}^+ + \pi_{2j}^0 \Delta er_{t-j}^0 + \pi_{2j}^- \Delta er_{t-j}^-\right) + \varepsilon_t \quad (4)$$

where the partial sums are defined as,

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j I(\Delta x_j \geq \Delta x_j^{upper}), \quad x_t^0 = \sum_{j=1}^{t} \Delta x_j I(\Delta x_j^{lower} < \Delta x_j < \Delta x_j^{upper}),$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j I(\Delta x_j \leq \Delta x_j^{lower}).$$

where $I(\cdot)$ is the indicator function, while Δx_j^{lower} and Δx_j^{upper} are the upper and lower thresholds of the central inaction band. The main issue of the three regimes NARDL model is how to select the two thresholds separating the regimes. In this study, we employ the data-based method proposed by Bagnai and Ospina (2015), which selects a symmetric quantile interval from $q\%$ to $(100-q)\%$ that minimises the sum of squared residuals of the model.

Once the model estimates are obtained, the bounds-testing procedure by Pesaran, Shin, and Smith (2001) and Shin, Yu, and Greenwood-Nimmo (2014) is used to test for the existence of a long-run asymmetric relation among the variables, and to examine the null hypotheses of long-run and short-run symmetry.

3.2 The Panel-NARDL model

The temporal dimension of our dataset of Russian gasoline prices is smaller compared to past studies using the NARDL model and it may adversely impact the quality of the model estimates. Instead, we have a very large cross-section at our disposal, including 79 Russian regions. Given this background, we also employ the panel-NARDL model suggested by Apergis and Payne (2014):

$$\Delta r_{it} = \alpha_i + \delta_i t + \rho r_{it-1} + \theta_1^+ c_{it-1}^+ + \theta_1^- c_{it-1}^- + \theta_2^+ er_{it-1}^+ + \theta_2^- er_{it-1}^- + \\ + \sum_{j=1}^{p-1} \gamma_j \Delta r_{it-j} + \sum_{j=1}^{q-1} (\pi_{1j}^+ \Delta c_{it-j}^+ + \pi_{1j}^- \Delta c_{it-j}^- + \pi_{2j}^+ \Delta er_{it-j}^+ + \pi_{2j}^- \Delta er_{it-j}^- + \varepsilon_{it}$$

with the following partial sums,

$$x_{it}^{+} = \sum_{j=1}^{t} \Delta x_{ij} I(\Delta x_{ij} \geq 0), \quad x_{it}^{-} = \sum_{j=1}^{t} \Delta x_{ij} I(\Delta x_{ij} \leq 0),$$

where $i = 1, \ldots, N$ and N is the number of regions. We modified this model to allow for hysteresis in prices:

$$\Delta r_{it} = \alpha_i + \delta_i t + \rho r_{it-1} + \theta_1^{+} c_{it-1}^{+} + \theta_1^{0} c_{it-1}^{0} + \theta_1^{-} c_{it-1}^{-} + \theta_2^{+} er_{it-1}^{+} + \theta_2^{0} er_{it-1}^{0} + \theta_2^{-} er_{it-1}^{-} + \\ + \sum_{j=1}^{p-1} \gamma_j \Delta r_{it-j} + \sum_{j=1}^{q-1} (\pi_{1j}^{+} \Delta c_{it-j}^{+} + \pi_{1j}^{-} \Delta c_{it-j}^{-} + \pi_{1j}^{0} \Delta c_{it-j}^{0} + \\ + \pi_{2j}^{+} \Delta er_{it-j}^{+} + \pi_{2j}^{-} \Delta er_{it-j}^{-} + \pi_{2j}^{0} \Delta er_{it-j}^{0}) + \varepsilon_i t \quad (5)$$

where:

$$x_{it}^{+} = \sum_{j=1}^{t} \Delta x_{ij} I(\Delta x_{ij} \geq \Delta x_{ij}^{upper}), \quad x_{it}^{-} = \sum_{j=1}^{t} \Delta x_{ij} I(\Delta x_{ij} \leq \Delta x_{ij}^{lower}),$$

$$x_{it}^{0} = \sum_{j=1}^{t} \Delta x_{ij} I(\Delta x_{ij}^{lower} < \Delta x_{ij} < \Delta x_{ij}^{upper}).$$

Finally, the bounds-testing procedure by Pesaran, Shin, and Smith (2001) and Shin, Yu, and Greenwood-Nimmo (2014) is again used to test for a long-run asymmetric relation among the variables, and to test the null hypotheses of long-run and short-run symmetry.

3.3 Panel cointegration with breaks

It is well known that panel data can increase the power of unit root and cointegration tests, see e.g. Baltagi (2008). This is particularly important in our case because long time series of retail gasoline prices for Russian regions are not available. Moreover, many Russian regions share common dynamics, so that cross-section dependence should be considered. Furthermore, several changes in the Russian legislation affecting gasoline pricing and the crises in 2008 in 2014 can have determined significant structural breaks. These are the reasons why we decided to use the panel approach and testing algorithm for large panel data proposed by Banerjee and Carrion-i-Silvestre (2015). This approach allows tackling both the problem of cross-sectional dependence, which can negatively affect the power of pooled unit root tests, and multiple heterogeneous breaks which can take place independently in different periods of time for various regions.

Let $Y_{it} = (r_{it}, x'_{it})'$ be an $m \times 1$ vector of non-stationary process with I(1) elements $x_{it} = (c^-_{it}, c^+_{it}, er^-_{it}, er^+_{it})'$ defined in (1), while F_t are unobservable common factors for regions. The data-generated process (DGP) is given by following system of equations:

$$y_{it} = D_{it} + x'_{it}\delta_{it} + u_{it} \tag{6}$$

$$u_{it} = F'_t \pi_i + e_{it} \tag{7}$$

$$(1 - L)F_t = C(L)w_t \tag{8}$$

$$(1 - \rho_i L)e_{it} = H_i(L)\varepsilon_{it} \tag{9}$$

$$x_{it} = \kappa_i + x_{it-1} + G'_t \varsigma_i + \Xi_i(L)v_{it} \tag{10}$$

$$G_t = \Gamma(L)w_t, \tag{11}$$

where $i = 1, \ldots, N$, $t = 1, \ldots, T$, $C(L) = \sum_{j=0}^{\infty} C_j L^j$, $H_i(L) = \sum_{j=0}^{\infty} h_j L^j$, $\Xi_i(L) = \sum_{j=0}^{\infty} \Xi_{it} L^j$, $\Gamma(L) = \sum_{j=0}^{\infty} \Gamma_j L^j$, and ε_{it}, w_{it}, ς_{it} are i.i.d. shocks with zero mean and finite variance. The deterministic term is given D_{it} by:

$$D_{it} = \mu_i + \beta_i t + \sum_{j=1}^{m_i} \theta_{ij} DU_{ijt} + \sum_{j=1}^{m_i} \gamma_{ij} DT_{ijt},$$

where $DU_{ijt} = 1$ for $t > T^b_{ij}$ and 0 otherwise, $DU_{ijt} = (1 - T^b_{ij})$ for $t > T^b_{ij}$ and 0 otherwise, where $T^b_{ij} = \lambda^b_{ij} T$ is a j^{th} break in i^{th} region, with $j = 1, \ldots, m_i$. $\lambda^b_{ij} \in \Lambda$, Λ is a close subset of $(0, 1)$. Because (6) is the cointegration equation, the coefficients δ_{it} must be consistent on each stable period of time.

The methodology proposed by Banerjee and Carrion-i-Silvestre (2015) does not introduce any particular restriction on the number of breaks in the region and on the equality of the dates for the breaks of the deterministic component and the cointegration vector. Banerjee and Carrion-i-Silvestre (2015) suggest 6 possible models specifications, which can be used for different types of structural breaks estimation. For simplicity and due to the size of our dataset, we considered the most general case with potential changes in the level, trend and in the cointegrating vector. Differently from other approaches, Banerjee and Carrion-i-Silvestre (2015) allows for some weak serial correlation in $(1 - \rho_i L)e_{it}$ and weak cross-section correlation.

The system (6 – 11) can be rewritten in first differences,

$$\Delta y_{it} = \Delta D_{it} + \Delta X'_{it}\delta_i + \Delta F'_t \pi_i + \Delta e_{it}, \tag{12}$$

where $\Delta X_i = [\Delta x_i, (\Delta x_i \Lambda DU_{i,1}), \ldots, (\Delta x_i \Lambda DU_{i,n_i})]$, Λ denotes the element-by-element product, and $\delta_i = (\delta'_{i,0}, \delta'_{i,1}, \ldots, \delta'_{i,n_i})$. To deal with cross-sectional dependence, Banerjee and Carrion-i-Silvestre (2015) take the orthogonal projection with respect to the control variables. In other words, all equation components are multiplied by the projected matrix $M_i = I - P_i^{\Delta x^d} = I - \Delta x_i^d (\Delta x_i^{d\prime} \Delta x_i^d)^{-1} \Delta x_i^{d\prime}$ to bring (12) to a standard common factor representation. Therefore, the final equation looks like:

$$M_i^{\Delta x_i^d} y_{it} = M_i^{\Delta x_i^d} \Delta F_t \pi_i + M_i^{\Delta x_i^d} \Delta e_{it} - P_i^{\Delta x_i^d} \Delta F_t \pi_i, \tag{13}$$

$$y_{it}^* = f_t \pi_i + z_{it}, \tag{14}$$

where $y_{it}^* = M_i^{\Delta x_i^d} y_{it}$, $f_t = M_i^{\Delta x_i^d} \Delta F_t$ and $z_{it} = M_i^{\Delta x_i^d} \Delta e_{it} - P_i^{\Delta x_i^d} \Delta F_t \pi_i$. According to the assumptions in Banerjee and Carrion-i-Silvestre (2015), the third term in (14) is asymptotically insignificant for panel unit root testing.

The estimation of the common factors is performed using principal components and is described in Bai and Ng (2004). If the number of the common factors r is given, the estimated principal components $\hat{f}$ can be computed as the r largest eigenvectors of the matrix $y^* y^{*\prime}$ multiplied by $\sqrt{T-1}$, where $y^* = [y_1^*, \ldots, y_N^*]$, $y_i^* = [y_{i1}^*, \ldots, y_{iT}^*]'$, T is the number of observations in each region, while N is the number of units. The next step is the estimation of the loading matrix $\hat{\Pi} = \hat{f}' y^* / (T-1)$. Finally, the residuals z_{it} can be computed as follows:

$$\hat{z}_{it} = y_{it}^* - \hat{f}_t \hat{\pi}_i. \tag{15}$$

The idiosyncratic shocks are recovered by computing $\hat{e}_{it} = \sum_{j=2}^{t} \hat{z}_{ij}$, and the unit root hypothesis can finally be tested at the regional level using this augmented Dickey-Fuller(ADF) type regression:

$$\Delta \hat{e}_{it} = \alpha_{i0} \hat{e}_{it-1} + \sum_{j=1}^{k_i} \alpha_{ij} \Delta \hat{e} + \varepsilon_{it}, \tag{16}$$

where k_i is the lag order for unit i. If the number of common factors r is not known, it can be estimated using the approach suggested in Bai and Ng (2004), where a sequence of tests check the hypothesis of equality of r to a stated number of components, which decreases from $\min\{N, T-1\}$ by 1 until the null is not rejected.

Once the order of integration of the idiosyncratic component is assessed, panel cointegration can be tested using the Panel Analysis of Nonstationarity in Idiosyncratic and Common components (PANIC) test by Bai and Ng (2004), as modified by Banerjee and Carrion-i-Silvestre (2015) to allow for structural breaks. In case of heterogeneous break dates, Banerjee and Carrion-i-Silvestre (2015) suggest to follow the iterative process of breaks detection proposed by Bai and Perron (1998): first, use ordinary least squares (OLS) with (12) rewritten as follows, $\Delta y_{it} = \Delta D_{it} + \Delta X_{it}' \delta_{it} + \Delta u_{it}$, where $\Delta u_{it} = \Delta F_t' \pi_i + \Delta e_{it}$, to estimate the first set of break dates $\tilde{\Delta} D_{it}^{(1)}$ and $\tilde{\delta}_{it}^{(1)}$. Then, using (7) in first differences, that is $\Delta u_{it} = \Delta F_t' \pi_i + \Delta e_{it}$, estimate the common factors and loadings using principal components on $\tilde{\Delta} u_{it}^{(1)} = \Delta y_{it} - \tilde{\Delta} D_{it}^{(1)} - \Delta X_{it}' \tilde{\delta}_{it}^{(1)}$, where the estimated factors and loadings are denoted as $\Delta \tilde{F}_t^{(1)}$ and $\tilde{\pi}_i^{(1)}$. Then, define $\Delta y_{it} - \Delta \tilde{F}_t^{(1)\prime} \tilde{\pi}_i^{(1)} = \Delta D_{it} + \Delta X_{it}' \delta_{it} + \Delta e_{it}$ and get a second set of break dates $\tilde{\Delta} D_{it}^{(2)}$, $\tilde{\delta}_{it}^{(2)}$, and subsequently a second set of estimated factors and loadings $\Delta \tilde{F}_t^{(2)}$ and $\tilde{\pi}_i^{(2)}$. This process is repeated until the sum of squared residuals across all equations is smaller than a given error tolerance set by the researcher.

Finally, a standardized test statistic to test for panel cointegration is constructed using the estimated break dates and the sum of the individual ADF cointegration statistics for each unit, see Banerjee and Carrion-i-Silvestre (2015) for more details.

4 Empirical analysis

4.1 Data Description and Preliminary analysis

This research focuses on the gasoline RON92 price dynamics in 79 Russian regions from February 2003 to March 2017, using data provided by Federal State Statistics Service - Rosstat (2018). Chechnya, Sevastopol, Republic of Crimea and the Yamalo-Nenets Autonomous Okrug were excluded from the sample because during the studied period there were several missing observations. The exchange rate USD/RUB comes from the database of the Central Bank of the Russian Federation (2018), while the Europe Brent spot FOB price provided by the US Energy Information Agency (EIA) was downloaded using the Quandl (2018) database. Throughout the paper, r, er, c represent the logs of the gasoline price, the exchange rate, and the crude oil price, respectively. The dynamics of the standardized logarithms of the crude oil price, the exchange rate and of gasoline prices are shown in Figure 1, together with gray vertical bars that highlight when a drop in monthly oil prices did not lead to a decrease in gasoline prices. At first glance, it seems that a potential asymmetric effect may be due to the exchange rate but not due to the crude oil prices.

The first step of our analysis was to test for the stationarity of the collected time series. Two unit roots tests were considered: the ADF test by Dickey and Fuller (1981) with intercept and trend and the number of lags chosen using the Bayesian Information Criterion (BIC), and the test by Zivot and Andrews (1992), which allows for one structural break in the intercept and trend. The results of these

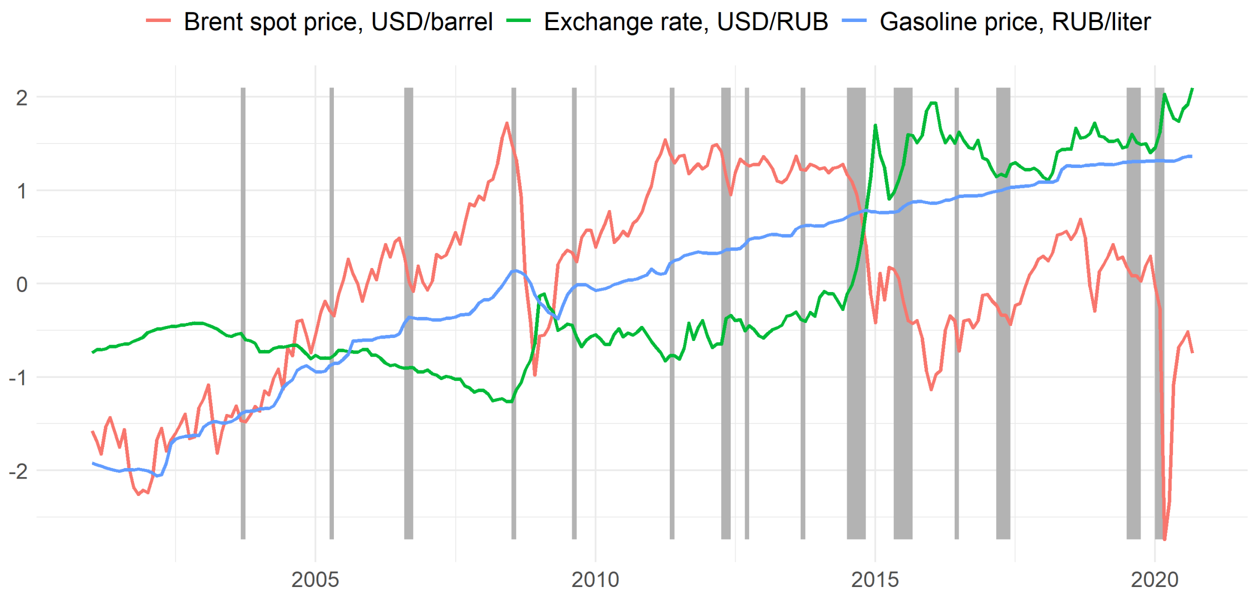

Figure 1: Standardized logarithms of the crude oil price (USD/barrel), the exchange rate (USD/RUB), and gasoline prices (RUB/liter). The gray vertical bars highlight a month when the drop in oil prices did not correspont to a decrease in gasoline prices.

tests for all Russian regions are reported in Appendix A in Tables 1-3[1], for data in levels and first differences. These tables also include the p-values for the Breusch-Godfrey (BG) Lagrange Multiplier test for serial correlation in the residuals, the selected number of lags for the ADF-test, and the chosen date for the structural break of the ZA-test.

Both the ADF and the ZA tests failed to reject the unit root hypotheis at the 5% level for almost all regions, except for The Komi Republic, Nenets Autonomous Okrug, Leningrad Oblast, Kabardino-Balkaria, Karachay-Cherkessia, Udmurtia, Yamalo-Nenets Autonomous Okrug, Yakutia, Sakhalin Oblast, The Jewish Autonomous Oblast, Chukotka Autonomous Okrug. The exchange rate and the crude oil price are I(1) processes according to the tests' results, even when taking structural breaks into account.

4.2 NARDL models

Tables 1-3 report the asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate, estimated using the NARDL model in (4) allowing for hysteresis for each region[2], together with the following specification tests: the Breusch-Pagan heteroskedasticity test, the Jarque-Bera test, the Breusch-Godfrey test for serial autocorrelation in the residuals (12 and 24 lags), the R^2

[1]The Technical Appendix can be found on the authors' website.
[2]The model estimates for the NARDL model (3) without hysteresis are available from the authors upon request.

and the adjusted-R^2. The tables also report the F tests of coefficient equality in the positive regime (P), in the inaction band (Z), and in the negative regime (N), for the short-run (SR) and the long-run (LR) coefficients. Following Pesaran et al. (2001) and Shin et al. (2014), we considered the critical values for both purely I(1) variables and I(0) variables. Note that according to the power analysis performed by Shin et al. (2014), the t and F tests for the NARDL perform well when using a sample of at least 200 observations. Given that our sample size consists of 160 data for each region, the significance of the estimated variables using the single-equation NARDL model should be accurately scrutinized.

The F-tests reported in tables 1-3 show that there is evidence of strong short-run asymmetry for both the crude price and the exchange rate, while this is not the case for long-run elasticities for which the null of no asymmetry is not rejected for most regions. Interestingly, the inaction band is rarely significant across regions. Long-run elasticities for the crude price are statistically different from zero for almost all regions with a mean value close to 0.10, whereas long-run elasticities for the exchange rate are rarely different from zero. The specification tests highlight that the NARDL model generally provides a decent fit to the data with R^2 ranging between 0.2 and 0.5 across regions, and the models' residuals are mostly not serially correlated. Nevertheless, the residuals are all heteroskedastic and not normally distributed, so that the t- and F-statistics should be taken with a grain of salt.

For the sake of space and interest, we report in Table 4 the asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate estimated with the panel-NARDL model (5) allowing for hysteresis, together with the F-statistics for the null hypothesis of no asymmetry. In this case, there is evidence of long-run asymmetry for both the exchange rate and crude oil prices, while the inaction band is again not statistically different from zero. However, the models' specification tests are in general worse compared to the previous case with single-equation NARDL models.

The quality of the NARDL and panel-NARDL specifications did not improve even after adding individual regional controls like the regional population, the share of soil roads, the density of cars per 1000 people, and the average wage level: none of the socio-economic controls was significant, and the properties of the residuals did not improve[3]. Moreover, we noticed that the models' parameters were unstable, particularly before and after the global financial crisis in 2008-2009. We tried to estimate a single-equation NARDL model with breaks, but the model estimates were rather poor, and they did not reach numerical convergence for some regions. Given our small dataset (160 observations), we decided to use a panel cointegrated model with breaks because it turned out to be more computationally robust. Therefore, this initial evidence showed that models that performed well for the Italian

[3]These additional model estimates are available from the authors upon request.

gasoline market (Bagnai and Ospina (2015)) and the UK fuel market (Greenwood-Nimmo and Shin (2013)), mostly failed to describe the gasoline pricing mechanism across Russian regions.

	Long run coefficients						F- stats for the null of no asymmetry								Misspecification tests					
	C+	C0	C-	ER+	ER0	ER-	$F^{SR,C}_{P=N}$	$F^{SR,C}_{P=Z=N}$	$F^{SR,ER}_{P=N}$	$F^{SR,ER}_{P=Z=N}$	$F^{LR,C}_{P=N}$	$F^{LR,C}_{P=Z=N}$	$F^{LR,ER}_{P=N}$	$F^{LR,ER}_{P=Z=N}$	HET	JB	BG(12)	BG(24)	R2	R2-adj
Belgorod Region	0.09	-0.15	0.09	0.08	-0.23	0.02	14.20$^{***}_{***}$	15.52$^{***}_{***}$	0.51	1.20	0.97	13.51$^{***}_{***}$	2.54$_{***}$	4.59$^{***}_{***}$	0.21	0.00	0.45	0.38	0.62	0.57
	4.18$_{***}$	-2.44	4.98$^{*}_{***}$	2.06	-1.16	0.32														
Bryansk Region	0.09	-0.10	0.09	0.10	-0.17	0.07	11.99$^{***}_{***}$	16.60$^{***}_{***}$	3.43$^{*}_{***}$	6.51$^{***}_{***}$	0.93	8.92$^{***}_{***}$	0.63	2.21$_{**}$	0.11	0.00	0.27	0.84	0.60	0.54
	4.17$_{***}$	-1.66	4.91$_{***}$	2.60	-0.84	1.08														
Vladimir Region	0.07	-0.07	0.07	0.08	-0.13	0.09	13.67$^{***}_{***}$	16.37$^{***}_{***}$	3.80$^{**}_{***}$	5.36$^{***}_{***}$	0.05	5.38$^{***}_{***}$	0.06	1.08	0.33	0.00	0.18	0.45	0.54	0.47
	3.53$_{***}$	-1.25	4.03$_{***}$	2.04	-0.67	1.32														
Voronedz Region	0.07	-0.10	0.08	0.06	-0.17	0.03	18.81$^{***}_{***}$	19.62$^{***}_{***}$	5.97$^{***}_{***}$	13.46$^{***}_{***}$	0.69	14.33$^{***}_{***}$	0.56	1.95$_{*}$	0.06	0.00	0.56	0.61	0.52	0.45
	3.37$_{**}$	-2.17	4.38$_{***}$	1.43	-0.95	0.46														
Ivanovo Region	0.06	-0.08	0.06	0.04	-0.07	0.06	15.21$^{***}_{***}$	19.74$^{***}_{***}$	3.98$^{**}_{***}$	6.41$^{***}_{***}$	0.04	7.82$^{***}_{***}$	0.37	0.65	0.25	0.00	0.41	0.75	0.51	0.44
	2.69	-1.66	3.22$_{**}$	0.92	-0.36	0.88														
Kaluga Region	0.09	-0.03	0.09	0.09	-0.16	0.11	14.84$^{***}_{***}$	16.59$^{***}_{***}$	2.55$_{***}$	9.23$^{***}_{***}$	0.013	6.94$^{***}_{***}$	0.52	2.47$_{**}$	0.09	0.00	0.47	0.65	0.62	0.57
	4.08$_{***}$	-0.66	4.78$_{***}$	2.26	-0.97	1.78														
Kostroma Region	0.08	-0.09	0.07	0.07	-0.16	0.12	9.29$^{***}_{***}$	12.47$^{***}_{***}$	4.44$^{***}_{***}$	7.21$^{***}_{***}$	0.25	8.78$^{***}_{***}$	0.98	1.98$_{*}$	0.00	0.00	0.49	0.51	0.48	0.41
	3.06$_{*}$	-1.70	3.51$_{***}$	1.55	-0.74	1.47														
Kursk Region	0.11	-0.09	0.11	0.14	-0.20	0.14	6.57$^{***}_{***}$	7.44$^{***}_{***}$	1.61	2.31$_{**}$	0.01	6.08$^{***}_{***}$	0.02	1.54	0.10	0.00	0.46	0.59	0.49	0.42
	4.25$_{***}$	-1.16	4.67$_{***}$	2.81	-0.76	1.55														
Lipetsk Region	0.08	-0.08	0.08	0.11	-0.10	0.10	17.64$^{***}_{***}$	19.86$^{***}_{***}$	11.33$^{***}_{***}$	12.64$^{***}_{***}$	0.47	8.23$^{***}_{***}$	0.01	1.38	0.25	0.00	0.08	0.12	0.61	0.55
	4.52$_{***}$	-1.51	5.19$^{*}_{***}$	3.14$_{**}$	-0.61	1.79														
Moscow Region	0.08	-0.05	0.08	0.08	-0.10	0.06	11.80$^{***}_{***}$	14.93$^{***}_{***}$	0.94	1.15	0.22	5.88$^{***}_{***}$	0.55	1.45	0.47	0.00	0.29	0.36	0.59	0.53
	4.36$_{***}$	-0.96	4.97$^{*}_{***}$	2.36	-0.55	0.97														
Oryel Rgion	0.07	-0.10	0.08	0.07	-0.10	0.04	14.53$^{***}_{***}$	15.30$^{***}_{***}$	2.17$_{**}$	2.19$_{**}$	1.39	7.37$^{***}_{***}$	0.89	1.53	0.78	0.00	0.37	0.76	0.59	0.54
	3.44$_{***}$	-1.61	4.22$_{***}$	1.95	-0.50	0.61														
Ryasan Region	0.07	-0.08	0.08	0.08	-0.13	0.07	16.25$^{***}_{***}$	18.28$^{***}_{***}$	2.14$_{**}$	4.31$^{***}_{***}$	0.53	6.47$^{***}_{***}$	0.08	1.15	0.05	0.09	0.41	0.62	0.58	0.52
	3.75$_{***}$	-1.37	4.44$_{***}$	2.09	-0.70	1.054														
Smolensk Region	0.07	-0.10	0.08	0.09	-0.12	0.05	9.35$^{***}_{***}$	13.42$^{***}_{***}$	3.27$^{*}_{***}$	4.36$^{***}_{***}$	2.38$_{**}$	8.64$^{***}_{***}$	1.61	3.00$_{***}$	0.24	0.01	0.41	0.39	0.68	0.63
	3.69$_{***}$	-1.66	4.55$_{***}$	2.40	-0.81	0.78														
Tambov Region	0.07	-0.11	0.08	0.09	-0.07	0.09	8.94$^{***}_{***}$	10.32$^{***}_{***}$	6.38$^{***}_{***}$	6.65$^{***}_{***}$	0.35	8.014$^{***}_{***}$	0.00	0.61	0.11	0.00	0.70	0.67	0.57	0.51
	3.77$_{***}$	-1.80	4.31$_{***}$	2.34	-0.36	1.38														
Tver Region	0.06	-0.12	0.07	0.05	-0.11	0.01	23.77$^{***}_{***}$	28.29$^{***}_{***}$	1.41	2.45$_{**}$	1.32	11.45$^{***}_{***}$	1.23	1.90$_{*}$	0.55	0.00	0.59	0.67	0.59	0.53
	3.69$_{***}$	-2.23	4.57$_{***}$	1.48	-0.61	0.22														
Tula Region	0.06	-0.04	0.06	0.09	-0.01	0.10	14.49$^{***}_{***}$	14.89$^{***}_{***}$	9.34$^{***}_{***}$	10.34$^{***}_{***}$	0.23	2.76$_{***}$	0.06	0.46	0.03	0.02	0.36	0.16	0.53	0.46
	3.31$_{**}$	-0.61	3.93$_{***}$	2.39	-0.05	1.54														
Yaroslavl Region	0.07	-0.10	0.07	0.05	-0.13	0.07	11.57$^{***}_{***}$	15.63$^{***}_{***}$	3.80$^{**}_{***}$	7.37$^{***}_{***}$	0.01	8.94$^{***}_{***}$	0.19	0.89	0.09	0.00	0.70	0.77	0.47	0.39
	2.88$_{*}$	-1.78	3.44$_{***}$	1.16	-0.64	0.94														
Moscow	0.07	-0.06	0.07	0.08	-0.10	0.06	12.76$^{***}_{***}$	17.07$^{***}_{***}$	2.52$_{**}$	3.16$^{*}_{***}$	0.82	7.12$^{***}_{***}$	0.35	1.56	0.16	0.00	0.21	0.16	0.62	0.57
	4.30$_{***}$	-1.27	4.95$_{***}$	2.61	-0.67	1.19														
Republic of Karelia	0.08	-0.05	0.09	0.12	-0.17	0.12	12.33$^{***}_{***}$	12.92$^{***}_{***}$	5.18$^{***}_{***}$	9.42$^{***}_{***}$	0.84	3.61$^{**}_{***}$	0.01	2.13$_{**}$	0.03	0.00	0.88	0.50	0.55	0.49
	3.55$_{***}$	-0.71	4.25$_{***}$	2.53	-0.94	1.59														
Republic of Komi	0.06	-0.20	0.11	0.13	-0.01	0.08	11.04$^{***}_{***}$	11.17$^{***}_{***}$	6.87$^{***}_{***}$	7.02$^{***}_{***}$	16.59$^{***}_{***}$	20.85$^{***}_{***}$	1.90$_{*}$	2.88$_{***}$	0.04	0.00	0.27	0.14	0.45	0.37
	3.52$_{***}$	-3.16$_{**}$	6.27$^{***}_{***}$	3.58$_{***}$	-0.06	1.12														
Arhangelsk Region	0.06	-0.07	0.07	0.10	-0.18	0.11	8.03$^{***}_{***}$	8.80$^{***}_{***}$	3.67$^{**}_{***}$	4.61$^{***}_{***}$	1.011	4.20$^{***}_{***}$	0.00	2.55$_{***}$	0.04	0.00	0.03	0.19	0.50	0.42
	3.20$_{**}$	-0.99	4.02$_{***}$	2.50	-1.09	1.53														
Vologda Region	0.06	-0.07	0.07	0.09	-0.05	0.10	12.00$^{***}_{***}$	14.68$^{***}_{***}$	7.75$^{***}_{***}$	8.45$^{***}_{***}$	0.96	4.94$^{***}_{***}$	0.05	0.78	0.28	0.00	0.99	0.63	0.53	0.46
	3.16$_{**}$	-1.21	3.89$_{***}$	2.32	-0.31	1.52														
Kaliningrad Region	0.04	-0.18	0.08	0.07	-0.20	-0.01	9.91$^{***}_{***}$	10.96$^{***}_{***}$	3.38$^{*}_{***}$	3.61$^{**}_{***}$	14.84$^{***}_{***}$	19.36$^{***}_{***}$	5.91$^{***}_{***}$	8.32$^{***}_{***}$	0.02	0.00	0.88	1.00	0.55	0.48
	2.93$_{*}$	-3.22$_{**}$	5.12$^{*}_{***}$	2.27	-1.61	-0.25														
Leningrad Region	0.07	-0.03	0.07	0.08	-0.14	0.08	18.84$^{***}_{***}$	23.87$^{***}_{***}$	5.08$^{***}_{***}$	6.08$^{***}_{***}$	0.01	10.40$^{***}_{***}$	0.01	2.62$_{***}$	0.08	0.02	0.52	0.85	0.73	0.69
	4.35$_{***}$	-1.02	5.06$^{*}_{***}$	2.59	-1.13	1.72														
Murmansk Region	0.04	-0.08	0.05	0.04	-0.03	0.02	10.43$^{***}_{***}$	15.24$^{***}_{***}$	4.11$^{***}_{***}$	5.14$^{***}_{***}$	0.77	5.66$^{***}_{***}$	0.57	0.74	0.11	0.00	0.67	0.56	0.55	0.49
	2.82	-1.48	3.57$_{***}$	1.29	-0.21	0.28														
Novogorod Region	0.06	-0.08	0.08	0.09	-0.08	0.08	13.97$^{***}_{***}$	14.71$^{***}_{***}$	8.95$^{***}_{***}$	11.59$^{***}_{***}$	2.48$_{**}$	7.78$^{***}_{***}$	0.26	1.53	0.06	0.00	0.43	0.66	0.62	0.57
	3.81$_{***}$	-1.46	4.73$_{***}$	2.73	-0.59	1.38														
Pskov Region	0.05	-0.10	0.07	0.07	-0.10	0.04	15.06$^{***}_{***}$	15.94$^{***}_{***}$	5.23$^{***}_{***}$	6.48$^{***}_{***}$	3.36$^{*}_{***}$	9.37$^{***}_{***}$	1.13	2.34$_{**}$	0.20	0.00	0.51	0.41	0.64	0.58
	3.33$_{**}$	-1.87	4.34$_{***}$	2.10	-0.79	0.68														

Table 1: The asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate, estimated with the NARDL model in (3) for each region. Specification tests: Breusch-Pagan heteroskedasticity test, Jarque-Bera test, Breusch-Godfrey test (12 and 24 lags), R^2 and adjusted R^2. F tests of coefficient equality in the positive regime (P), in the inaction band (Z), and in the negative regime (N), for the short-run (SR) and the long-run (LR) coefficients. The upper *, **, *** show if the null is rejected at the 0.1, 0.05 and 0.01 significant levels for the model with purely I(1) variables, whereas the lower *, **, *** for purely I(0) variables.

	Long run coefficients						F- stats for the null of no asymmetry								Misspecification tests					
	C+	C0	C-	ER+	ER0	ER-	$F^{SR,C}_{P=N}$	$F^{SR,C}_{P=Z=N}$	$F^{SR,ER}_{P=N}$	$F^{SR,ER}_{P=Z=N}$	$F^{LR,C}_{P=N}$	$F^{LR,C}_{P=Z=N}$	$F^{LR,ER}_{P=N}$	$F^{LR,ER}_{P=Z=N}$	HET	JB	BG(12)	BG(24)	R2	R2-adj
St. Petersburg	0.07	-0.08	0.08	0.09	-0.18	0.08	20.39$^{***}_{***}$	27.03$^{***}_{***}$	5.52$^{***}_{***}$	7.46$^{***}_{***}$	3.04$_{***}$	12.59$^{***}_{***}$	0.19	3.55$^{**}_{***}$	0.07	0.03	0.08	0.38	0.71	0.67
	4.76$_{***}$	-1.87	5.54$^{**}_{***}$	3.16$_{**}$	-1.32	1.67														
Adygea	0.07	-0.08	0.08	0.10	-0.20	0.11	10.37$^{***}_{***}$	12.46$^{***}_{***}$	3.45$^{*}_{***}$	5.28$^{***}_{***}$	0.87	8.58$^{***}_{***}$	0.01	2.76$_{***}$	0.25	0.01	0.65	0.69	0.48	0.40
	4.40$_{***}$	-1.55	5.20$^{*}_{***}$	3.04$_{*}$	-1.15	1.79														
Kalmykia	0.08	-0.09	0.08	0.09	-0.22	0.09	9.74$^{***}_{***}$	10.36$^{***}_{***}$	4.85$^{***}_{***}$	5.07$^{***}_{***}$	0.52	6.24$^{***}_{***}$	0.00	1.94$_{*}$	0.62	0.00	0.65	0.38	0.45	0.37
	3.81$_{***}$	-1.39	4.45$_{***}$	2.30	-1.04	1.32														
Krasnodar Krai	0.06	-0.06	0.06	0.07	-0.17	0.08	15.59$^{***}_{***}$	17.51$^{***}_{***}$	1.99$_{*}$	3.39$^{*}_{***}$	0.46	5.98$^{***}_{***}$	0.05	2.23$_{**}$	0.07	0.00	0.70	0.59	0.57	0.51
	3.76$_{***}$	-1.25	4.46$_{***}$	2.39	-1.09	1.50														
Astrahanskaya Oblast	0.09	-0.07	0.10	0.13	-0.18	0.13	10.69$^{***}_{***}$	12.05$^{***}_{***}$	5.47$^{***}_{***}$	5.91$^{***}_{***}$	0.15	6.17$^{***}_{***}$	0.00	2.06$_{**}$	0.27	0.00	0.29	0.29	0.44	0.36
	4.75$_{***}$	-1.05	5.40$^{**}_{***}$	3.28$_{**}$	-0.88	1.90														
Volgogradskaya Oblast	0.08	-0.15	0.08	0.10	-0.39	0.09	14.47$^{***}_{***}$	17.13$^{***}_{***}$	5.39$^{***}_{***}$	9.35$^{***}_{***}$	1.45	14.97$^{***}_{***}$	0.04	6.19$^{***}_{***}$	0.09	0.00	0.10	0.33	0.49	0.41
	4.39$_{***}$	-2.63	5.26$^{*}_{***}$	2.76	-2.11	1.47														
Rostovskaya Oblast	0.07	-0.07	0.08	0.10	-0.25	0.10	6.66$^{***}_{***}$	9.00$^{***}_{***}$	2.14$_{**}$	2.67$_{***}$	0.80	7.44$^{***}_{***}$	0.01	3.55$^{**}_{***}$	0.01	0.00	0.41	0.61	0.58	0.52
	4.27$_{***}$	-1.42	4.93$_{***}$	2.96$_{*}$	-1.43	1.66														
Dagestan	0.08	-0.62	0.16	0.16	-1.04	0.00	2.58$_{***}$	2.82$_{***}$	0.20	4.53$^{***}_{***}$	10.34$^{***}_{***}$	10.88$^{***}_{***}$	6.60$^{***}_{***}$	8.08$^{***}_{***}$	0.28	0.00	0.03	0.02	0.49	0.42
	2.82	-2.63	5.44$^{**}_{***}$	3.11$_{*}$	-1.57	-0.02														
Ingushetia	0.17	0.35	0.13	0.26	-0.76	0.36	4.41$^{***}_{***}$	5.32$^{***}_{***}$	0.53	1.74	2.47$_{**}$	2.76$_{***}$	3.32$^{*}_{***}$	9.64$^{***}_{***}$	0.35	0.00	0.53	0.63	0.45	0.37
	4.99$^{*}_{***}$	2.63	5.46$^{**}_{***}$	4.67$_{***}$	-2.15	3.86$_{***}$														
Kabardino-Balkaria	0.06	-0.04	0.06	0.09	-0.18	0.09	2.61$_{***}$	3.50$^{**}_{***}$	3.05$_{***}$	8.80$^{***}_{***}$	0.01	3.40$^{*}_{***}$	0.03	1.99$_{*}$	0.01	0.00	0.01	0.14	0.37	0.28
	3.79$_{***}$	-0.73	4.33$_{***}$	2.67	-0.97	1.40														
Karachay-Cherkessia	0.06	-0.07	0.06	0.08	-0.13	0.07	5.21$^{***}_{***}$	6.65$^{***}_{***}$	4.46$^{***}_{***}$	7.82$^{***}_{***}$	0.00	5.33$^{***}_{***}$	0.06	1.19	0.13	0.00	0.04	0.91	0.41	0.33
	3.5$_{***}$	-1.23	3.98$_{***}$	2.32	-0.68	1.18														
Northern Ossetia-Alania	0.05	-0.05	0.06	0.05	-0.12	0.06	24.42$^{***}_{***}$	26.92$^{***}_{***}$	6.26$^{***}_{***}$	14.30$^{***}_{***}$	0.98	5.59$^{***}_{***}$	0.05	0.77	0.05	0.00	0.13	0.11	0.49	0.41
	2.36	-0.92	3.42$_{**}$	1.25	-0.63	0.88														
Stavropol Krai	0.06	-0.07	0.06	0.10	-0.16	0.08	3.58$^{**}_{***}$	4.31$^{***}_{***}$	3.67$^{**}_{***}$	5.98$^{***}_{***}$	1.02	4.85$^{***}_{***}$	0.28	2.88$_{***}$	0.06	0.00	0.10	0.42	0.46	0.38
	3.45$_{***}$	-1.14	4.28$_{***}$	2.78	-1.13	1.32														
Bashkortostan	0.07	-0.13	0.08	0.06	-0.25	0.02	15.65$^{***}_{***}$	17.43$^{***}_{***}$	2.88$_{***}$	4.73$^{***}_{***}$	1.3199	10.91$^{***}_{***}$	1.39	3.56$^{**}_{***}$	0.44	0.00	0.10	0.33	0.42	0.33
	3.76$_{***}$	-2.19	4.65$_{***}$	1.69	-1.26	0.27														
Mariy El	0.08	-0.07	0.08	0.08	-0.10	0.08	12.45$^{***}_{***}$	18.63$^{***}_{***}$	5.13$^{***}_{***}$	7.17$^{***}_{***}$	0.10	7.94$^{***}_{***}$	0.03	0.77	0.80	0.00	0.61	0.22	0.56	0.50
	3.34$_{**}$	-1.3	4.12$_{***}$	1.74	-0.53	1.17														
Mordovia	0.10	-0.08	0.11	0.15	-0.10	0.13	5.40$^{***}_{***}$	6.16$^{***}_{***}$	4.43$^{***}_{***}$	9.32$^{***}_{***}$	1.98$_{*}$	5.47$^{***}_{***}$	0.33	1.72	0.28	0.00	0.15	0.20	0.53	0.46
	3.96$_{***}$	-1.01	4.79$_{***}$	3.15$_{**}$	-0.54	1.61														
Tatarstan	0.13	-0.15	0.15	0.14	-0.21	0.06	17.42$^{***}_{***}$	18.47$^{***}_{***}$	3.91$^{**}_{***}$	6.18$^{***}_{***}$	5.04$^{***}_{***}$	14.00$^{***}_{***}$	2.66$_{***}$	4.09$^{**}_{***}$	0.23	0.00	0.24	0.37	0.57	0.51
	4.79$_{***}$	-1.93	5.82$^{**}_{***}$	2.67	-0.82	0.65														
Udmurtia	0.07	-0.12	0.08	0.08	-0.24	0.03	15.60$^{***}_{***}$	20.67$^{***}_{***}$	3.04$_{***}$	3.23$^{*}_{***}$	4.66$^{***}_{***}$	12.86$^{***}_{***}$	1.94$_{*}$	4.44$^{***}_{***}$	0.13	0.00	0.21	0.15	0.47	0.39
	4.03$_{***}$	-2.16	5.26$^{*}_{***}$	2.26	-1.28	0.49														
Chuvashia	0.06	-0.07	0.07	0.07	-0.16	0.07	15.71$^{***}_{***}$	17.94$^{***}_{***}$	5.30$^{***}_{***}$	7.32$^{***}_{***}$	0.76	5.19$^{***}_{***}$	0.01	1.07	0.29	0.00	0.88	0.87	0.53	0.46
	3.20$_{**}$	-1.22	3.88$_{***}$	1.71	-0.76	1.04														
Perm Krai	0.07	-0.08	0.08	0.09	-0.09	0.05	9.83$^{***}_{***}$	10.34$^{***}_{***}$	6.12$^{***}_{***}$	6.70$^{***}_{***}$	1.55	5.98$^{***}_{***}$	0.84	1.72	0.18	0.00	0.28	0.52	0.47	0.40
	3.51$_{***}$	-1.28	4.36$_{***}$	2.21	-0.57	0.79														
Kirov region	0.07	-0.10	0.08	0.09	-0.07	0.06	10.25$^{***}_{***}$	13.75$^{***}_{***}$	6.77$^{***}_{***}$	7.35$^{***}_{***}$	1.78	5.72$^{***}_{***}$	0.34	0.85	0.33	0.00	0.45	0.29	0.44	0.36
	3.18$_{**}$	-1.35	4.09$_{***}$	1.96	-0.36	0.81														
Nizhny Novgorod	0.07	-0.07	0.07	0.09	-0.15	0.12	12.65$^{***}_{***}$	16.28$^{***}_{***}$	7.58$^{***}_{***}$	10.27$^{***}_{***}$	0.24	4.59$^{***}_{***}$	0.41	1.54	0.37	0.00	0.86	0.84	0.47	0.40
	3.54$_{***}$	-1.10	4.12$_{***}$	2.24	-0.70	1.64														
Orenburg region	0.08	-0.12	0.09	0.06	-0.35	0.04	19.81$^{***}_{***}$	21.34$^{***}_{***}$	6.03$^{***}_{***}$	9.22$^{***}_{***}$	0.71	15.68$^{***}_{***}$	0.55	4.52$^{***}_{***}$	0.32	0.00	0.62	0.78	0.44	0.36
	3.87$_{***}$	-2.31	4.98$^{*}_{***}$	1.57	-1.80	0.54														
Penza region	0.07	-0.14	0.08	0.07	-0.19	0.03	14.52$^{***}_{***}$	16.75$^{***}_{***}$	1.62	1.85$_{*}$	2.32$_{**}$	13.09$^{***}_{***}$	1.02	2.80$_{***}$	0.11	0.00	0.84	0.38	0.60	0.54
	3.90$_{***}$	-2.46	4.86$_{***}$	1.90	-1.07	0.52														
Samara region	0.08	-0.11	0.09	0.07	-0.21	0.03	13.20$^{***}_{***}$	14.61$^{***}_{***}$	1.95$_{*}$	2.14$_{**}$	1.66	9.12$^{***}_{***}$	1.33	2.92$_{***}$	0.08	0.00	0.17	0.25	0.61	0.56
	3.78$_{***}$	-1.77	4.61$_{***}$	1.80	-1.02	0.39														
Saratov region	0.08	0.00	0.08	0.12	-0.18	0.15	1.43	1.65	2.64$_{***}$	3.88$^{**}_{***}$	0.50	2.77$_{***}$	0.67	2.96$_{***}$	0.11	0.00	0.35	0.29	0.49	0.42
	3.72$_{***}$	0.01	4.15$_{***}$	2.86$_{*}$	-0.97	2.20														

Table 2: (CONTINUED) The asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate, estimated with the NARDL model in (3) for each region. Specification tests: Breusch-Pagan heteroskedasticity test, Jarque-Bera test, Breusch-Godfrey test (12 and 24 lags), R^2 and adjusted R^2. F tests of coefficient equality in the positive regime (P), in the inaction band (Z), and in the negative regime (N), for the short-run (SR) and the long-run (LR) coefficients. The upper *, **, *** show if the null is rejected at the 0.1, 0.05 and 0.01 significant levels for the model with purely I(1) variables, whereas the lower *, **, *** for purely I(0) variables.

	Long run coefficients						F- stats for the null of no asymmetry								Misspecification tests					
	C+	C0	C-	ER+	ER0	ER-	$F^{SR,C}_{P=N}$	$F^{SR,C}_{P=Z=N}$	$F^{SR,ER}_{P=N}$	$F^{SR,ER}_{P=Z=N}$	$F^{LR,C}_{P=N}$	$F^{LR,C}_{P=Z=N}$	$F^{LR,ER}_{P=N}$	$F^{LR,ER}_{P=Z=N}$	HET	JB	BG(12)	BG(24)	R2	R2-adj
Ulyanovsk region	0.08	-0.16	0.10	0.08	-0.22	0.02	23.72$^{***}_{***}$	25.83$^{***}_{***}$	2.29$_{**}$	3.84$^{**}_{***}$	3.69$^{**}_{***}$	16.93$^{***}_{***}$	2.47$_{**}$	4.46$^{***}_{***}$	0.08	0.00	0.16	0.44	0.64	0.59
	4.17$_{***}$	-2.75	5.21$^{*}_{***}$	2.07	-1.15	0.33														
Kurgan region	0.08	-0.14	0.10	0.08	-0.37	0.03	11.44$^{***}_{***}$	19.76$^{***}_{***}$	2.31$_{**}$	2.40$_{**}$	3.70$^{**}_{***}$	12.26$^{***}_{***}$	1.55	5.14$^{***}_{***}$	0.03	0.00	0.05	0.12	0.56	0.49
	4.12$_{***}$	-2.12	5.13$^{*}_{***}$	1.96	-1.69	0.40														
Sverdlovsk region	0.09	-0.09	0.09	0.12	-0.23	0.11	4.70$^{***}_{***}$	8.16$^{***}_{***}$	2.05$_{*}$	3.17$^{*}_{***}$	0.71	9.65$^{***}_{***}$	0.11	3.21$^{*}_{***}$	0.06	0.00	0.24	0.85	0.54	0.47
	4.85$_{***}$	-1.64	5.45$^{**}_{***}$	3.26$_{**}$	-1.23	1.73														
Tyumen region	0.08	-0.09	0.08	0.08	-0.21	0.07	8.86$^{***}_{***}$	11.48$^{***}_{***}$	1.51	3.42$^{*}_{***}$	0.13	14.71$^{***}_{***}$	0.01	2.80$_{***}$	0.31	0.00	0.64	0.85	0.59	0.53
	4.29$_{***}$	-2.08	5.10$^{*}_{***}$	2.16	-1.30	1.25														
Chelyabinsk region	0.08	-0.18	0.12	0.11	-0.10	-0.01	8.94$^{***}_{***}$	9.38$^{***}_{***}$	4.70$^{***}_{***}$	5.27$^{***}_{***}$	11.43$^{***}_{***}$	18.30$^{***}_{***}$	7.61$^{***}_{***}$	8.34$^{***}_{***}$	0.27	0.00	0.32	0.30	0.52	0.45
	4.30$_{***}$	-2.86$_{*}$	5.84$^{**}_{***}$	2.78	-0.72	-0.14														
Altai Republic	0.13	-0.25	0.17	0.16	-0.24	0.04	10.11$^{***}_{***}$	12.01$^{***}_{***}$	3.03$_{***}$	4.37$^{***}_{***}$	6.51$^{***}_{***}$	12.60$^{***}_{***}$	3.27$^{*}_{***}$	4.66$^{***}_{***}$	0.07	0.00	0.31	0.67	0.57	0.51
	3.74$_{***}$	-2.15	4.88$_{***}$	2.30	-0.89	0.37														
Buryatia	0.06	-0.09	0.07	0.09	-0.19	0.08	1.77	4.72$^{***}_{***}$	1.23	6.50$^{***}_{***}$	1.90$_{*}$	3.94$^{**}_{***}$	0.03	1.73	0.24	0.00	0.55	0.15	0.56	0.49
	2.33	-1.08	3.19$_{**}$	1.78	-0.98	0.94														
Tyva Republic	0.14	-0.30	0.25	0.27	-0.40	0.09	3.50$^{**}_{***}$	3.86$^{**}_{***}$	1.37	1.61	14.45$^{***}_{***}$	14.45$^{***}_{***}$	5.01$^{***}_{***}$	8.22$^{***}_{***}$	0.00	0.00	0.10	0.36	0.55	0.48
	3.35$_{**}$	-1.75	5.95$^{***}_{***}$	3.27$_{**}$	-1.10	0.65														
Khakassia	0.13	-0.19	0.13	0.13	-0.41	0.10	13.90$^{***}_{***}$	17.49$^{***}_{***}$	0.48	0.95	0.48	13.21$^{***}_{***}$	0.40	3.69$^{**}_{***}$	0.01	0.01	0.33	0.63	0.60	0.54
	4.45$_{***}$	-2.30	5.17$^{*}_{***}$	2.45	-1.47	1.08														
Altai krai	0.09	-0.21	0.12	0.13	-0.18	0.07	8.16$^{***}_{***}$	8.88$^{***}_{***}$	3.38$^{*}_{***}$	4.86$^{***}_{***}$	4.38$^{***}_{***}$	10.96$^{***}_{***}$	1.32	2.64$_{***}$	0.29	0.00	0.09	0.27	0.59	0.53
	3.38$_{**}$	-2.22	4.47$_{***}$	2.28	-0.79	0.71														
Zabaikalskiy krai	0.05	-0.60	0.12	0.14	-0.81	0.06	12.15$^{***}_{***}$	12.73$^{***}_{***}$	0.85	10.84$^{***}_{***}$	10.07$^{***}_{***}$	12.35$^{***}_{***}$	2.38$_{**}$	4.40$^{***}_{***}$	0.03	0.00	0.16	0.11	0.51	0.44
	2.33	-3.07$_{*}$	5.16$^{*}_{***}$	3.14$_{**}$	-1.45	0.81														
Krasnoyarsk krai	0.10	-0.14	0.11	0.13	-0.26	0.14	6.47$^{***}_{***}$	12.38$^{***}_{***}$	2.01$_{*}$	4.36$^{***}_{***}$	0.17	9.23$^{***}_{***}$	0.04	2.11$_{**}$	0.34	0.00	0.95	0.94	0.52	0.45
	4.03$_{***}$	-1.84	4.56$_{***}$	2.53	-1.01	1.60														
Irkutsk region	0.06	-0.11	0.08	0.10	-0.30	0.09	3.91$^{**}_{***}$	9.76$^{***}_{***}$	1.33	5.97$^{***}_{***}$	2.58$_{***}$	5.36$^{***}_{***}$	0.04	3.43$^{*}_{***}$	0.27	0.00	0.36	0.48	0.56	0.50
	2.62	-1.31	3.62$_{***}$	2.06	-1.52	1.10														
Kemerovo region	0.04	-0.24	0.07	0.03	-0.24	-0.03	15.27$^{***}_{***}$	22.48$^{***}_{***}$	2.41$_{**}$	2.95$_{***}$	8.08$^{***}_{***}$	19.42$^{***}_{***}$	1.96$_{*}$	3.28$^{*}_{***}$	0.24	0.00	0.59	0.94	0.61	0.55
	2.28	-3.61$_{***}$	3.75$_{***}$	0.74	-1.16	-0.39														
Novosibirsk region	0.08	-0.16	0.10	0.11	-0.13	0.09	8.38$^{***}_{***}$	10.84$^{***}_{***}$	3.00$_{***}$	4.11$^{***}_{***}$	3.87$^{**}_{***}$	9.48$^{***}_{***}$	0.17	0.92	0.03	0.00	0.32	0.60	0.50	0.43
	3.60$_{***}$	-1.95	4.57$_{***}$	2.28	-0.50	1.07														
Omsk region	0.08	-0.21	0.09	0.10	-0.21	0.07	10.79$^{***}_{***}$	13.80$^{***}_{***}$	4.39$^{***}_{***}$	4.88$^{***}_{***}$	0.86	11.72$^{***}_{***}$	0.35	1.61	0.01	0.00	0.03	0.03	0.43	0.35
	3.84$_{***}$	-2.56	4.52$_{***}$	2.08	-0.82	0.83														
Tomsk region	0.09	-0.18	0.10	0.11	-0.06	0.10	13.94$^{***}_{***}$	17.98$^{***}_{***}$	5.43$^{***}_{***}$	5.54$^{***}_{***}$	2.13$_{**}$	11.81$^{***}_{***}$	0.03	0.49	0.08	0.00	0.19	0.31	0.59	0.53
	4.016$_{***}$	-2.36	4.83$_{***}$	2.48	-0.24	1.33														
Yakutiya	0.05	-0.23	0.08	0.11	-0.72	0.04	3.62$^{**}_{***}$	4.11$^{***}_{***}$	1.57	2.44$_{**}$	3.10$_{***}$	4.56$^{***}_{***}$	3.40$^{*}_{***}$	6.85$^{***}_{***}$	0.01	0.00	0.80	0.58	0.40	0.32
	3.24$_{**}$	-1.67	5.41$^{**}_{***}$	3.91$_{***}$	-1.81	0.78														
Kamchatka	0.07	-0.11	0.07	0.09	-0.26	0.12	7.94$^{***}_{***}$	8.62$^{***}_{***}$	2.89$_{***}$	10.82$^{***}_{***}$	0.02	5.95$^{***}_{***}$	0.22	3.31$^{*}_{***}$	0.01	0.00	0.58	0.87	0.42	0.34
	3.11$_{*}$	-1.36	3.34$_{**}$	2.01	-1.36	1.46														
Primorski krai	0.05	-0.04	0.04	0.07	-0.08	0.11	7.45$^{***}_{***}$	13.82$^{***}_{***}$	3.73$^{**}_{***}$	7.59$^{***}_{***}$	0.08	3.31$^{*}_{***}$	0.97	2.30$_{**}$	0.29	0.01	0.26	0.46	0.48	0.40
	2.88$_{*}$	-0.66	3.08$_{*}$	2.12	-0.59	1.82														
Khabarovsk krai	0.07	-0.05	0.06	0.10	-0.08	0.12	3.25$^{*}_{***}$	5.83$^{***}_{***}$	2.38$_{**}$	2.96$_{***}$	0.24	4.25$^{***}_{***}$	0.21	1.07	0.45	0.00	0.51	0.31	0.42	0.34
	3.14$_{**}$	-0.71	3.30$_{**}$	2.12	-0.42	1.52														
Amur region	0.05	-0.06	0.06	0.09	-0.25	0.11	3.25$^{*}_{***}$	4.65$^{***}_{***}$	2.99$_{***}$	4.71$^{***}_{***}$	0.20	1.70	0.07	1.69	0.04	0.00	0.28	0.08	0.41	0.33
	2.36	-0.50	3.67$_{***}$	2.46	-0.99	1.44														
Magadan region	0.12	-0.21	0.12	0.20	-0.38	0.23	3.67$^{**}_{***}$	6.58$^{***}_{***}$	7.56$^{***}_{***}$	14.48$^{***}_{***}$	0.02	12.56$^{***}_{***}$	0.23	5.49$^{***}_{***}$	0.02	0.00	0.70	0.96	0.41	0.32
	4.54$_{***}$	-2.07	5.07$^{*}_{***}$	3.48$_{***}$	-1.58	2.28														
Sahalin	0.05	0.81	0.04	0.09	-1.05	0.18	3.07$_{***}$	4.32$^{***}_{***}$	4.59$^{***}_{***}$	32.11$^{***}_{***}$	0.48	6.55$^{***}_{***}$	5.78$^{***}_{***}$	8.12$^{***}_{***}$	0.23	0.00	0.56	0.50	0.40	0.32
	3.02$_{*}$	2.56	2.58	3.21$_{**}$	-0.61	3.50$_{***}$														
Jewish region	0.07	-0.03	0.06	0.10	-0.16	0.14	1.91$_{*}$	6.11$^{***}_{***}$	3.26$^{*}_{***}$	7.07$^{***}_{***}$	0.29	3.71$^{**}_{***}$	0.78	2.90$_{***}$	0.07	0.00	0.47	0.16	0.42	0.34
	3.28$_{**}$	-0.49	3.43$_{***}$	2.33	-0.93	1.88														
Chukotka	0.06	0.02	0.03	0.10	-1.30	0.24	2.06$_{**}$	9.71$^{***}_{***}$	0.73	6.07$^{***}_{***}$	0.39	1.69	2.28$_{**}$	6.45$^{***}_{***}$	0.25	0.00	0.25	0.26	0.20	0.08
	1.85	0.07	1.02	1.65	-1.81	2.21														

Table 3: (CONTINUED) The asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate, estimated with the NARDL model in (3) for each region. Specification tests: Breusch-Pagan heteroskedasticity test, Jarque-Bera test, Breusch-Godfrey test (12 and 24 lags), R^2 and adjusted R^2. F tests of coefficient equality in the positive regime (P), in the inaction band (Z), and in the negative regime (N), for the short-run (SR) and the long-run (LR) coefficients. The upper *, **, *** show if the null is rejected at the 0.1, 0.05 and 0.01 significant levels for the model with purely I(1) variables, whereas the lower *, **, *** for purely I(0) variables.

Long run coefficients							
C+	**C0**	**C-**	**ER+**	**ER0**	**ER-**		
-0.05	-0.07	-0.09	0.19	-0.05	-0.06		
-13.265^{***}_{***}	-1.908	-11.86^{***}_{***}	21.44^{***}_{***}	-5.98_{***}	-6.25^{***}_{***}		
Misspecification tests							
HET	**JB**	**R^2**	**R^2-adj**	**BG(12)**	**BG(24)**		
0.00	0.00	0.40	0.39	0.10	0.15		
F- STATS FOR THE NULL OF NO ASYMMETRY							
$F^{SR,C}_{P=Z}$	$F^{SR,C}_{Z=N}$	$F^{SR,C}_{P=N}$	$F^{SR,C}_{P=Z=N}$	$F^{SR,ER}_{P=Z}$	$F^{SR,ER}_{Z=N}$	$F^{SR,ER}_{P=N}$	$F^{SR,ER}_{P=Z=N}$
347.66^{***}_{***}	361.49^{***}_{***}	450.87^{***}_{***}	727.34^{***}_{***}	352.65^{***}_{***}	373.85^{***}_{***}	336.83^{***}_{***}	695.19^{***}_{***}
$F^{LR,C}_{P=Z}$	$F^{LR,C}_{Z=N}$	$F^{LR,C}_{P=N}$	$F^{LR,C}_{P=Z=N}$	$F^{LR,ER}_{P=Z}$	$F^{LR,ER}_{Z=N}$	$F^{LR,ER}_{P=N}$	$F^{LR,ER}_{P=Z=N}$
68.30^{***}_{***}	63.34^{***}_{***}	120.13^{***}_{***}	140.97^{***}_{***}	0.15	0.54	94.70^{***}_{***}	94.85^{***}_{***}

Table 4: The asymmetric long-run coefficients and associated t-statistics for crude oil and exchange rate, estimated with the panel-NARDL model in (5). Specification tests: Breusch-Pagan heteroskedasticity test (p-value), Jarque-Bera test (p-value), R^2 and adjusted R^2, Breusch-Godfrey tests (12 and 24 lags - mean of the p-values across all regions). F tests of coefficient equality in the positive regime (P), in the inaction band (Z), and/or in the negative regime (N), for the short-run (SR) and the long-run (LR) coefficients. The upper *, **, *** show if the null is rejected at the 0.1, 0.05 and 0.01 significant levels for the model with purely I(1) variables, whereas the lower *, **, *** for purely I(0) variables.

4.3 Panel cointegration models with breaks

Figure 1 shows that both the USDRUB exchange rate and the crude oil price underwent periods of strong volatility, particularly aroung the global financial crisis in 2008, and when the oil price collapsed in 2014. These are the main reasons why the residuals of the previous NARDL models were often heteroskedastic and not normally distributed. We tackled this issue by estimating a panel cointegrated models with breaks.

To decrease the degree of computational complexity, we considered a maximum of 2 possible structural breaks, and all control variables share the same break dates within each region. However, different regions can have breaks at different times. We employed the model with a trend to exclude the possibility of spurious regression because both the control variables and the gasoline price have a trend. The number of breaks and their dates was computed using the approach proposed by Bai and Perron (1998)[4].

The automatic procedure by Bai and Perron (1998) selected for most regions two breaks in 2007 and 2010, which broadly corresponds to the period when the global financial crisis affected Russia. Interestingly, despite the dramatic drop in the oil prices and the rocketing exchange rate that took place in 2014-2015, this period was never chosen as a break date for the Russian regions. One possible explanation is that the shocks to the oil price and the exchange rate canceled each other out, and the gasoline price remained mostly unaffected. In this regard, we remark that the Bank of Russia abandoned in November 2014 the managed floating exchange rate regime based on a permissible range of a dual-currency basket Ruble values (with regular interventions on and outside the borders of

[4]The Matlab code can be found on the homepage of prof. Pierre Perron.

this band), and it moved to a fully floating exchange rate regime. This fact might well explain why there was not a structural break in 2014, differently from the crisis of 2007-09 when the exchange rate was under a managed floating exchange rate regime, see `http://www.cbr.ru/eng/dkp/about_inflation/history/` for more details. The number of common factors estimated using the approach proposed by Bai and Ng (2004) was equal to the largest possible value given by the total number of Russian regions (79)[5]. After the estimation with common factors was performed, the idiosyncratic residuals were computed, and the unit root hypothesis could finally be tested at the regional level using the augmented Dickey-Fuller(ADF) type regression in eq. (16). Once the order of integration of the idiosyncratic component was assessed, the null hypothesis of panel cointegration was tested using the PANIC test by Bai and Ng (2004), as modified by Banerjee and Carrion-i-Silvestre (2015) to allow for structural breaks.

The single ADF tests with 1 lag did not reject the unit root hypothesis at the 5% level only for 5 regions (Vologda region, Novgorod region, Yakutia, Evreiskaya Avtonomnaya Oblast, Chukotka), while the panel test for cointegration strongly rejected the null hypothesis of no panel cointegration[6]. Given this evidence, we estimated a panel cointegration model with two breaks and 79 common factors. A summary of the model estimates for each region is reported in the tables 4-5 in the Technical Appendix, while the full set of results is available from the authors upon request.

The model estimates are highly heterogeneous across regions, but some common findings can be highlighted. To simplify the interpretation of the main results, we used thermomaps to present the results more conveniently: Figures 2-7 show the difference between the long-run elasticities for positive and negative cumulative changes of the variable of interest during various time samples. The closer to zero is the difference, the lower is the degree of asymmetry in the region. If the difference is positive, the long-run effect of the variable increase is higher than the effect of its decrease, and vice versa. Moreover, Wald tests for the null of no asymmetry are reported in table 5 for each region.

First, according to the Wald tests, there are no asymmetric effects due to changes in the oil price for most regions, but there are significant asymmetric effects due to changes in the exchange rate. This is clearly visible when looking at Figures 2-4, which show that the long-run elasticities to the increase and decrease of the oil price are almost equal for most regions during the examined periods. Second, the long-run elasticities of the gasoline price to the positive changes of the exchange rate are mainly negative (and vice versa) for most regions in the European part of Russia during the first time period

[5] The Bai and Ng (2004) algorithm is implemented in the R package `PANICr`.

[6] The panel test statistic by Carrion-i-Silvestre (2015), which is computed as a specific standardized sum of the individual ADF (SADF) cointegration statistics, was equal to 47.28: under the null hypothesis of no cointegration, the limiting distribution of this statistic converges to a N(0,1), see eq. (14) in Theorem 2 by Banerjee and Carrion-i-Silvestre (2015) for more details.

before 2007, see Figure 5. However, it can be seen from Figure 6 that, in general, the difference of the long-run elasticities to the exchange rate tended to zero in most regions already in the second sample between 2007 and 2010, and the asymmetry has continued to smooth down after 2010, as highlighted by Figure 7. Furthermore, it is possible to note that the constant and the trend are significant in almost all regions (see again tables 4-5 in the Technical Appendix): after the first break, there was a general drop in both intercept and trend components, but after the second break the constant coefficients recovered, while the trend coefficients continued to fall. This evidence thus shows that there was a significant drop in the gasoline price during the Great Recession, and its growth pace also decreased. However, after 2010, prices have shifted up and continued to grow but with a smaller growth rate. Therefore, it can be argued that the introduction of structural breaks was a necessary step to examine the time-changing dynamics of long-run asymmetries in the gasoline pricing mechanism.

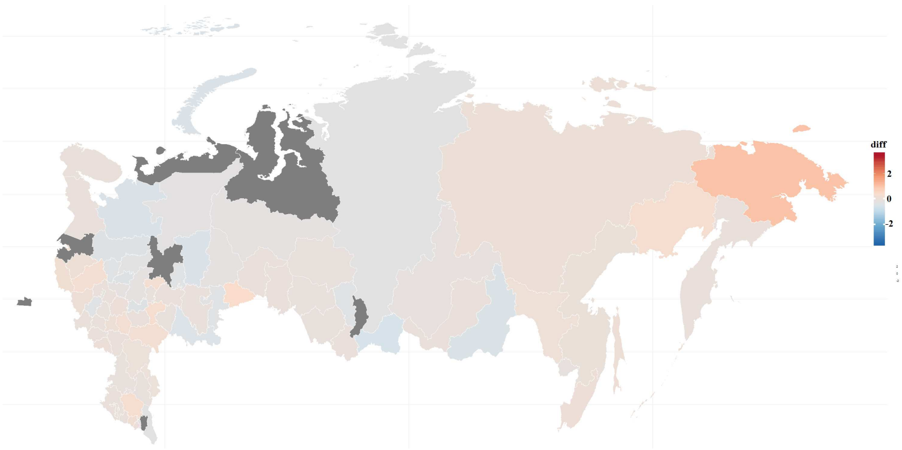

Figure 2: Differences between the positive and negative long-run elasticities of the petrol price to the crude oil price across Russian regions: **Before the first structural break** ($t < 2007$).

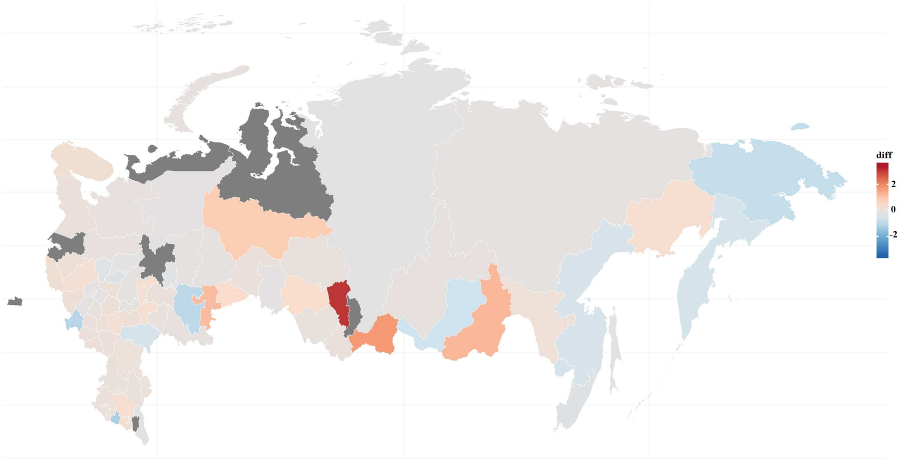

Figure 3: **Between the two structural breaks** ($2007 < t < 2010$).

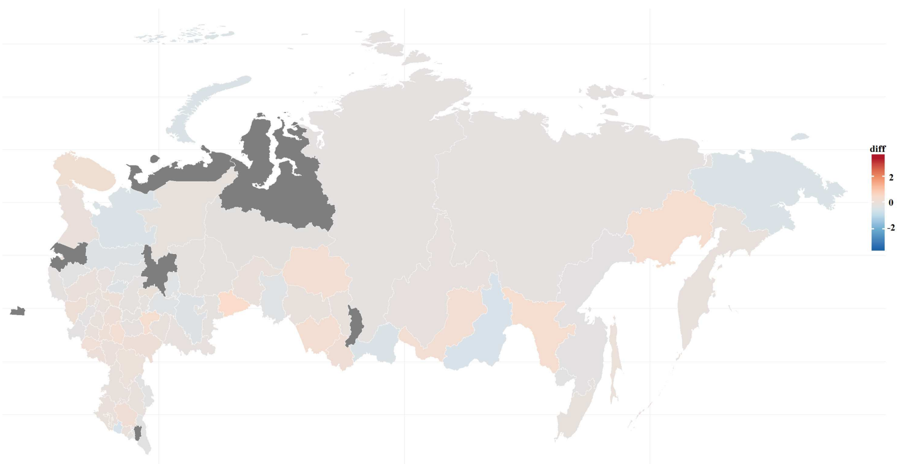

Figure 4: **After the second structural break** ($t > 2010$).

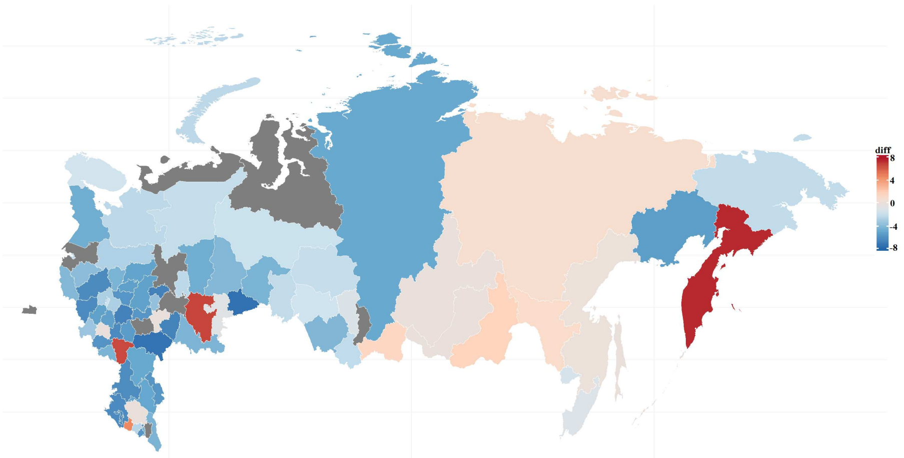

Figure 5: Differences between the positive and negative long-run elasticities of the petrol price to the exchange rate across Russian regions: **Before the first structural break** ($t < 2007$).

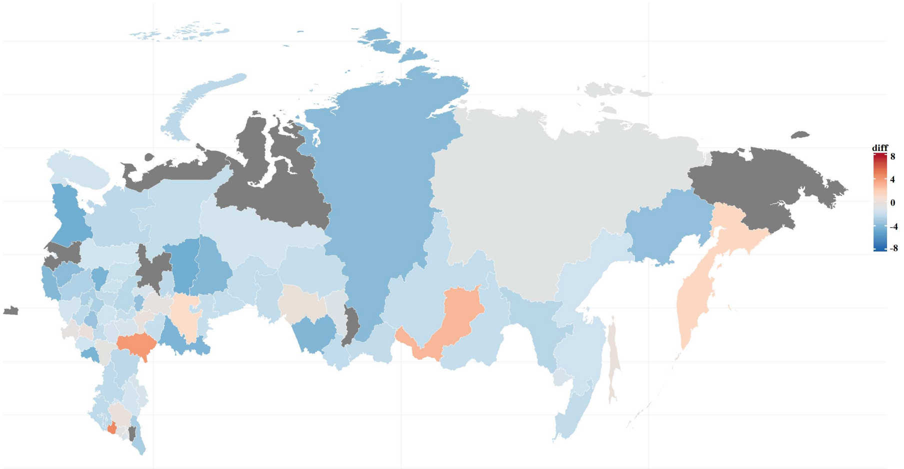

Figure 6: **Between the two structural breaks** ($2007 < t < 2010$).

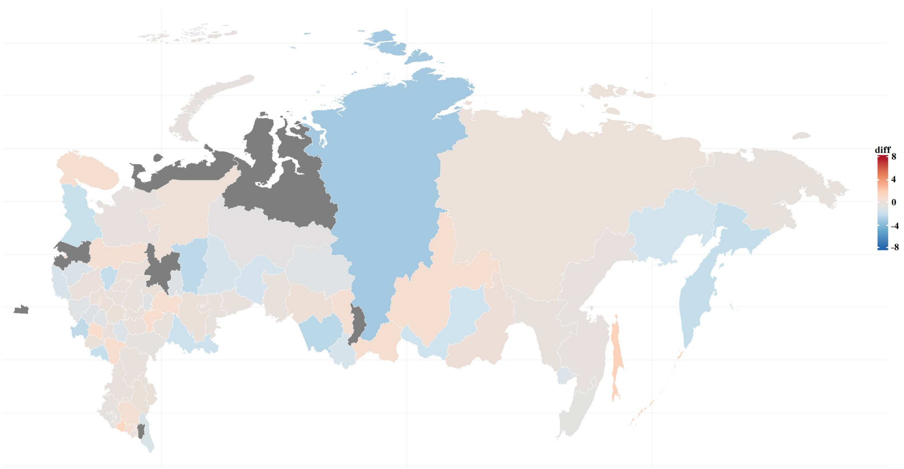

Figure 7: **After the second structural break** ($t > 2010$).

	Wald tests for the null of no asymmetry	
Region	$H_0 : c^+ = c^-$	$H_0 : er^+ = er^-$
Belgorod Region	0.48	0.00
Bryansk region	0.00	0.41
Vladimir region	0.46	0.00
Voronezh region	0.55	0.00
Ivanovo region	0.20	0.00
Kaluga region	0.37	0.00
Kostroma region	0.31	0.00
Kursk region	0.40	0.00
Lipetsk region	0.28	0.00
Moscow region	0.88	0.00
Orel region	0.53	0.00
Ryazan region	0.58	0.00
Smolensk region	0.43	0.00
Tambov region	0.48	0.00
Tver region	0.03	0.00
Tula region	0.62	0.00
Yaroslavl region	0.31	0.00
Moscow	0.60	0.00
Republic of Karelia	0.66	0.00
Republic of Komi	0.00	0.00
Arkhangelsk region	0.00	0.00
Vologda region	0.01	0.00
Kaliningrad region	0.62	0.00
Leningrad region	0.00	0.00
Murmansk region	0.19	0.00
Novgorod region	0.05	0.00
Pskov region	0.00	0.00
St. Petersburg	0.03	0.00
Adigeya Republic	0.41	0.00
Republic of Kalmykia	0.55	0.00
Krasnodar krai	0.00	0.00
Astrakhan region	0.61	0.00
Volgograd region	0.71	0.00
Rostov region	0.53	0.00
Republic of Dagestan	0.00	0.01
Republic of Ingushetia	0.00	0.00
Kabardino-Balkar Republic	0.00	0.00
Karachai-Cherkess Republic	0.02	0.00
Republic of Northern Ossetia - Alania	0.02	0.00
Stavropol krai	0.00	0.00
Bashkortostan Republic	0.00	0.00
Mariy El Republic	0.34	0.00
Mordovia Republic	0.46	0.00
Tatarstan	0.63	0.00
Udmurt Republic	0.18	0.00
Chuvash Republic	0.01	0.00
Perm krai	0.35	0.00
Kirov region	0.46	0.00
Nizhny Novgorod region	0.02	0.00
Orenburg region	0.00	0.00
Penza region	0.91	0.00
Samara region	0.05	0.00
Saratov region	0.51	0.00
Ulyanovsk region	0.00	0.00
Kurgan region	0.54	0.00
Sverdlovsk region	0.82	0.00
Tyumen region	0.00	0.00
Chelyabinsk region	0.00	0.00
Altai Republic	0.36	0.00
Buryatia Republic	0.00	0.00
Tyva Republic	0.00	0.00
Republic Of Khakassia	0.14	0.00
Altai krai	0.71	0.00
Zabaikalskiy krai	0.00	0.00
Krasnoyarsk krai	0.04	0.00
Irkutsk region	0.22	0.00
Kemerovo region	0.00	0.01
Novosibirsk region	0.00	0.01
Omsk region	0.68	0.00
Tomsk region	0.59	0.00
Yakutiya region	0.50	0.57
Kamchatkiy krai	0.02	0.00
Primorski krai	0.13	0.00
Khabarovsk krai	0.03	0.00
Amur region	0.52	0.00
Magadan region	0.00	0.00
Sahalin	0.34	0.00
Jewish Autonomous region	0.02	0.00
Chukotka	0.00	0.00

Table 5: Panel cointegration: Wald tests for the null of no asymmetry

5 Robustness checks

The last stage of our work was to perform a series of robustness checks by including additional variables into our models, and to verify how our previous results changed.

5.1 Regional elections

Balsevich and Podkolzina (2013) suggested that regional governments can influence gasoline prices by using local gasoline companies at the time of regional elections. Their idea is that price regulations are more active during election periods to keep the prices stable. If this hypothesis is true, we should observe a significant change in the model parameters in the proximity of local elections.

To check this hypothesis, we used the previous control variables multiplied with dummy variables for the periods of both regional and presidential election campaigns $[c^+ * D_i, c^- * D_i, er^+ * D_i, er^- * D_i]$, where $*$ is an element-by-element vector product[7]. The dummies were constructed in a following way: $D_{it} = 1$, if the voting took place in month t, or during the nearest 2 months in the i^{th} region, while $D_{it} = 0$ otherwise. We selected 3 months as a proxy for the duration of the election campaign. The dates of the regional elections were collected from Wikipedia (2017).

Figures 8-19 show the relationship between the coefficients previously estimated with the baseline panel cointegration model and those obtained with the model allowing for potential election campaigns effects. The points lie close to the diagonal line of the graphs for most regions, thus showing that the introduction of the new control variables does not significantly affect the panel model estimates. Interestingly, it is possible to observe that the long-run effects of positive changes in the oil price before 2010 are smaller than those in the baseline case for a large group of Russian regions, which seems to show that political pressures to keep the price stables could take place before 2010. However, this evidence changed after 2010, with robust estimates laying above the diagonal line for most regions, thus showing that gasoline prices could react to crude prices with fewer constraints. The long-run effects of positive changes in the exchange rate did not show any significant changes in the proximity of elections, while the long-run effects of negative changes in the exchange rate were mainly smaller than the baseline case before 2010, but this evidence disappeared after that date.

In this regard, we remark that the law dealing with the election of governors was changed twice between 2003 and 2017: in December 2004, the direct elections of governors were abolished and the governors were confirmed in office by the regional legislative bodies following a proposal by the Russian

[7]We considered both regional and presidential elections because there were no regional elections for 11 regions during the 2003-2017 time sample, and only 38 regions had regional gubernatorial elections held more than once in the same sample.

President. In April 2012, the direct elections of governors were reinstated, but the law was amended in 2013 to give the regions the right to replace the national elections of their governors with a vote in the regional parliament. Since then, six regions voluntarily refused direct governor elections: Dagestan, Ingushetia, North Ossetia and Karachay-Cherkessia (2013), Kabardino-Balkaria (2014), and Adygea (2016). Therefore, there were no regional elections between the first and second structural breaks, while between 2010 and 2017 the majority of Russian regions either did not have a direct election of the governor or they had only one, see `https://rg.ru/2004/12/29/gubernatori-dok.html` and `https://rg.ru/2012/05/04/gubernatori-dok.html` for more details. This factor might have contributed to the observed decrease in the pricing asymmetry, thanks to the disappearance of the local political pressure.

In general, this evidence seems to point out to a more competitive gasoline market after 2010, even when proxies for political campaigns are taken into account. Moreover, it confirms that the effects of the exchange rate on gasoline prices are more difficult to control than those of the oil price, due to larger and more variable elasticities.

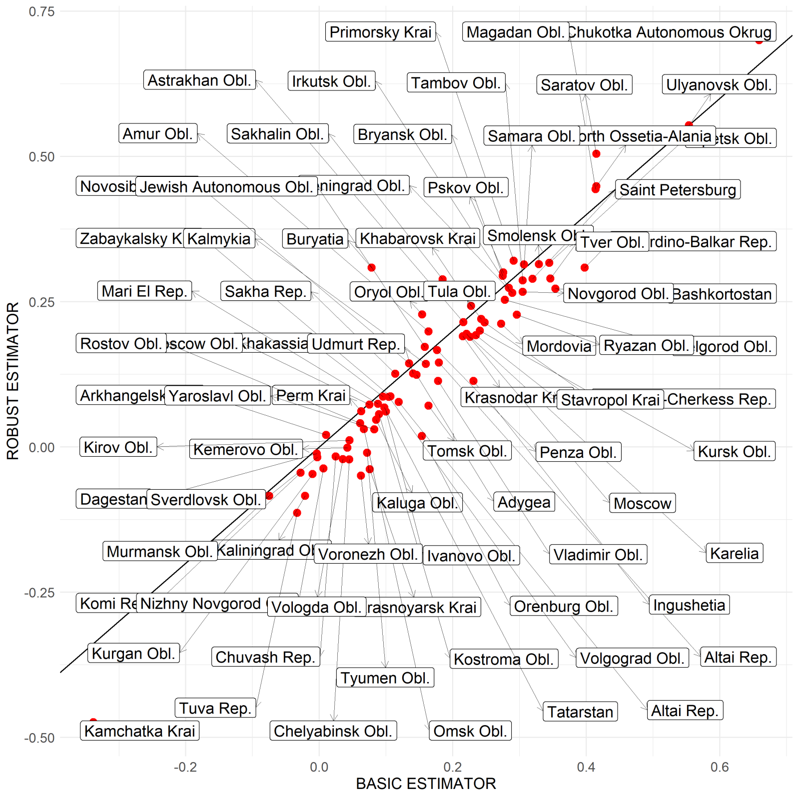

Figure 8: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the oil price before the first structural break** ($t < 2007$).

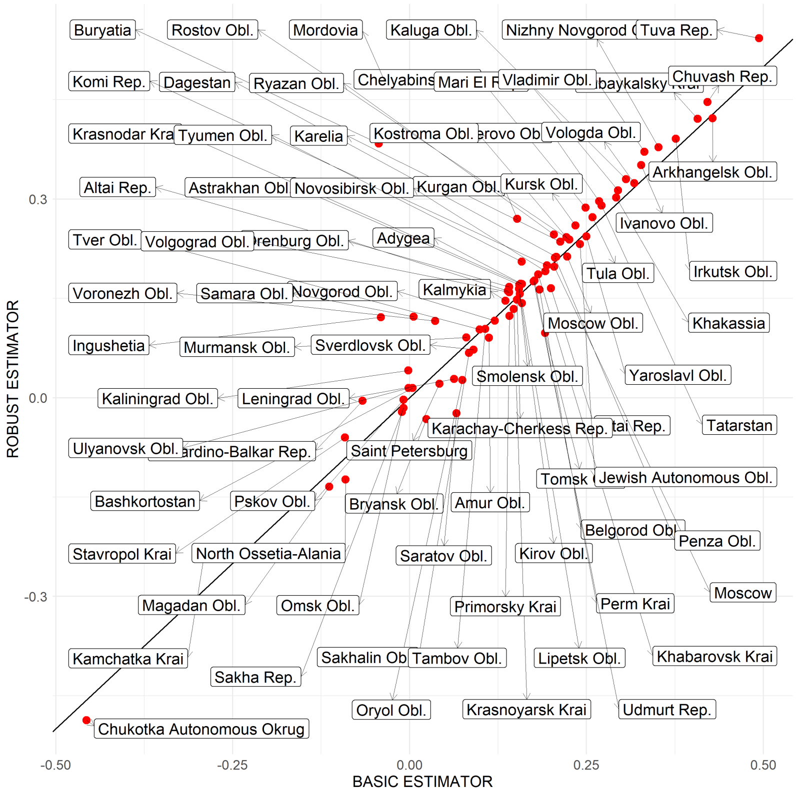

Figure 9: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the oil price before the first structural break** ($t < 2007$)**.**

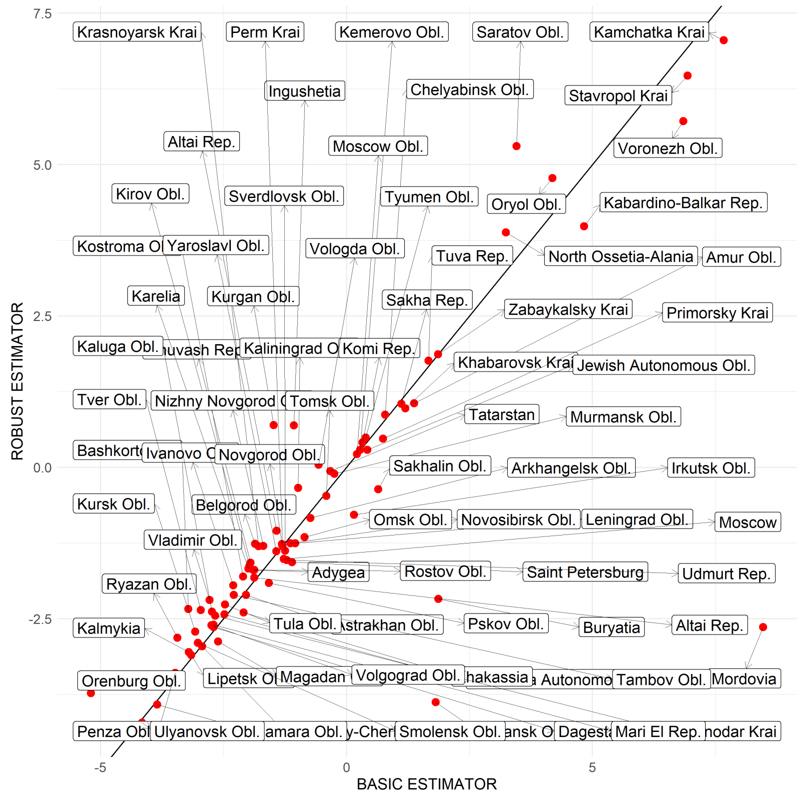

Figure 10: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the exchange rate before the first structural break ($t < 2007$).**

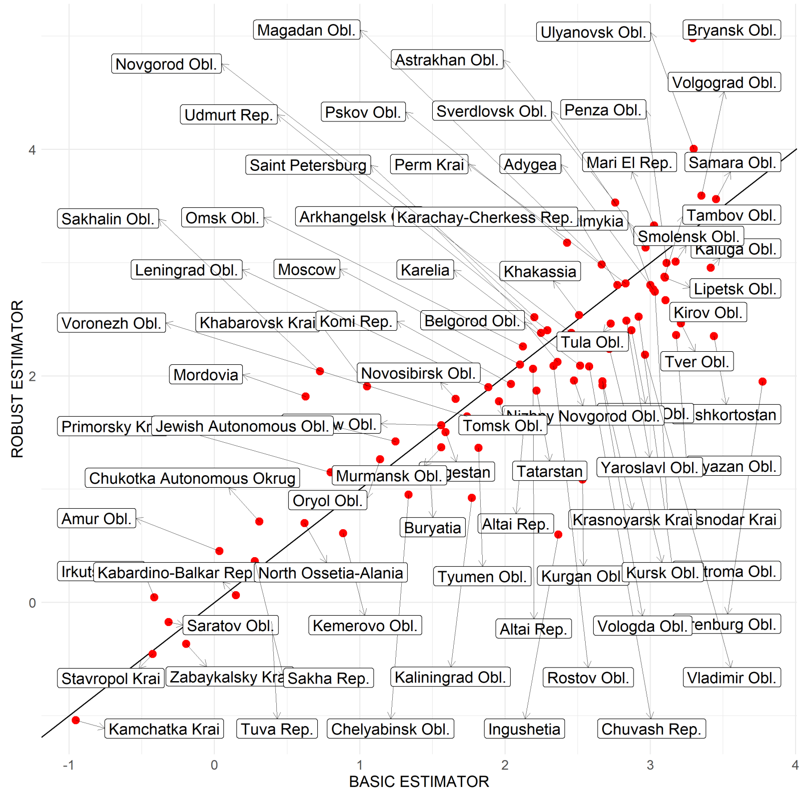

Figure 11: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the exchange rate before the first structural break ($t < 2007$).**

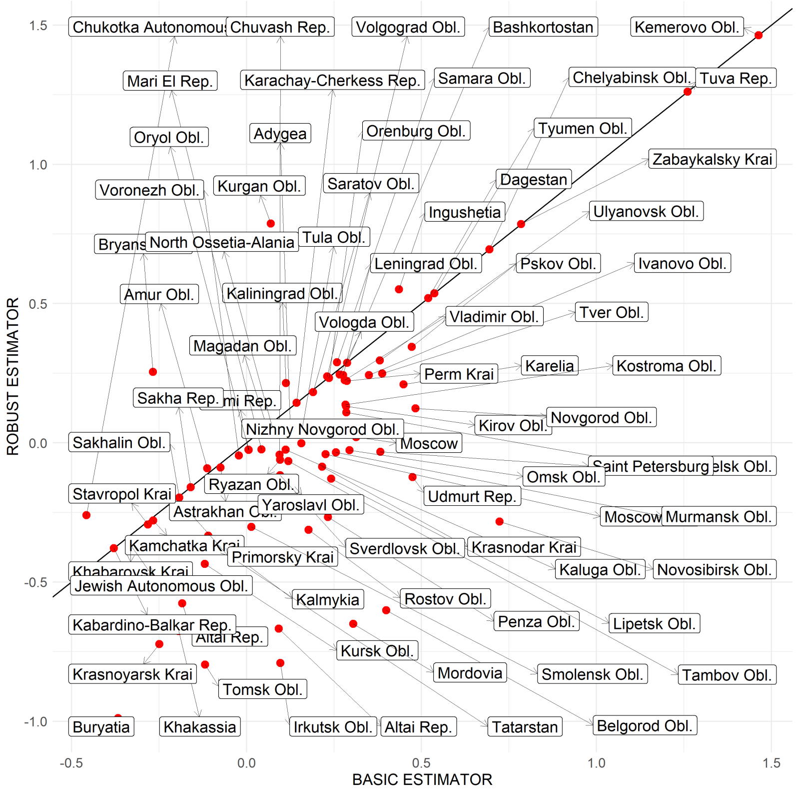

Figure 12: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the oil price between the two structural breaks** ($2007 < t < 2010$).

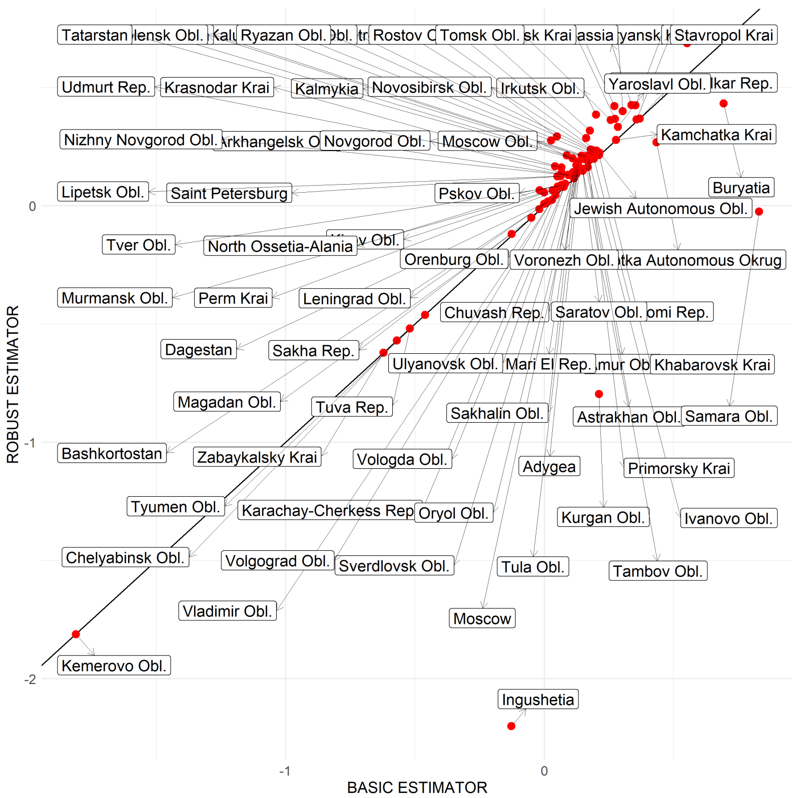

Figure 13: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the oil price between the two structural breaks** ($2007 < t < 2010$).

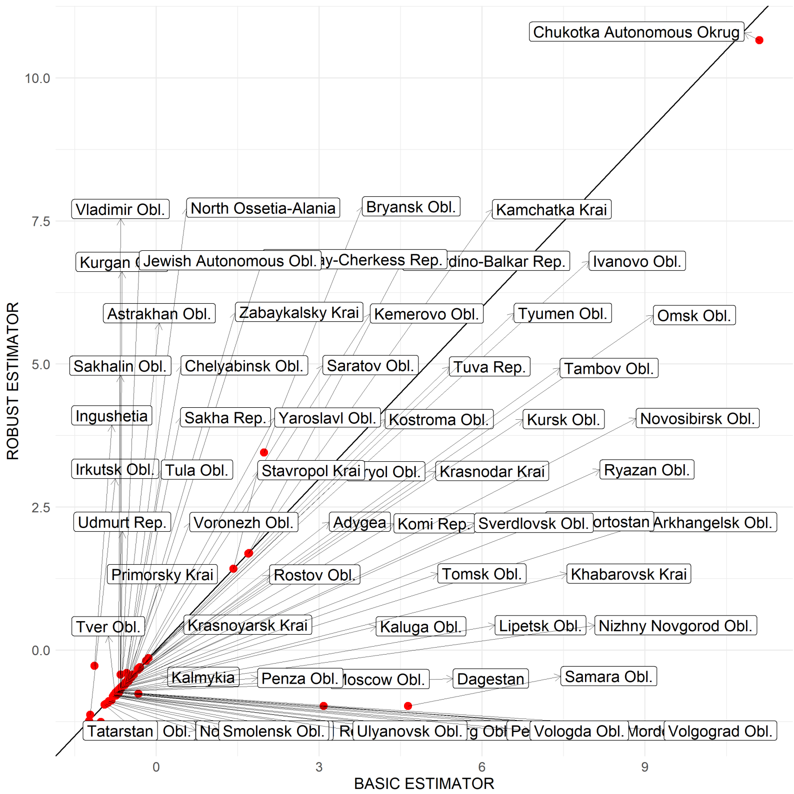

Figure 14: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the exchange rate between the two structural breaks** ($2007 < t < 2010$).

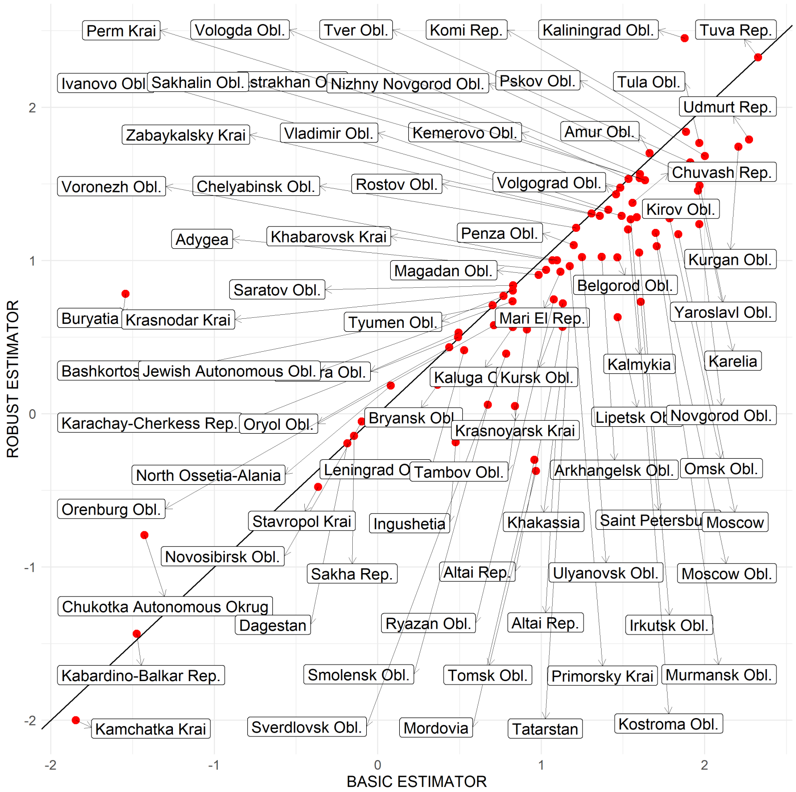

Figure 15: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the exchange rate between the two structural breaks** ($2007 < t < 2010$).

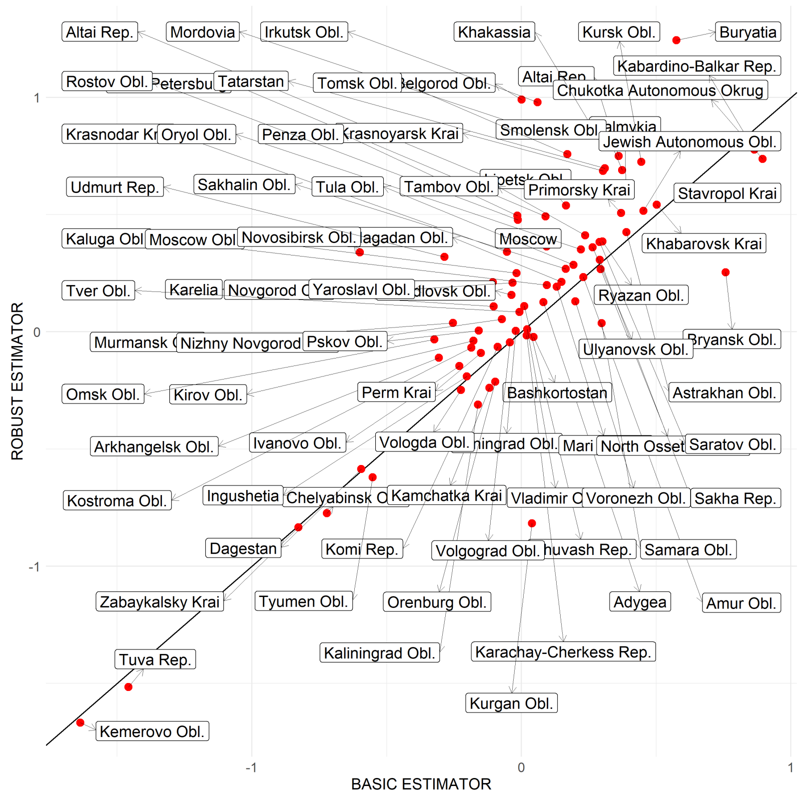

Figure 16: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the oil price after the second structural break** ($t > 2010$).

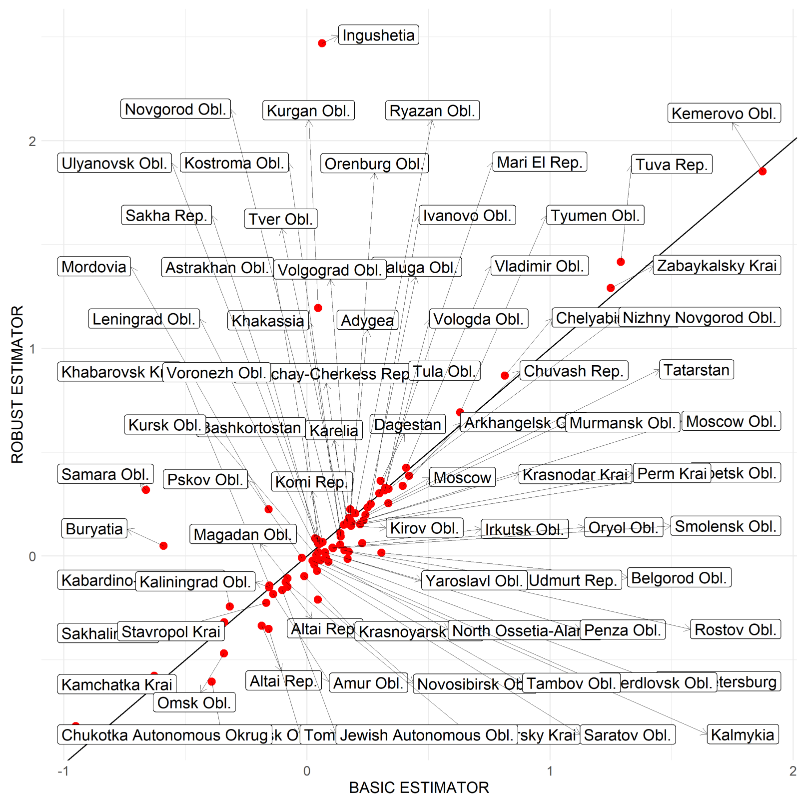

Figure 17: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the oil price after the second structural break** ($t > 2010$).

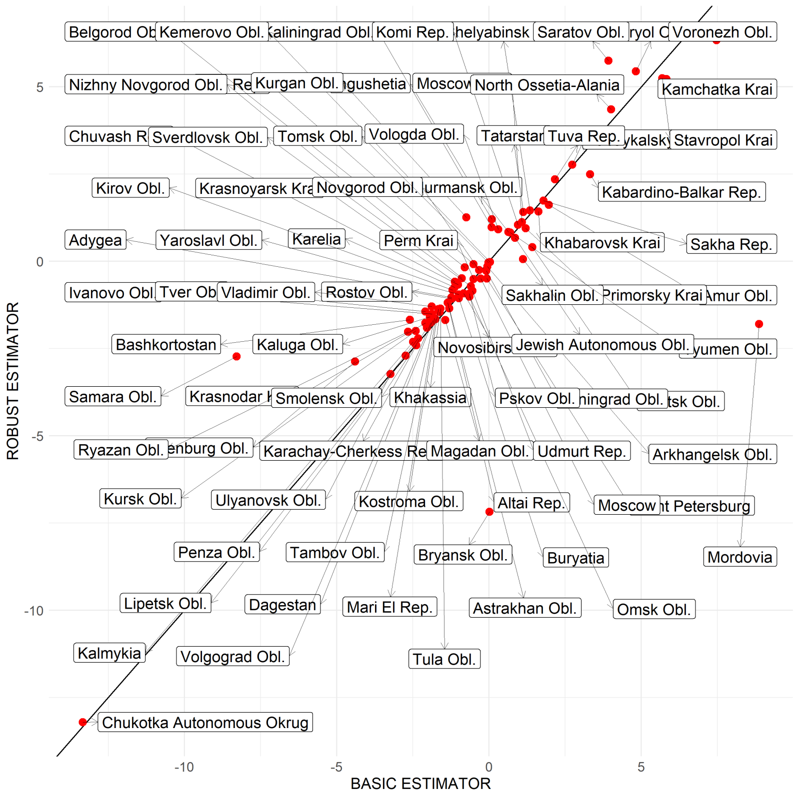

Figure 18: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of positive changes in the exchange rate after the second structural break** ($t > 2010$).

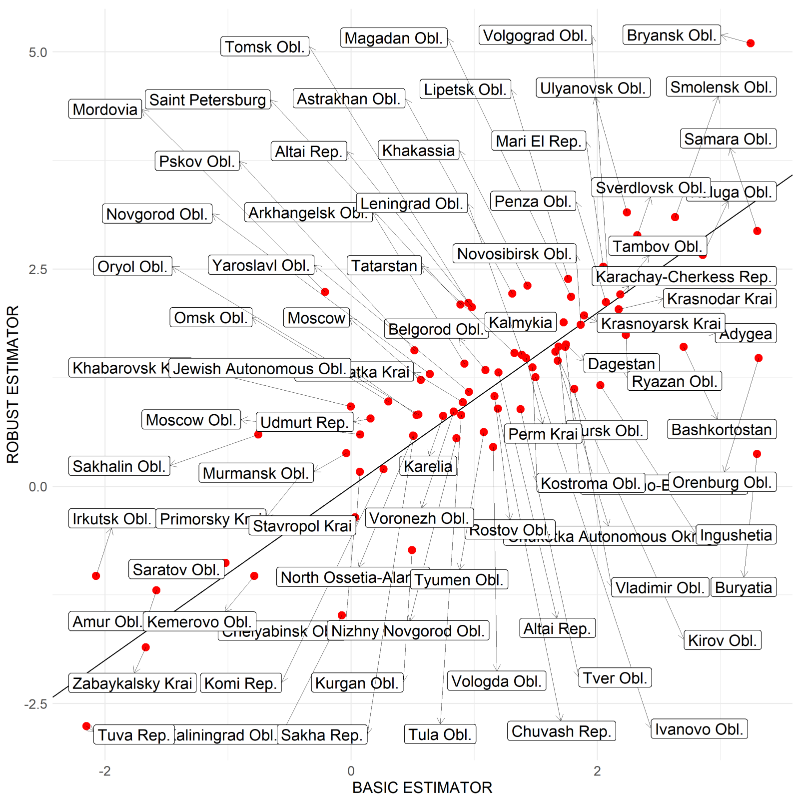

Figure 19: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for regional election campaign. **Long-run effect of negative changes in the exchange rate after the second structural break** ($t > 2010$).

5.2 Taxes and other robustness checks

We previously discussed in the literature review that only yearly pre-tax gasoline prices are available in Russia, and all retail statistics are classified by octane number, whereas the excise tax depends on the ecological class of the fuel. Therefore, it is not straightforward to compute after-tax gasoline prices without significant simplifications. Given these limitations, we decided to employ a single tax rate for all regions, using the excise tax reported in the Tax Code of the Russian Federation (Article 193) and taking into account its changes over time. We then verified how this additional control variable could affect the estimates of our panel cointegration model.

Figures 1-12 in the technical appendix show the scatter plots of the coefficients estimated with the baseline panel cointegration model with breaks, against those obtained with panel models containing the average excise tax as a control variable.

The long-run effects of the price changes in the oil price lie on the diagonal of the graphs for almost all regions between 2007 and 2010, while these effects are lower before 2007 and after 2010. Instead, the long-run effects of changes in the exchange rate lie relatively close to the diagonal line of the graphs for most regions without any particular pattern, even though the effects of negative changes show a large variability for many regions.

This evidence seems to point out that excise taxes have been actively used in the last decade as a tool to fine-tune the gasoline prices following changes in crude oil prices. Therefore, Russian practice seems to have become more in line with international practice, where excise taxes are used to manage the gasoline price in case of adverse changes in its fundamentals or close to elections, see Bagnai and Ospina (2015) and references therein[8]: in this regard, there is a large literature (particularly in the US) that shows how excise taxes can be used in the election cycles to increase the chances of being (re)-elected, see Decker and Wohar (2007), Esteller-Moré and Rizzo (2014), Fredriksson and Mamun (2014), and references therein. To confirm this evidence with excise taxes, an additional analysis at the micro-level would definitely be needed, so we leave this interesting issue as an avenue for further research.

We remark that this evidence is quite similar to that reported for Italy by Bagnai and Ospina (2015) when they examined the effect of taxation on the long-run coefficients. Moreover, in addition to taxation, Bagnai and Ospina (2015) also performed a series of robustness checks involving several other variables that could have a role in the asymmetric pricing of gasoline: namely, crude price volatility, seasonal variation, inventory dynamics, and the degree of capacity utilization. The introduction of

[8]For example, Bagnai and Ospina (2015, p. 49) clearly state that "*the inflationary impact of a currency devaluation could be kept under control by a small reduction in the excises*".

crude oil volatility estimated using a GARCH model did not have a significant impact on the long-run coefficients (not reported), while seasonal dummies were either not significant, or the models augmented with these dummies failed to converge, due to the small sample sizes and the complete lack of seasonality in our dataset.

As for inventory stocks and capacity utilization, these variables were not available at the time of writing this paper.

6 Conclusions and policy implications

This paper checked the potential existence of asymmetric responses of the Russian gasoline prices to the changes in crude oil prices and the Dollar/Ruble exchange rate. The empirical analysis showed that the nonlinear models by Shin, Yu, and Greenwood-Nimmo (2014) and Apergis and Payne (2014) mostly failed to provide robust estimations, showing several misspecification problems. The panel cointegration models allowing for structural breaks showed better results, instead: the model proposed by Banerjee and Carrion-i-Silvestre (2015) improved considerably the data fit and suggested that the pricing asymmetry is present at the regional level but it has changed over time. The Wald tests failed to reject the null hypothesis of symmetric oil price effects on the gasoline price, but the null hypothesis of symmetric effects for the exchange rate was strongly rejected. However, in this latter case, the degree of asymmetry has decreased after 2007, thus highlighting the presence of a more competitive gasoline market. A set of robustness checks confirmed that our results also hold with different model specifications, which consider the effects of elections and changes in the taxation regimes.

In general, the empirical analysis highlighted that the models which worked well for gasoline pricing in Italy, the UK, and in other foreign markets, cannot be used to explain the gasoline price dynamics in the Russian market and structural breaks must also be taken into account. Moreover, this research showed that the "rocket and feather" hypothesis was indeed true for the Russian gasoline market at the regional level up to the Global Financial crisis, but after 2010 the pricing asymmetry became less significant, and mostly related to the indirect effects of the exchange rate dynamics.

These results can be important for regulatory purposes since it is clear that the successful development of the Saint-Petersburg International Mercantile Exchange[9], the wise management of excise taxes and the increased transparency in gasoline retail prices contributed to decreasing the gasoline pricing asymmetry that was strongly present before the Global Financial crisis in 2008. In this regard, it is

[9]The SPIMEX was founded in 2008, and it is the largest commodities exchange in Russia that hosts 99% of organized trading in crude oil and refined products, natural gas, timber and mineral fertilizers in the country, see https://spimex.com/en/about/about for more details.

important to note that the massive increase in online services and mobile apps showing the prices of gas stations in real-time (like Yandex Navigator, for example) helped to increase price transparency and market efficiency[10].

Another implication of the evidence found in this work is that the effects of the exchange rate on gasoline prices are much more difficult to control, and require a larger set of policy measures. In this regard, it is well known that the main factors affecting the volatility of the Ruble exchange rate are oil prices and sanctions, see Aganin and Peresetsky (2018) for a detailed discussion. Given this reality, Russian policymakers have started to develop and implement plans to gradually decrease the importance of hydrocarbons exports in the Russian economy, and to mitigate the effects of sanctions. The recent development of a plan by Russia's energy ministry for gas and nuclear companies Gazprom and Rosatom to begin producing clean hydrogen using electrolysis and pyrolysis from 2024 (see Fadeeva (2020)) is a good step in this direction, and it can deal with both these two issues: first, hydrogen will become an important new global energy carrier in the next decades, and it will likely compete with hydrocarbon markets (see Melnikov, Mitrova, and Chugunov (2019)). Second, using sanctions against green energy exports is much more difficult to justify, particularly in light of the global efforts to mitigate the effects of climate change, which were formally agreed and developed with the 2015 Paris Agreement within the United Nations Framework Convention on Climate Change[11]. A similar policy could be to export electricity generated using nuclear power and onshore wind farms. The development of the latter is becoming increasingly problematic in Europe due to growing opposition from the local populations and the lack of land (particularly in Germany), see Dohmen et al. (2019) and Buck (2019) for more details. Developing the large wind generation potential in Russia (Boute and Willems (2012), Eurek et al. (2017)) could help to diversify the local economy and to shield it from new sanctions, by actively contributing to the global response to the threat of climate change.

[10]One of the first applications for screening gasoline prices in Russia was introduced by Rosneft on the 08/16/2012 (https://sensortower.com/android/RU/saitsoft/app/azs-rosnieft/ru.pichesky.rosneft/overview).Yandex released the Yandex Zapravki app to compare gasoline prices on the 06/16/2015, which was later integrated into Yandex Navigator and Yandex Maps (https://sensortower.com/ios/ru/yandex-llc/app/iandieks-zapravki/963153237/overview). Since December 2018, Yandex Navigator allows the user to pay for fuel using a bankcard linked to this app (Master Card, Visa) or using Apple Pay (https://www.vedomosti.ru/business/articles/2019/04/24/800096-avtomobilisti-1-mlrd-rublei). In February 2020, fuel sales via Yandex.Zapravki reached the mark of 1 million liters per day – about 0.6% of the daily sales of gasoline and diesel fuel at Russian gas stations. Yandex is currently working with independent gas station operators, whose market share is 1.5%. Almost half (45%) of Yandex.Zapravki sales are located in Moscow and the Moscow region, Saint Petersburg comes second with a share of 9%, while Tatarstan, Samara, Sverdlovsk, Novosibirsk and Chelyabinsk regions follow with a share of 13% (https://www.vedomosti.ru/business/articles/2020/03/06/824647-cherez-yandeks). Finally, we remark that Gazpromneft launched the AZS.GO app on the 12/13/2018, which also gives the ability to purchase fuel (https://sensortower.com/ios/ru/llc-gazpromneft-center/app/azs-go-zapravki-gazpromnieft/1440058029/overview).

[11]http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

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Asymmetry and hysteresis in the Russian gasoline market

Technical appendix - not for publication. To be posted on the authors' web sites.

Anna Kolesnikova Dean Fantazzini

A Monthly data: Unit root testing

Table 1: Unit root testing of gasoline prises in rgregions: in levels

	Levels							
Parameter	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
Belgorod.oblast	−5.16***	3	0.879	0.864	−4.745	01.09.2008	0.616	0.007
Bryansk.oblast	−4.539***	1	0.192	0.643	−4.97*	01.10.2008	0.192	0.134
Vladimir.oblast	−4.203***	1	0.517	0.712	−4.992*	01.10.2008	0.043	0.096
Voronezh.oblast	−4.102***	1	0.106	0.287	−4.865*	01.03.2004	0.016	0.047
Ivanovo.oblast	−4.754***	1	0.544	0.737	−4.529	01.07.2008	0.023	0.063
Kaluga.oblast	−5.347***	3	0.357	0.28	−5.298**	01.10.2008	0.253	0.223
Kostroma.oblast	−4.834***	1	0.377	0.765	−4.716	01.10.2008	0.295	0.17
Kursk.oblast	−4.421***	1	0.096	0.319	−5.223**	01.08.2008	0.049	0.011
Lipetsk.oblast	−5.259***	3	0.513	0.887	−4.86*	01.08.2008	0.036	0
Moscow.oblast	−4.636***	1	0.163	0.545	−4.596	01.09.2008	0.13	0.095
Oryol.oblast	−4.501***	1	0.572	0.928	−4.82*	01.09.2008	0.284	0.505
Ryazan.oblast	−4.432***	1	0.125	0.426	−4.517	01.10.2008	0.093	0.167
Smolensk.oblast	−5.169***	1	0.299	0.553	−5.873***	01.10.2008	0.139	0.124
Tambov.oblast	−4.717***	1	0.548	0.696	−4.214	01.09.2008	0.331	0.009
Tver.oblast	−4.16***	1	0.054	0.235	−4.701	01.10.2008	0.092	0.037
Tula.oblast	−3.904**	1	0.454	0.862	−4.613	01.10.2008	0.006	0.002
Yaroslavl.oblast	−4.194***	1	0.432	0.674	−4.258	01.08.2008	0.077	0.01
Moscow	−5.023***	1	0.532	0.875	−4.556	01.09.2008	0.082	0.031
Republic.Of.Karelia	−3.978**	1	0.378	0.788	−5.281**	01.10.2008	0.061	0.002
The.Republic.Of.Komi	−3.337*	1	0.55	0.834	−6.002***	01.10.2008	0.351	0.026
Arkhangelsk.oblast	−4.429***	4	0.813	0.629	−5.244**	01.10.2008	0.009	0.02
Nenets.Autonomous.Okrug	−2.719	1	0.567	0.646	−3.955	01.06.2005	0.359	0.641
Vologda.oblast	−3.418*	1	0.317	0.603	−6.002***	01.10.2008	0.693	0
Kaliningrad.oblast	−4.263***	2	0.489	0	−8.046***	01.10.2008	0.134	0.234
Leningrad.oblast	−2.837	13	0.997	0.956	−6.092***	01.10.2008	0.212	0.688
Murmansk.oblast	−3.543**	13	0.165	0.124	−6.205***	01.12.2008	0.157	0.038
Novgorod.oblast	−4.955***	2	0.651	0.893	−5.875***	01.10.2008	0.34	0.337
Pskov.oblast	−4.477***	2	0.373	0.035	−6.377***	01.10.2008	0.052	0.255
The.Republic.Of.Kalmykia	−3.612**	1	0.132	0.447	−4.386	01.09.2008	0.184	0.012
Krasnodar.Krai	−4.096***	1	0.606	0.79	−5.055*	01.09.2008	0.045	0.119

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Table 1 – continued from previous page

	Levels							
Parameter	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
Astrakhan.oblast	−4.383***	2	0.577	0.566	−4.723	01.10.2008	0.095	0.05
Volgograd.oblast	−3.679**	1	0.619	0.183	−4.727	01.09.2008	0.01	0.002
Rostov.oblast	−4.596***	1	0.174	0.412	−6.041***	01.10.2008	0.001	0.017
The.Republic.Of.Dagestan	−3.953**	1	0.043	0.296	−4.768	01.09.2008	0.051	0.115
The.Republic.Of.Ingushetia	−3.528**	1	0.057	0.319	−5.823***	01.11.2008	0.386	0.044
Kabardino.Balkar.Republic	−3.342*	1	0.244	0.612	−5.54**	01.04.2004	0.349	0.228
Karachay.Cherkess.Republic	−3.377*	1	0.184	0.469	−4.518	01.04.2004	0.157	0.002
Republic.Of.North.Ossetia...Alania	−3.541**	1	0.621	0.87	−4.366	01.09.2008	0.08	0.026
Stavropol.Krai	−3.842**	1	0.075	0.108	−5.42**	01.10.2008	0.498	0.262
Volga.Federal.district	−4.342***	1	0.599	0.865	−4.974*	01.10.2008	0.192	0.044
Republic.Of.Bashkortostan	−3.5**	1	0.503	0.919	−4.149	01.09.2008	0.169	0.103
The.Republic.Of.Mari.El	−4.559***	2	0.536	0.774	−5.089**	01.10.2008	0.131	0.217
The.Republic.Of.Mordovia	−4.821***	2	0.042	0.156	−5.204**	01.08.2008	0.001	0.009
The.Republic.Of.Tatarstan	−4.396***	2	0.298	0.751	−4.571	01.09.2008	0.016	0.024
Udmurtia	−2.901	1	0.182	0.37	−4.808	01.10.2008	0.225	0.058
Chuvash.Republic	−3.725**	1	0.55	0.882	−5.374**	01.10.2008	0.435	0.303
Perm.Krai	−4.2***	2	0.126	0.214	−5.595***	01.10.2008	0.082	0.017
Kirov.oblast	−3.979**	1	0.132	0.549	−5.368**	01.10.2008	0.033	0.028
Nizhny.Novgorod.oblast	−3.904**	1	0.759	0.926	−5.651***	01.10.2008	0.026	0.032
Orenburg.oblast	−3.9**	2	0.544	0.791	−5.253**	01.09.2008	0.005	0
Penza.oblast	−4.196***	1	0.282	0.754	−5.278**	01.09.2008	0.125	0.046
Samara.oblast	−4.384***	1	0.252	0.479	−4.992*	01.10.2008	0.066	0.008
Saratov.oblast	−5.195***	2	0.643	0.792	−5.07*	01.10.2008	0.596	0.546
Ulyanovsk.oblast	−4.555***	1	0.284	0.695	−4.706	01.09.2008	0.86	0.102
Kurgan.oblast	−4.264***	1	0.043	0.239	−5.826***	01.10.2008	0.008	0.001
Sverdlovsk.oblast	−4.106***	1	0.13	0.119	−5.267**	01.10.2008	0.7	0.622
Tyumen.oblast	−4.322***	1	0.446	0.851	−5.351**	01.10.2008	0.002	0.005
Khanty.Mansi.Autonomous.Okrug.Yugra	−4.337***	1	0.294	0.669	−4.925*	01.10.2008	0.002	0.005
Yamalo.Nenets.Autonomous.Okrug	−2.807	1	0.933	0.967	−3.821	01.10.2008	0.544	0.783
Chelyabinsk.oblast	−3.63**	1	0.157	0.167	−5.379**	01.10.2008	0.177	0.039
The.Republic.Of.Altai	−3.998***	1	0.282	0.598	−6.591***	01.10.2008	0.014	0.001
The.Republic.Of.Buryatia	−4.407***	1	0.341	0.609	−5.046*	01.10.2008	0.682	0.074
Tuva	−4.449***	1	0.028	0.204	−5.073*	01.10.2008	0.004	0.001

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Table 1 – continued from previous page

	Levels							
Parameter	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
The.Republic.Of.Khakassia	-5.92^{***}	4	0.814	0.981	-5.353^{**}	01.09.2008	0.229	0.084
Altai.Krai	-4.998^{***}	1	0.071	0.086	-6.182^{***}	01.08.2008	0.027	0.004
Zabaykalsky.Krai	-3.553^{**}	1	0.074	0.283	-4.477	01.10.2008	0.644	0.403
Krasnoyarsk.Krai	-4.537^{***}	1	0.107	0.381	-5.866^{***}	01.09.2008	0.09	0.003
Irkutsk.oblast	-3.932^{**}	1	0.052	0.188	-5.654^{***}	01.10.2008	0.803	0.048
Kemerovo.oblast	-4.381^{***}	1	0.083	0.173	-5.455^{**}	01.09.2008	0.062	0
Novosibirsk.oblast	-3.753^{**}	1	0.094	0.104	-5.799^{***}	01.07.2008	0.151	0.005
Omsk.oblast	-4.123^{***}	2	0.013	0.04	-4.926^{*}	01.07.2008	0.002	0.001
Tomsk.oblast	-4.377^{***}	1	0.234	0.254	-5.682^{***}	01.08.2008	0.037	0
The.Republic.Of.Sakha..Yakutia.	-2.802	1	0.532	0.857	-3.861	01.04.2008	0.603	0.387
Kamchatka.Krai	-3.914^{**}	1	0.547	0.519	-4.416	01.03.2004	0	0.002
Primorsky.Krai	-3.504^{**}	1	0.535	0.531	-3.994	01.10.2008	0.607	0.144
Khabarovsk.Krai	-3.619^{**}	1	0.41	0.628	-4.482	01.09.2008	0.482	0.045
Amur.oblast	-3.967^{**}	1	0.456	0.685	-4.369	01.07.2009	0.03	0.045
Magadan.oblast	-4.121^{***}	1	0.173	0.264	-4.747	01.01.2009	0	0.002
Sakhalin.oblast	-3.271^{*}	1	0.986	0.775	-4.318	01.08.2009	0.831	0.11
Jewish.Autonomous.oblast	-3.302^{*}	1	0.492	0.849	-4.194	01.11.2007	0.687	0.056
Chukotka.Autonomous.Okrug	-1.621	1	0.083	0.228	-5.929^{***}	01.06.2008	0.234	0.335

Table 2: Unit root testing of gasoline prises in rgregions: in differences

	Differences							
Region	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
Belgorod.oblast	−6.685***	0	0.029	0.033	−5.406***	01.07.2006	0.673	0.456
Bryansk.oblast	−6.825***	0	0.143	0.161	−5.093**	01.08.2005	0.891	0.452
Vladimir.oblast	−6.279***	0	0.785	0.387	−5.488***	01.08.2005	0.892	0.089
Voronezh.oblast	−5.554***	0	0.208	0.031	−5.494***	01.12.2009	0.001	0.008
Ivanovo.oblast	−6.85***	0	0.527	0.222	−5.475***	01.08.2006	0.77	0.362
Kaluga.oblast	−6.186***	0	0.005	0.008	−5.875***	01.11.2009	0.844	0.702
Kostroma.oblast	−7.27***	0	0.491	0.191	−5.593***	01.08.2006	0.52	0.271
Kursk.oblast	−6.039***	0	0.035	0.157	−5.834***	01.06.2008	0.344	0.296
Lipetsk.oblast	−5.964***	3	0.098	0.34	−5.328**	01.07.2006	0.634	0.309
Moscow.oblast	−5.818***	0	0.452	0.17	−5.604***	01.08.2005	0.999	0.179
Oryol.oblast	−6.255***	0	0.613	0.277	−5.087**	01.08.2005	0.419	0.544
Ryazan.oblast	−5.905***	0	0.122	0.07	−5.964***	01.08.2005	0.313	0.265
Smolensk.oblast	−5.914***	0	0.15	0.107	−5.006**	01.12.2009	0.244	0.241
Tambov.oblast	−6.67***	0	0.358	0.137	−5.016**	01.07.2006	0.883	0.586
Tver.oblast	−6.177***	0	0.02	0.04	−5.278**	01.08.2005	0.846	0.363
Tula.oblast	−5.784***	0	0.706	0.5	−5.255**	01.08.2005	0.682	0.329
Yaroslavl.oblast	−7.159***	0	0.736	0.242	−5.837***	01.08.2006	0.798	0.763
Moscow	−5.451***	0	0.228	0.225	−5.514***	01.12.2009	0.118	0.248
Republic.Of.Karelia	−6.094***	0	0.263	0.357	−5.248**	01.07.2008	0.087	0.115
The.Republic.Of.Komi	−7.254***	0	0.791	0.53	−5.354***	01.07.2008	0.407	0.105
Arkhangelsk.oblast	−6.621***	1	0.031	0.107	−4.73*	01.07.2008	0.027	0.071
Nenets.Autonomous.Okrug	−8.039***	0	0.521	0.648	−4.656*	01.06.2008	0.387	0.544
Vologda.oblast	−6.685***	0	0.824	0.543	−5.193**	01.06.2008	0.095	0
Kaliningrad.oblast	−6.5***	0	0.458	0	−5.021**	01.08.2008	0.011	0.006
Leningrad.oblast	−3.938***	11	0.718	0.932	−4.86**	01.12.2009	0.78	0.792
Murmansk.oblast	−3.906***	11	0.127	0.075	−4.785*	01.08.2008	0.26	0.013
Novgorod.oblast	−4.954***	0	0.019	0.151	−5.137**	01.06.2008	0.016	0.044
Pskov.oblast	−5.593***	0	0.175	0.005	−5.211**	01.06.2008	0.004	0.003
The.Republic.Of.Kalmykia	−6.931***	0	0.216	0.24	−4.944**	01.12.2009	0.991	0.803
Krasnodar.Krai	−6.167***	0	0.725	0.448	−5.284**	01.08.2005	0.77	0.144
Astrakhan.oblast	−6.268***	1	0.232	0.15	−4.623*	01.08.2005	0.166	0.02

Continued on next page

Table 2 – continued from previous page

	Differences							
Region	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
Volgograd.oblast	−5.671***	0	0.558	0.075	−5.002**	01.06.2008	0.386	0.207
Rostov.oblast	−6.841***	0	0.805	0.123	−5.378***	01.12.2009	0.684	0.372
The.Republic.Of.Dagestan	−7.301***	0	0.057	0.142	−5.367***	01.11.2010	0.864	0.084
The.Republic.Of.Ingushetia	−6.537***	0	0.094	0.167	−5.308**	01.09.2008	0.002	0
Kabardino.Balkar.Republic	−7.11***	0	0.997	0.577	−5.114**	01.08.2005	0.103	0.029
Karachay.Cherkess.Republic	−7.147***	0	0.723	0.482	−5.174**	01.08.2005	0.049	0.007
Republic.Of.North.Ossetia...Alania	−7.387***	0	0.054	0.105	−4.642*	01.03.2005	0.656	0.804
Stavropol.Krai	−6.279***	0	0.976	0.045	−5.194**	01.08.2005	0.115	0.041
Volga.Federal.district	−5.641***	0	0.219	0.263	−5.254**	01.11.2009	0.893	0.812
Republic.Of.Bashkortostan	−7.738***	0	0.627	0.624	−5.164**	01.09.2005	0.56	0.768
The.Republic.Of.Mari.El	−6.215***	0	0.166	0.207	−5.476***	01.11.2009	0.451	0.695
The.Republic.Of.Mordovia	−5.797***	0	0.268	0.024	−5.504***	01.04.2005	0.649	0.062
The.Republic.Of.Tatarstan	−6.292***	0	0.019	0.129	−5.653***	01.12.2009	0.94	0.03
Udmurtia	−6.731***	0	0.552	0.259	−5.041**	01.08.2006	0.472	0.584
Chuvash.Republic	−6.911***	0	0.597	0.706	−5.572***	01.07.2008	0.97	0.087
Perm.Krai	−5.726***	0	0.04	0.076	−4.814**	01.09.2008	0.045	0.02
Kirov.oblast	−7.059***	0	0.119	0.338	−5.191**	01.08.2006	0.977	0.558
Nizhny.Novgorod.oblast	−6.298***	0	0.62	0.558	−5.126**	01.06.2008	0.082	0.065
Orenburg.oblast	−5.751***	0	0.133	0.245	−5.524***	01.02.2011	0.076	0.042
Penza.oblast	−5.369***	0	0.215	0.142	−5.153**	01.12.2009	0.316	0.375
Samara.oblast	−5.9***	0	0.171	0.051	−5.228**	01.02.2011	0.245	0.411
Saratov.oblast	−5.172***	0	0.01	0.08	−5.066**	01.08.2005	0.773	0.072
Ulyanovsk.oblast	−7.012***	4	0.167	0.277	−5.142**	01.08.2005	0.827	0.082
Kurgan.oblast	−7.092***	0	0.018	0.08	−5.624***	01.11.2009	0.779	0.844
Sverdlovsk.oblast	−6.265***	0	0.081	0.029	−4.892**	01.08.2006	0.556	0.199
Tyumen.oblast	−6.453***	0	0.151	0.207	−5.493***	01.06.2008	0.002	0
Khanty.Mansi.Autonomous.Okrug.Yugra	−6.576***	0	0.044	0.085	−5.542***	01.08.2006	0.022	0.014
Yamalo.Nenets.Autonomous.Okrug	−6.764***	0	0.828	0.7	−5.131**	01.03.2011	0.443	0.258
Chelyabinsk.oblast	−6.081***	0	0.466	0.074	−5.664***	01.07.2008	0.023	0.003
The.Republic.Of.Altai	−7.52***	0	0.154	0.235	−5.103**	01.06.2008	0.024	0.05
The.Republic.Of.Buryatia	−6.683***	0	0.369	0.114	−4.831**	01.08.2008	0.167	0.059
Tuva	−8.298***	0	0.005	0.036	−5.079**	01.07.2008	0.555	0.21
The.Republic.Of.Khakassia	−6.294***	0	0.025	0.02	−5.284**	01.07.2008	0.33	0.039

Continued on next page

Table 2 – continued from previous page

	Differences							
Region	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
Altai.Krai	−7.259***	4	0.207	0.105	−5.491***	01.06.2008	0.243	0.063
Zabaykalsky.Krai	−7.041***	0	0.134	0.157	−4.962**	01.08.2008	0.665	0.668
Krasnoyarsk.Krai	−6.879***	0	0.02	0.068	−5.629***	01.07.2008	0.558	0.007
Irkutsk.oblast	−6.173***	0	0.028	0.062	−5.159**	01.07.2008	0.048	0.011
Kemerovo.oblast	−7.023***	4	0.195	0.336	−5.205**	01.06.2008	0.466	0.035
Novosibirsk.oblast	−6.211***	0	0.016	0.018	−5.204**	01.06.2008	0.015	0.001
Omsk.oblast	−6.579***	4	0.153	0.257	−4.782*	01.08.2006	0.819	0.106
Tomsk.oblast	−6.32***	0	0.029	0.028	−5.202**	01.07.2006	0.602	0.561
The.Republic.Of.Sakha..Yakutia.	−7.817***	0	0.96	0.865	−4.899**	01.10.2008	0.653	0.619
Kamchatka.Krai	−6.1***	0	0.173	0.135	−5.338**	01.02.2004	0	0
Primorsky.Krai	−6.946***	0	0.51	0.384	−4.582*	01.08.2008	0.082	0.178
Khabarovsk.Krai	−6.541***	0	0.464	0.352	−4.947**	01.08.2008	0.131	0.07
Amur.oblast	−6.864***	0	0.488	0.358	−5.059**	01.08.2008	0.423	0.077
Magadan.oblast	−7.022***	0	0.089	0.063	−5.347***	01.10.2008	0.165	0.154
Sakhalin.oblast	−6.207***	0	0.947	0.48	−4.572	01.09.2008	0.316	0.095
Jewish.Autonomous.oblast	−7.111***	0	0.819	0.637	−5.364***	01.08.2008	0.716	0.182
Chukotka.Autonomous.Okrug	−8.35***	0	0.236	0.446	−4.673*	01.05.2009	0.126	0.237

Table 3: Unit root testing of independent variables

	Levels							
Region	**ADF**	**lags**	**BG(6)**	**BG(12)**	**ZA**	**breakpoint**	**BG(6)**	**BG(12)**
er	-1.122	2	0.059	0.384	-2.787	01.08.2013	0.704	0.784
c	-1.883	1	0.085	0.213	-3.086	01.08.2013	0.474	0.597
	Differences							
er	-6.837^{***}	0	0.071	0.396	-5.1^{**}	01.06.2014	0.001	0.001
c	-5.068^{***}	0	0.073	0.139	-5.272^{**}	01.12.2009	0.307	0.456

Region	*Break dates*		*Coefficient estimates*																		
	Break1	**Break2**	**Const**	**Trend**	**c+**	**c-**	**er+**	**er-**	**Const*d1**	**Trend*d1**	**c+ * d1**	**c- * d1**	**er+ * d1**	**er- * d1**	**Const*d2**	**Trend*d2**	**c+ * d2**	**c- * d2**	**er+ * d2**	**er- * d2**
Belgorod Region	01 02 07	01 05 09	2.31***	0.03***	0.27***	0.18**	-1.85*	2.36***	-0.18*	-0.02	0.12	-0.16	1.03	-0.89	0.5179***	-0.01	-0.27	0.12	1.06***	-1.27**
Bryansk region	01 02 07	01 05 09	2.26***	0.02	0.27	0.02	1.81	3.29***	0.25***	0.01	0.54*	0.52**	0.17	-2.92**	-0.21	-0.02**	0.48***	-0.41***	-1.79***	-0.04
Vladimir region	01 12 06	01 05 09	2.28***	0.04***	0.18***	0.33***	-2.78***	2.96***	-0.33***	-0.02**	0.1	-0.26***	2.09**	-1.55**	0.66***	-0.01***	-0.15***	0.07	0.90***	-1.15
Voronezh region	01 06 04	01 04 09	2.25***	0.02	0.06	0.03	6.84**	1.73	0.18***	0.01	-0.08	0.09	−7.31**	-0.64	0.08	−0.01***	0.14	0.00	0.62***	−0.90***
Ivanovo region	01 02 07	01 05 09	2.28***	0.04***	0.10	0.32***	−2.30**	2.87***	−0.28***	−0.02**	0.25	-0.15	1.96**	−1.37*	0.71***	0.00	-0.33	-0.07	0.43***	−1.37**
Kaluga region	01 03 07	01 05 09	2.34***	0.04***	0.08	0.30***	−2.73***	3.41***	−0.56***	-0.2	0.03	-0.12	2.09**	−2.59***	0.77***	−0.02**	0.01	-0.06	0.79***	-0.56
Kostroma region	01 02 07	01 05 09	2.29***	0.04***	0.09	0.22***	−2.10**	2.91***	−0.29***	−0.02*	0.19	-0.02	1.80**	−1.37*	0.76***	-0.01	-0.27	-0.08	0.44***	−1.44***
Kursk region	01 03 07	01 04 09	2.32***	0.03***	0.24***	0.23**	−3.07***	2.71***	−0.56***	0.01	-0.35	0.11	2.62***	−1.58*	0.99***	−0.04***	0.20	−0.19*	0.67***	−1.03*
Lipetsk region	01 02 07	01 05 09	2.30***	0.03***	0.34***	0.15**	−3.15***	3.10***	−0.28***	-0.01	-0.10	-0.10	2.49***	−1.63**	0.61***	-0.01	-0.18	0.06	0.83***	−1.33***
Moscow region	01 04 07	01 05 09	2.32***	0.02***	0.22***	0.20**	-1.27	2.10***	−0.75***	0.00	0.09	-0.07	0.49	-0.27	0.94***	−0.02**	-0.12	0.04	1.01***	−1.53***
Orel region	01 07 04	01 05 09	2.26***	0.01	0.15	0.07	4.18	1.13	0.17***	0.00	-0.15	0.05	-4.61	-0.42	0.22	−0.01***	0.07	0.03	0.64***	−0.59**
Ryazan region	01 03 07	01 05 09	2.31***	0.03***	0.30***	0.20**	−3.43***	3.18***	−0.50***	0.00	-0.2	0.01	2.88***	−2.10***	0.90***	−0.02***	0.00	0.00	0.77***	−0.94*
Smolensk region	01 03 07	01 05 09	2.31***	0.03***	0.33***	0.15**	−3.02***	3.17***	−0.65***	0.00	-0.32	-0.01	2.15***	−2.50***	0.91***	−0.02***	0.04	-0.05	0.98***	-0.54
Tambov region	01 02 07	01 05 09	2.31***	0.03***	0.30***	0.11	−2.29***	3.10***	-0.01	-0.01	-0.19	0.05	1.88**	−2.18***	0.29**	-0.01	-0.07	-0.08	0.50***	-0.77
Tver region	01 03 07	01 05 09	2.31***	0.03***	0.34***	0.10	−2.96***	3.21***	−0.45***	-0.01	0.04	-0.05	2.20***	−1.30*	0.82***	-0.01	-0.35***	0.05	0.88***	−1.83***
Tula region	01 03 07	01 05 09	2.30***	0.03***	0.24***	0.25***	−2.46***	2.73***	−0.57***	0.00	-0.08	-0.12	1.85**	-0.75	1.02***	−0.03***	-0.05	0.06	0.88***	−1.83***
Yaroslavl region	01 04 07	01 04 09	2.32***	0.04***	0.08	0.25***	−1.42***	2.84***	−0.61***	0.00	0.06	0.03	1.08	-0.87	0.98***	−0.03***	-0.12	−0.18**	0.44**	−1.88***
Moscow	01 04 07	01 05 09	2.40***	0.02***	0.07	0.23***	0.21	1.56***	−0.65***	0.00	0.15	-0.09	-0.91	0.14	0.83***	−0.02***	-0.09	0.01	0.87***	−1.49***
Republic of Karelia	01 03 07	01 05 09	2.45***	0.03***	0.23***	0.22***	−1.99***	2.52***	−0.70***	0.00	0.22	-0.05	1.28	-0.55	0.88***	−0.02***	-0.33	-0.05	0.87***	−1.77***
Republic of Komi	01 03 07	01 04 09	2.42***	0.04***	-0.07	0.19***	0.32	2.04***	−0.63***	0.01	0.08	0.0000	-0.85	-0.15	0.89***	−0.03***	-0.01	−0.13**	0.63***	−1.78***
Arkhangelsk region	01 12 06	01 05 09	2.44***	0.04***	0.01	0.43***	-0.73	2.24***	−0.51***	−0.02**	0.27	−0.34***	0.14	0.87	0.88***	−0.01***	-0.32*	-0.03	0.68***	−1.33***
Vologda region	01 02 07	01 05 09	2.40***	0.04***	0.04	0.32***	-0.56	2.67***	−0.64***	-0.01	0.23	−0.24***	-0.18	−1.07*	0.96***	−0.02***	-0.26*	0.00	0.87***	−1.52***
Kaliningrad region	01 12 07	01 05 09	2.50***	0.02***	-0.02	0.00	−0.99**	1.77***	−1.88***	0.02***	0.13	0.19***	-0.04	0.11	2.14***	−0.05***	-0.14	−0.15**	1.07***	−1.84***
Leningrad region	01 03 07	01 06 11	2.34***	0.02**	0.20***	0.06	-1.04	1.88***	−0.45***	0.00	-0.01	-0.06	0.10	−1.35**	1.02***	−0.01***	-0.31*	-0.02	0.96***	−0.50**
Murmansk region	01 04 07	01 06 09	2.54***	0.02***	-0.03	0.08	-0.24	1.56***	−0.69***	0.00	−0.28*	-0.08	-0.49	0.15	1.01***	−0.02***	-0.31*	0.10	0.88***	−1.60***
Novgorod region	01 04 07	01 05 09	2.41***	0.02***	0.30***	0.12*	−1.31***	2.45***	−0.77***	0.00	0.18	-0.05	0.42	-0.49	0.96***	−0.01***	-0.41**	0.02	0.99***	−1.82***
Pskov region	01 04 07	01 05 09	2.42***	0.02***	0.27***	0.00	−1.58***	2.43***	−0.74***	0.00	0.20	0.08	0.70	-0.42	0.93***	−0.01*	-0.43**	-0.01	0.93***	−1.91***
St. Petersburg	01 04 07	01 05 09	2.37***	0.02***	0.32***	0.04	-1.1	2.20***	−0.60***	0.00	0.06	0.01	0.18	-0.59	0.59***	-0.01	-0.23	0.03	1.04***	−1.32***
Adigeya Republic	01 03 07	01 05 09	2.37***	0.03***	0.15***	0.16***	−1.89***	3.02***	−0.38***	-0.01	-0.02	-0.02	1.44***	−1.99***	0.71***	−0.02***	-0.06	0.02	0.65***	−0.93***
Republic of Kalmykia	01 03 07	01 04 09	2.35***	0.03***	0.16***	0.14*	−3.20***	3.00***	−0.53***	0.01	-0.26	0.02	2.56***	−1.47***	0.57***	−0.03***	0.22	-0.11	0.71***	−1.27***
Krasnodar krai	01 03 07	01 12 11	2.35***	0.03***	0.22***	0.16**	−2.67***	3.03***	−0.36***	−0.02***	0.00	-0.09	2.18***	−2.20***	0.81***	−0.01***	-0.27***	0.02	0.58***	−0.86***
Astrakhan region	01 03 07	01 04 09	2.38***	0.03***	0.22***	0.15**	−2.04***	2.75***	−0.65***	0.01	-0.29	-0.01	1.38***	−1.12***	0.71***	−0.04***	0.17	-0.10	0.74***	−1.45***
Volgograd region	01 03 07	01 05 09	2.37***	0.04***	0.10*	0.14*	−2.75***	3.35***	−0.37***	−0.02***	0.12	-0.11	2.02***	−1.89***	0.53***	−0.01*	-0.15	0.03	0.84***	−1.27***
Rostov region	01 03 07	01 05 09	2.38***	0.03***	0.06	0.23***	−1.88***	2.33***	−0.43***	-0.01	0.12	-0.06	1.38*	-0.97	0.62***	−0.02***	-0.07	-0.05	0.65***	−1.17***
Republic of Dagestan	01 01 07	01 02 11	2.28***	0.03***	0.00	0.21***	−2.71***	1.59**	-0.09	−0.04***	0.52***	-0.19	2.00*	−1.78**	1.02***	0.02***	-0.59***	0.10	0.85***	0.15
Republic of Ingushetia	01 05 07	01 04 11	2.41***	0.02***	0.23***	-0.04	-1.07	2.36***	−0.50***	−0.01*	0.20*	-0.09	-0.06	−1.89***	0.82***	0.00	-0.43***	0.10	1.16***	-0.34
Kabardino-Balkar Republic	01 08 04	01 11 08	2.31***	-0.01	0.40	-0.06	4.83*	0.15	0.24***	0.03*	−0.77***	0.43**	-3.13	-1.62	0.05	−0.02***	0.46***	-0.25***	−1.50***	1.59***
Karachai-Cherkess Republic	01 01 07	01 11 11	2.38***	0.03***	0.25***	0.15**	−2.93***	2.77***	−0.28***	−0.01***	-0.10	-0.10	2.45***	−2.28***	0.72***	−0.01*	-0.23**	0.01	0.55***	−0.58***
Republic of Northern Ossetia - Alania	01 11 04	01 03 11	2.27***	0.00	0.42*	-0.09	3.24	0.62	0.16***	0.01	-0.34	0.07	-3.78	-0.54	0.68***	0.00	-0.12	0.18***	0.77***	-0.11
Stavropol krai	01 07 04	01 11 08	2.37***	-0.01	0.23	-0.09	6.93***	-0.42	0.17***	0.04**	-0.52*	0.45***	−5.51**	0.06	0.02	−0.02***	0.38***	-0.25***	−1.24***	0.50

Table 4: Panel cointegration: model estimates

	Break dates		*Coefficient estimates*																	
Region	**Break1**	**Break2**	**Const**	**Trend**	**c+**	**c-**	**er+**	**er-**	**Const*d1**	**Trend*d1**	**c+ * d1**	**c- * d1**	**er+ * d1**	**er- * d1**	**Const*d2**	**Trend*d2**	**c+ * d2**	**c- * d2**	**er+ * d2**	**er- * d2**
Bashkortostan Republic	01 02 07	01 06 11	2.31***	0.03***	0.35***	0.00	−3.21***	3.43***	−0.19***	−0.02***	-0.06	0.00	2.63***	−2.73***	0.70***	0.00	-0.31***	0.04	0.62***	−0.73***
Mariy El Republic	01 02 07	01 04 09	2.33***	0.04***	0.08	0.29***	−2.70***	3.03***	−0.35***	-0.01	-0.05	−0.17*	1.91**	−1.91**	0.65***	−0.02**	0.04	0.00	0.94***	−0.97*
Mordovia Republic	01 11 04	01 04 09	2.31***	0.00	0.27	-0.04	8.47***	0.62	0.19***	0.01	0.03	0.21	−8.80**	0.33	0.15	0.00	-0.28***	-0.12	0.40***	−0.83***
Tatarstan	01 03 07	01 04 09	2.37***	0.03***	0.10	0.27***	-0.32	2.21***	−0.64***	0.01	-0.12	-0.16	-0.90	-1.04	0.72***	−0.03**	0.21	0.06	1.46***	-0.89
Udmurt Republic	01 04 07	01 05 09	2.40***	0.03***	0.14**	0.18***	−1.21***	2.29***	−0.44***	-0.01	-0.33*	-0.13	0.55	-0.02	0.48***	-0.01	-0.43**	-0.02	0.68***	−2.13***
Chuvash Republic	01 02 07	01 04 09	2.37***	0.04***	0.02	0.42***	−1.95***	2.58***	−0.61***	-0.01	0.07	−0.31***	1.15	-1.02	0.85***	−0.03***	-0.01	0.00	0.93***	−1.38***
Perm krai	01 01 07	01 05 09	2.40***	0.03***	0.06	0.18***	−1.30*	2.83***	−0.65***	-0.01	0.22	−0.14*	0.55	−1.22**	0.70***	−0.01**	-0.21	0.00	0.80***	−1.41***
Kirov region	01 12 06	01 05 09	2.39***	0.04***	0.05	0.16*	−1.97***	3.10***	−0.50***	−0.02**	0.24	-0.12	1.26*	−1.52**	0.60***	−0.01*	-0.22	0.03	0.77***	−1.45***
Nizhny Novgorod region	01 02 07	01 04 09	2.33***	0.04***	0.01	0.35***	−1.69***	2.47***	−0.42***	-0.01	0.15	−0.26***	0.99	-0.67	0.65***	−0.02**	-0.08	-0.02	0.80***	−1.62***
Orenburg region	01 03 07	01 06 11	2.29***	0.04***	0.15**	0.14*	−5.19***	3.77***	−0.24***	−0.03***	0.08	−0.16*	4.42***	−3.33**	0.70***	0.00	-0.25	0.04	0.79***	−0.46**
Penza region	01 03 07	01 05 09	2.29***	0.04***	0.17***	0.21***	−3.47***	3.11***	−0.26***	−0.02**	0.06	-0.11	2.78***	−1.91***	0.49***	-0.01	-0.19	-0.04	0.75***	−1.04**
Samara region	01 12 06	01 11 08	2.24***	0.03***	0.31***	0.01	−3.85***	3.45***	0.78***	−0.03*	-0.05	0.83***	8.48***	−2.96***	−0.74***	0.00	-0.01	-0.66***	−4.44***	-0.15
Saratov region	01 11 04	01 05 09	2.21***	0.00	0.41*	0.06	3.45	-0.31	0.16***	0.02	-0.22	0.09	3.77	1.14	0.29***	-0.01	-0.12	-0.03	0.47***	−0.70**
Ulyanovsk region	01 02 07	01 05 09	2.27***	0.02***	0.55***	0.00	−4.15***	3.29***	−0.22**	-0.01	0.17	0.08	3.38***	−2.05**	0.51***	0.00	-0.29	0.04	0.93***	−1.06**
Kurgan region	01 04 07	01 04 09	2.40***	0.03***	-0.01	0.15**	−1.48**	2.53***	−0.64**	0.01	0.08	0.06	0.82	-0.32	0.69***	−0.03**	0.05	-0.10	0.74***	−2.03**
Sverdlovsk region	01 12 06	01 05 09	2.39***	0.03***	0.00	0.09	−1.24*	2.97***	−0.39***	-0.01	0.10	0.03	0.69	−2.18***	0.54***	−0.02**	-0.03	-0.04	0.65***	-0.64
Tyumen region	01 10 08	01 03 11	2.46***	0.02***	0.07	0.16***	0.39	1.82***	−1.22***	−0.03***	−0.47**	−0.62***	−0.69**	−1.05**	1.72***	0.02***	-0.62***	0.47***	0.30*	−0.74**
Chelyabinsk region	01 10 08	01 04 11	2.42***	0.02***	0.05	0.25***	0.79*	1.33***	−1.67***	−0.03***	0.65***	−0.82***	−1.35**	-0.12	2.23***	0.01***	-0.76***	0.56***	0.56**	−1.30***
Altai Republic	01 12 06	01 04 09	2.43***	0.03***	0.12	0.14	-1.42	2.13***	−0.48***	0.02	-0.30	0.20	0.65	-1.00	0.75***	−0.04***	0.24	-0.22**	0.92***	-0.93
Buryatia Republic	01 11 04	01 11 08	2.31***	0.03	0.08	-0.04	1.86	1.49	0.35***	0.00	-0.44	−0.74***	1.22	−3.03**	0.04	−0.02***	0.50***	-0.55***	−2.85***	1.81***
Tyva Republic	01 10 08	01 03 11	2.48***	0.02***	-0.03	0.49***	1.66***	0.39	−2.26***	−0.04***	1.29***	−1.01***	−1.85**	1.93***	3.49***	0.03***	-1.42***	0.80***	0.50*	−2.54***
Republic Of Khakassia	01 01 07	01 04 09	2.36***	0.04***	0.09	0.29***	−2.48**	2.51***	−0.52***	0.01	-0.28	0.01	1.79	-1.39	1.02***	−0.04***	0.21	-0.15	0.86***	-1.07
Altai krai	01 01 07	01 04 09	2.43***	0.03***	0.18***	0.20**	−1.87**	2.19***	−0.46***	0.00	-0.08	-0.07	1.13	-1.10	0.74***	−0.02*	-0.28	-0.39***	0.52***	−1.21**
Zabaikalskiy krai	01 10 08	01 03 11	2.53***	0.01**	0.10	0.41***	1.86***	-0.19	−1.46***	−0.03***	0.67***	−1.02***	−2.37**	1.50**	2.85***	0.02*	-0.93***	0.84***	0.87***	−1.48**
Krasnoyarsk krai	01 12 06	01 04 09	2.46***	0.03***	0.08	0.14*	−1.78**	2.67***	−0.43***	0.01	-0.32	0.13	1.27	−1.83***	0.88***	−0.03***	0.22	-0.15*	0.67***	-0.77
Irkutsk region	01 07 07	01 05 09	2.47***	0.01	0.28***	0.38***	0.15	-0.41	−1.55***	−0.04***	-0.18	-0.17	-1.36	2.01**	2.13***	−0.04***	-0.22	-0.15	1.27***	−1.66**
Kemerovo region	01 10 08	01 03 10	2.42***	0.02***	0.04	0.27***	0.28	0.88***	−3.43***	−0.09***	1.42***	−2.07***	-0.42	0.65	3.34***	0.08***	-1.68***	1.61***	-0.24	-1.67
Novosibirsk region	01 02 07	01 10 09	2.40***	0.02***	0.13*	0.19**	-1.13	1.66***	0.16*	−0.04***	0.59***	-0.14	0.63	−1.76***	−0.35***	−0.03***	-0.73***	-0.15*	0.31***	0.21
Omsk region	01 04 07	01 04 09	2.36***	0.02***	0.07	-0.01	-0.85	2.12***	-0.14	-0.01	0.22	0.19**	0.39	-0.33	0.22	-0.01	-0.39*	-0.37***	0.21**	−1.82**
Tomsk region	01 02 07	01 04 09	2.37***	0.02***	0.16**	0.19**	-0.41	1.95***	−0.24**	0.01	-0.28	0.06	-0.16	-0.99	0.38***	−0.02***	0.01	-0.35***	0.40***	−1.01**
Yakutiya region	01 04 08	01 04 11	2.68***	0.00	0.11**	-0.01	1.11*	0.27	0.32	0.01*	−0.27**	-0.04	−1.64**	-0.42	0.21	−0.01***	0.17	0.06	0.67***	0.23
Kamchatkiy krai	01 06 04	01 10 08	2.55***	-0.01	-0.33	-0.29	7.67**	-0.95	0.18***	0.02	0.07	0.57**	−5.96**	-0.89	0.17	-0.01	0.22**	-0.34***	−1.83***	1.86***
Primorski krai	01 04 07	01 05 09	2.53***	0.01	0.20**	0.14**	0.74	0.79*	−0.97***	0.04***	−0.44***	0.03	−1.30**	0.37	1.24***	−0.04***	0.08	-0.23***	0.46***	−1.18***
Khabarovsk krai	01 03 07	01 05 09	2.56***	0.01***	0.23***	0.18***	1.19*	1.05**	−0.91***	0.04***	−0.56***	0.03	−1.83**	0.02	1.02***	-0.05***	0.27	−0.34***	0.43***	−1.05***
Amur region	01 04 07	01 05 09	2.53***	0.00	0.16**	0.11	1.37*	0.03	−1.03***	0.05***	-0.27	0.06	−2.10**	1.63***	1.19***	−0.04***	0.07	−0.25***	0.60***	−1.61***
Magadan region	01 03 07	01 06 09	2.55***	0.01**	0.41***	-0.11	−2.61**	2.66***	−0.73***	0.01	-0.35	-0.01	1.38	1.68**	1.24***	−0.02***	-0.26	0.03	1.18***	−0.87*
Sahalin	01 06 07	01 06 09	2.59***	0.01	0.18**	0.08	0.64	0.72	−1.18***	0.05***	−0.37*	0.03	-1.31	0.76	1.55***	−0.04***	-0.02	−0.25***	0.47***	−1.48***
Jewish Autonomous region	01 03 07	01 05 09	2.58***	0.02***	0.16**	0.24***	0.42	1.24**	−1.04***	0.04***	−0.48**	-0.03	-1.06	-0.42	1.02**	-0.05***	0.29	−0.34***	0.43***	-0.71
Chukotka	01 11 05	01 04 08	2.60***	−0.03***	0.66***	−0.46***	−2.09**	0.31	-0.07	0.04***	−1.12**	−0.89***	13.19***	-1.73	1.02**	-0.01	0.24	−0.49***	−11.24***	1.37

Table 5: (CONTINUED) Panel cointegration: model estimates

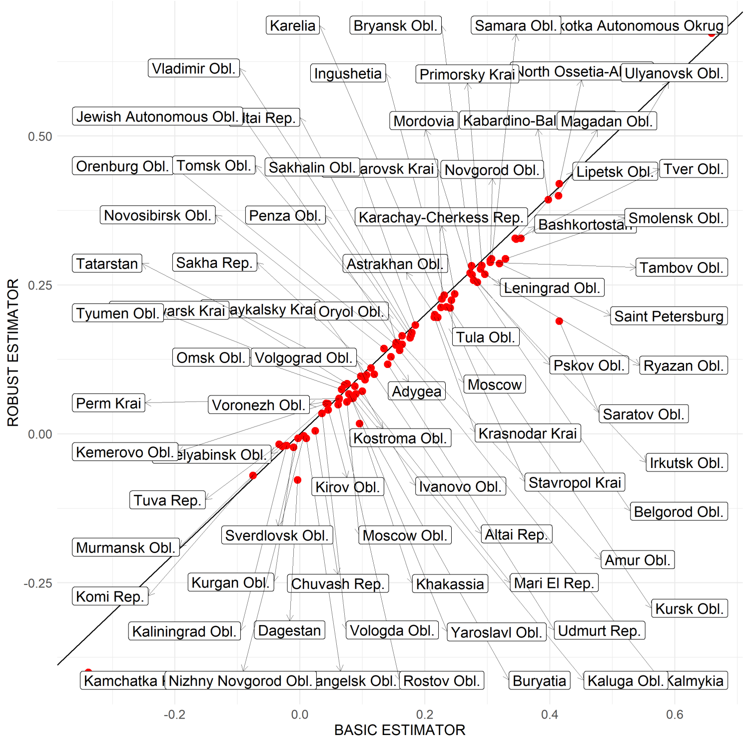

Figure 1: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variable for gasoline taxes. **Long-run effect of positive changes in the oil price before the first structural break** ($t < 2007$).

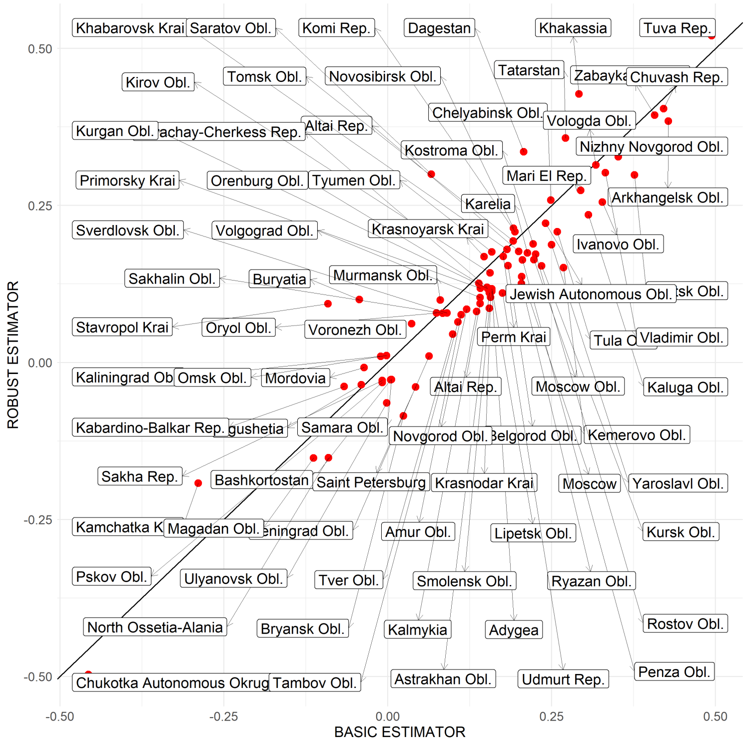

Figure 2: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the oil price before the first structural break** ($t < 2007$)**.**

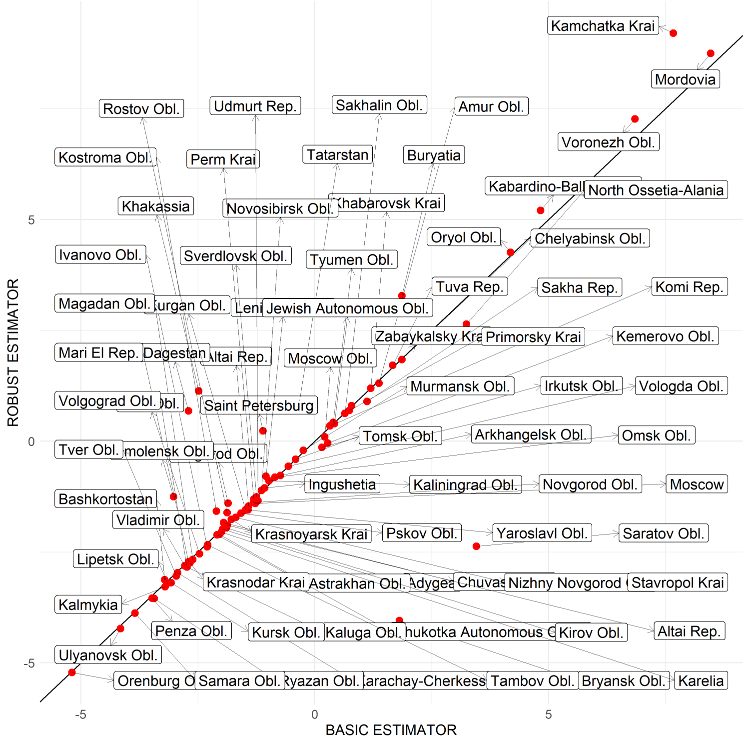

Figure 3: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of positive changes in the exchange rate before the first structural break** ($t < 2007$).

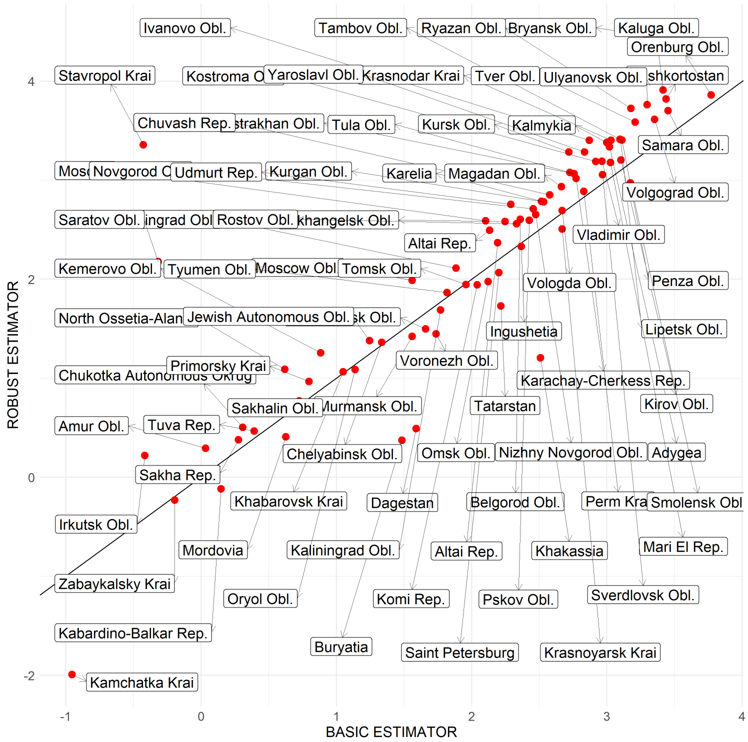

Figure 4: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the exchange rate before the first structural break** ($t < 2007$).

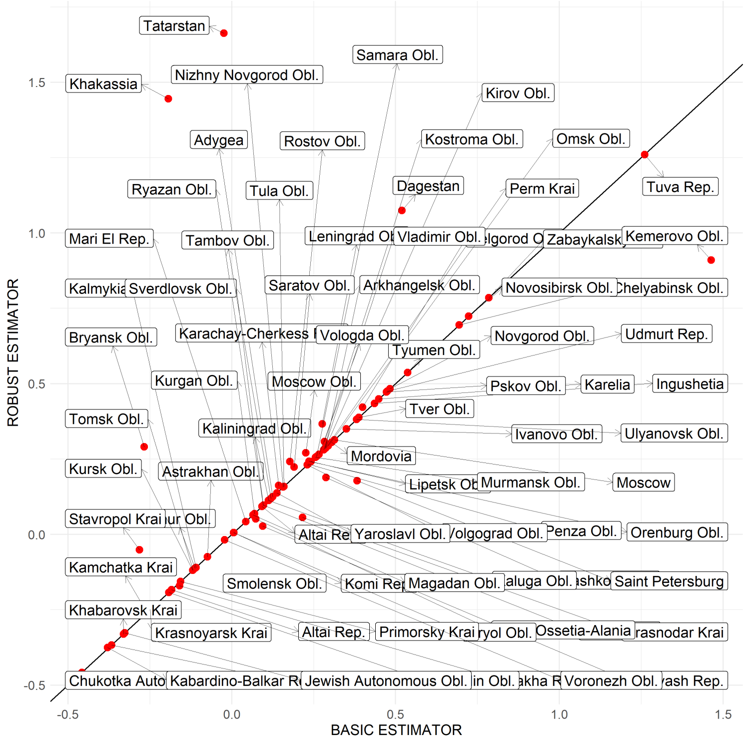

Figure 5: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variable for gasoline taxes. **Long-run effect of positive changes in the oil price between the two structural breaks** ($2007 < t < 2010$).

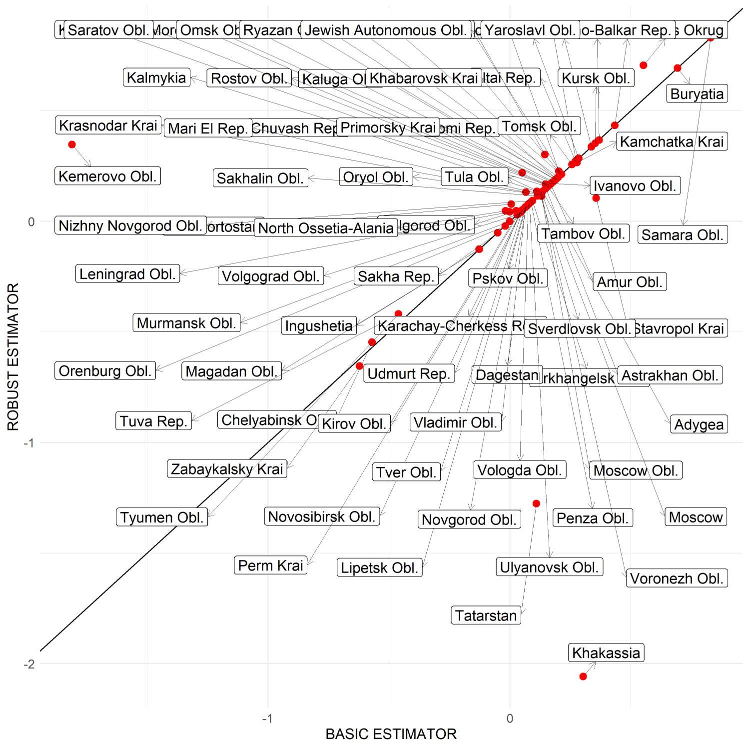

Figure 6: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the oil price between the two structural breaks** ($2007 < t < 2010$).

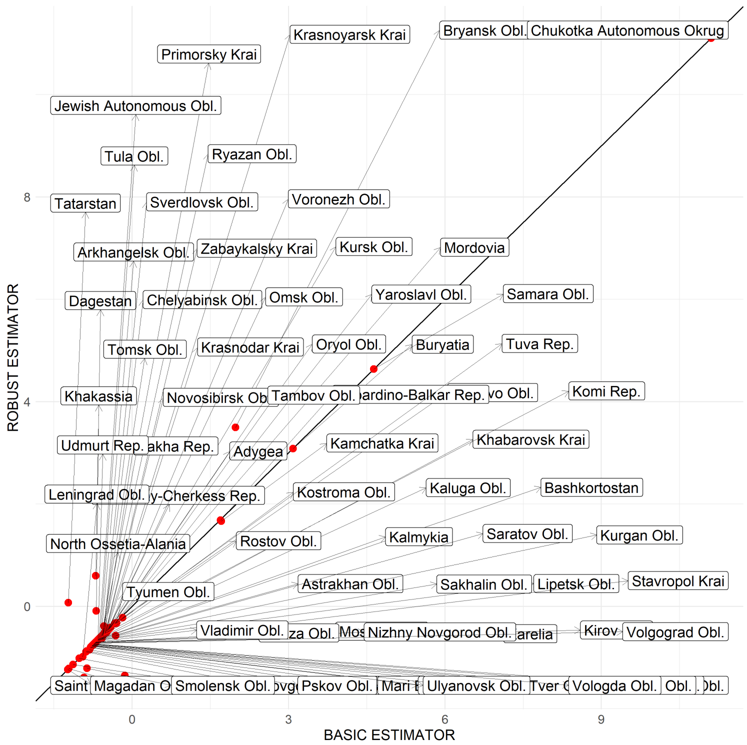

Figure 7: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of positive changes in the exchange rate between the two structural breaks** $(2007 < t < 2010)$.

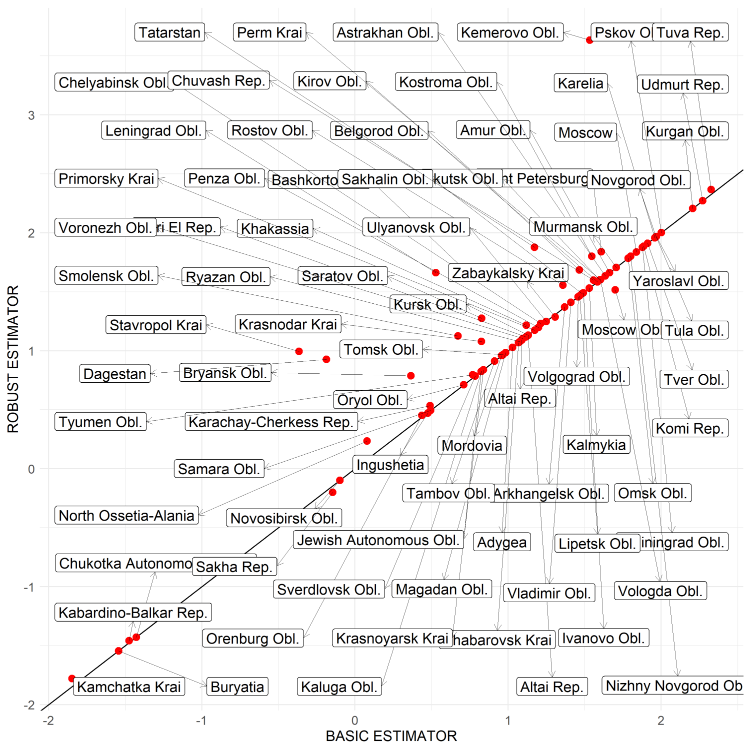

Figure 8: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the exchange rate between the two structural breaks** $(2007 < t < 2010)$.

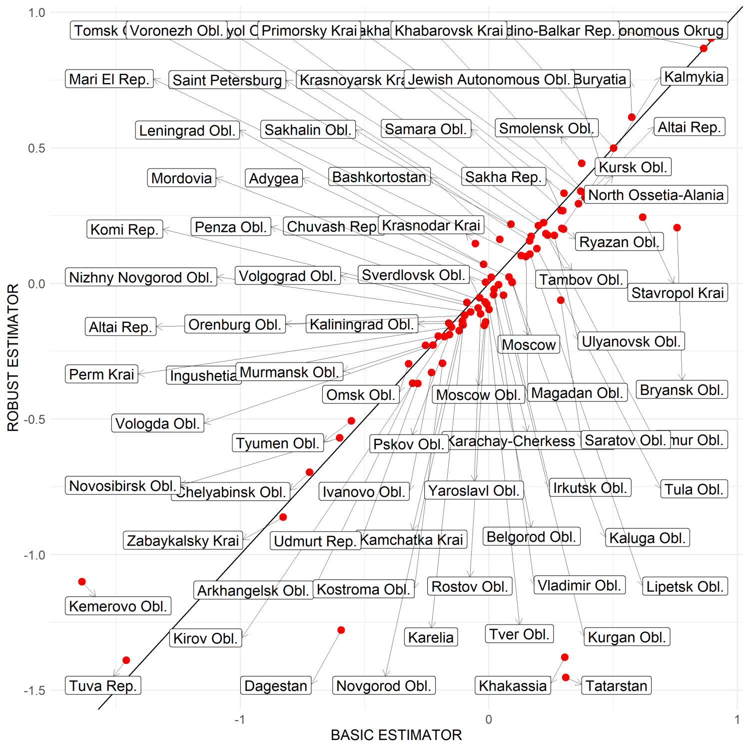

Figure 9: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variable for gasoline taxes. **Long-run effect of positive changes in the oil price after the second structural break** ($t > 2010$).

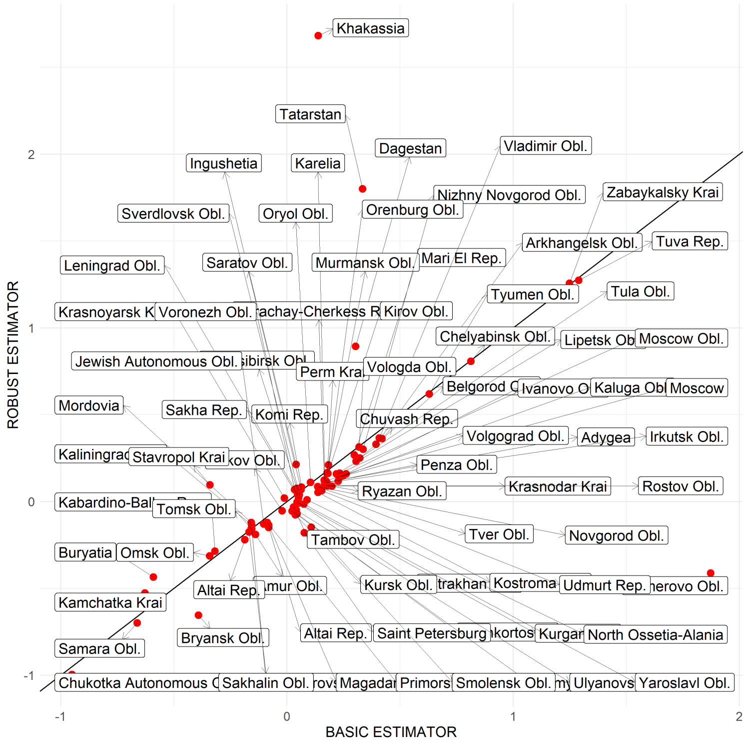

Figure 10: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the oil price after the second structural break** ($t > 2010$).

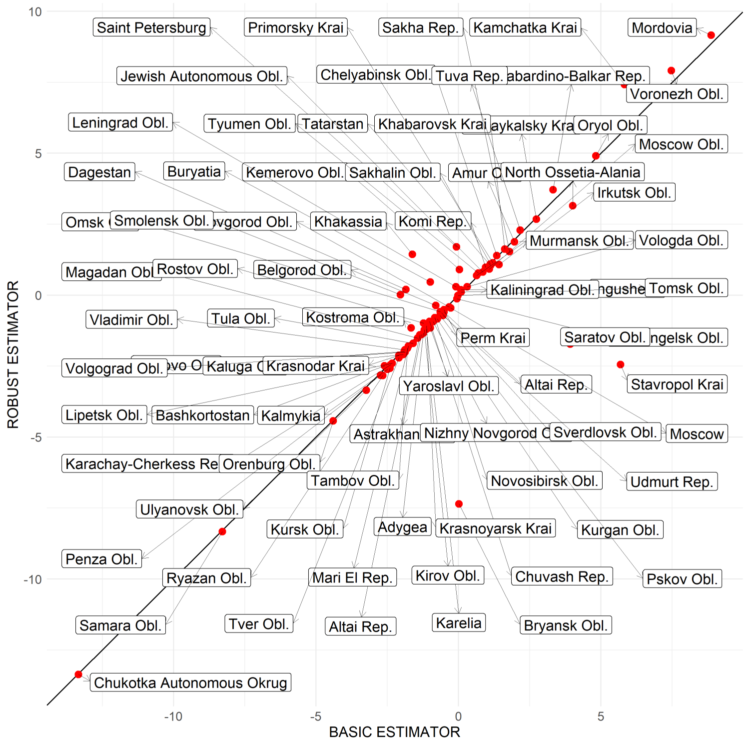

Figure 11: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of positive changes in the exchange rate after the second structural break** ($t > 2010$).

Figure 12: Scatter plot of the panel cointegration coefficients before and after the introduction of the control variables for gasoline taxes. **Long-run effect of negative changes in the exchange rate after the second structural break** ($t > 2010$).