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Price convergence and market integration in Russia

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ABSTRACT

Following the price-liberalization reforms implemented by Russia in 1992, an initial period of disconnect between regional markets began to transform around 1994. This paper analyzes the spatial pattern of goods market integration that evolved within Russia in 1994–2000, classifying country's regions into three categories: integrated with a benchmark region, not integrated but tending towards integration, and not integrated and not tending towards integration. To quantify tendencies towards integration, an AR(1) model of regional price differentials is augmented with a trend term that is capable of displaying asymptotic decay (indicating price convergence). The results obtained suggest that only about one-fifth of Russia's regions appear as not integrated and showing no tendency towards integration over the sample period.
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1. Introduction

Political changes and Russia's rapid shift in the early 1990s from a centrally planned economy to one governed by market principles gave rise to a dramatic regional fragmentation of its national market. In 1994, this process of fragmentation began to subside due to the emergence of market institutions. From that time on, a progressive improvement in market integration was observed, as Berkowitz and DeJong (2001, 2003) and Gluschenko (2003) have documented. Obviously, integration of the Russian market is spatially heterogeneous: each region can be integrated with some set of other regions and not integrated with another set. Moreover, a feature of the transition process is that some non-integrated regions are nonetheless moving towards integration. The above papers consider the temporal pattern of market integration in Russia rather than the spatial pattern because they use cross-sectional analysis, thus obtaining results averaged over country's regions.

The aim of this paper is to characterize the spatial pattern of goods market integration in Russia in 1994–2000, applying time series analysis. The spatial pattern is produced by classifying each region as belonging to one of three groups: integrated with a benchmark region, not integrated but tending towards integration, or not integrated and not tending towards integration. The law of one price serves as the criterion of market integration. The data for the empirical analysis are monthly time series of the cost of a staples basket across 75 (of the 89) regions of Russia.

The variable to be analyzed is the price differential between a given region and the benchmark region. Given stationarity of the price ratio, the law of one price holds, hence these regions are deemed to be integrated. The conventional AR(1) model with no unit root describes this behavior. In turn, a transition towards integration appears as a non-stationary ratio that tends towards stationarity over time. Such a process is modeled by an autoregression with a nonlinear, asymptotically decaying trend: a region is deemed as tending towards integration when its price ratio exhibits trend decay. If region's price differential satisfies neither model, the region is deemed not integrated and not tending towards integration. The models are also augmented to account for a structural break caused by the 1998 financial crisis in Russia. The results obtained suggest that 54% of the covered Russian regions are integrated with the benchmark region, 24% tend towards integration, and 22% are non-integrated and show no trend towards integration.

Examining market integration in Russia through time series analysis has been the subject of studies by Berkowitz et al. (1998), Gardner and Brooks (1994), and Goodwin et al. (1999). Considering the early transition years (i.e. the first half of the 1990s), these studies characterize the Russian market as poorly integrated but showing signs of potential improvement. The spatial patterns obtained suggest that only a few regions or cities can be deemed integrated in a certain

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sense. Berkowitz and DeJong (1999), albeit applying a cross-sectional approach, find an interesting feature of the spatial pattern of Russia's market integration. They identify a Red Belt group of pro-Communist and anti-market-reform regions as a culprit behind segmentation of the Russian market.

This paper contributes to the above literature in two aspects. From a methodological standpoint, it proposes a new methodology of analyzing price convergence in the time series context. From an empirical standpoint, the paper is complementary those cited above in that it provides broader spatial and temporal coverage: the analysis covers almost all Russian regions and a time span ending in 2000 (albeit missing the very early years of transition, 1992–1994). Together with Berkowitz and DeJong (2001, 2003) and Gluschenko (2003), the results of this paper provide a two-dimensional, time-space pattern of Russia's market integration from the early years of transition to the beginning of the 2000s.

The remainder of the paper is organized as follows. Section 2 describes methodology of the analysis and the data used. Section 3 presents empirical results obtained. Section 4 concludes.

2. Methodology and data

2.1. Strategy of the analysis

Perfect integration of a spatially dispersed goods market implies the absence of impediments to the movement of goods between all spatial segments (e.g., national regions). In other words, a perfectly integrated market would operate like a single competitive market despite spatial dispersion of its segments. The price of a (tradable) good across regions would be uniform so that the law of one price, maintained by inter-regional arbitrage, holds. Thus, the law of one price may be used as a theoretical benchmark for empirically analyzing goods market integration.

Market integration in Russia can be seen as a two-stage process, involving an initial stage of progressive segmentation beginning in January 1992 and a second stage of progressive integration beginning around 1994. The second stage is the subject of this study. Taking a pair of regions, the goal is to identify three types of classifications in the second stage of the evolution: (a) integrated regions, where price equality already prevails; (b) non-integrated regions tending towards integration, i.e. prices are converging towards a common level; and (c) non-integrated regions that show no indication of a trend towards integration. For brevity, hereafter regions from the second group are referred to as "regions tending towards integration," and regions from the third group are referred to as simply "non-integrated regions."

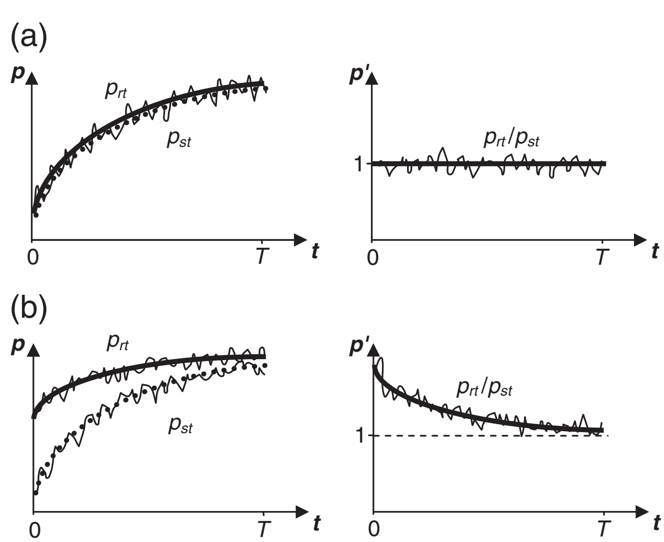


Fig. 1. Two concepts of price convergence: (a) short-run convergence (ordinary cointegration); (b) long-run convergence (catching-up) combined with short-run one.

In the above context, the term *convergence of prices* becomes ambiguous. Indeed, when considering types (a) and (b), two fundamentally distinct concepts of convergence are possible. Fig. 1 illustrates the difference between the concepts: the thin lines depict actual dynamics of prices, while the thick lines represent their theoretical long-run paths. (Hereafter, p_{rt} and p_{st} denote the price of a good in regions r and s, respectively, at time t; p' stands for a relative price.)

These two concepts can be described as follows:

Fig. 1(a) implies regions r and s are type (a). They are *in* spatial equilibrium, such that price disparities between regions are merely random shocks dying out over time. Prices fluctuate around parity and permanently tend to return to it. This is the case dealt with in the literature on the law of one price and purchasing power parity (PPP); it is sometimes referred to as "convergence to the law of one price/PPP" in this literature. The term "convergence" here relates to the shocks, implying their convergence to zero. It characterizes the short-run behavior of prices, while the long-run behavior of prices is described by the path

$$p_{rt} / p_{st} = 1, t = 0, ..., T. \tag{1}$$

Thus, this concept can be designated as "short-run convergence."

Fig. 1(b) implies that regions r and s are type (b). The regions are *tending towards* spatial equilibrium:

$$\lim_{t\to\infty} p_{rt} / p_{st} = 1. \tag{2}$$

(In the figure, the price in s catches up with the price in r.) Price disparity permanently diminishes over time, fluctuating around this general trend due to random shocks. This is the case characterized in the literature on economic growth (regarding incomes, outputs, etc.) as "convergence." In the short run, the price disparity converges to the long-run path (i.e. random deviations die out over time), and the path itself converges to the parity line $p_{rt}/p_{st} = 1$ over the long run. In this case, "convergence" implies that the differences in prices over a long period of time deterministically converge to zero. Thus, this concept can be designated as "long-run convergence."[1]

In Eqs. (1) and (2), absolute price parity is taken as the steady state. This implies perfect integration—a rare condition in the real world. We would reasonably expect persistent (equilibrium) differences in prices between r and s induced by natural market frictions such as physical distance and difficulty accessing a number of regions. Thus, it may be more realistic to relax the criterion for market integration, allowing for such market frictions. In this case, relative price parity would have to be dealt with, and unity in the right-hand side of Formulae (1) and (2) would be substituted for an arbitrary constant ratio of prices, α_{rs}.

The trouble is that this α reflects both the effect of "natural," irremovable market frictions (which are compatible with the notion of integration) and the effect of artificial, transient ones that impede market integration. This can be formalized as, e.g., $\alpha = \alpha_n(L_{rs}) \cdot \alpha_a$, where α_n is the effect of transportations costs proxied by distance between r and s, L_{rs}, and α_a is the effect of "anti-integration forces." As Gluschenko (2010a) finds, the latter effect is considerable in Russia. In the context of a pairwise time series analysis, however, there is no way to identify α_n and α_a separately. This is why the strict version of the law of one price is adopted in this study as a criterion of integration, any deterministic difference in prices being interpreted as an indication of non-integration. Certainly, this may result in some understatement of the degree of market integration in Russia.

[1] Econometrically, prices p_{rt} and p_{st} in Fig.1(a) are nonstationary (unit root) processes. However, both have the same trend so that their ratio is stationary around 1. In Fig. 2(b), individual prices are also unit root processes, but they have different trends that converge to each other over time. Thus, the price ratio here is a nonstationary process tending to stationarity over time.

Testing for the equality of prices or price levels, i.e. for relationship (1), is a conventional exercise in papers on the law of one price and PPP. The test is whether the logarithms of local prices $P_{rt} = \log(p_{rt})$ and $P_{st} = \ln(p_{st})$ are cointegrated with the predetermined cointegrating vector (1, –1), or, equivalently, whether price differential $P_{rst} = \log(p_{rt}/p_{st})$ is stationary. However, in providing an "all-or-nothing" answer, this traditional approach is ineffective in revealing a transitional case described by relationship (2), i.e. the case when a process $\{P_{rst}\}_{t=0,\ldots,T}$ is not stationary, but tends to a stationary one over time. Using conventional cointegration analysis, such a process would simply be recognized as nonstationary, giving no way to separate region groups (b) and (c).

There are several approaches to this problem. The issue of long-run convergence is extensively addressed in the economic growth literature (see e.g. the survey by Durlauf and Quah, 1999). The most popular is the cross-sectional approach (examining β-convergence); different methods associated with the distribution dynamics approach are also of considerable use. Both approaches yield a spatially aggregated result, not a spatial pattern of convergence. They are thus unsuitable for solving our proposed problem. Therefore let us turn to the time series approach.

Carlino and Mills (1996) consider a concept referred to as "stochastic convergence." They employ a cointegration relationship with a deterministic linear trend. Provided that the trend of an inter-regional differential is directed towards zero, stationarity around this trend is supposed to be evidence of convergence. Cushman et al. (2001) apply a similar way to test for convergence of prices for foods in Kiev, Ukraine, to the prices for respective goods in the US. However, time series models with a linear trend are not compatible with relationship (2): having reached the zero value, the differential would be driven further by such a trend and increase again (in absolute value) with the opposite sign.

Bernard and Durlauf (1995) define convergence essentially as in relationship (2), referring to such a concept as "forecast convergence." However, turning to the issue of testing for convergence, they assume economies to be in the steady state already, and they apply standard cointegration analysis. Thus, the authors actually restrict their definition of convergence to Eq. (1), and they do not deal with "genuine," long-run convergence. Instead, they examine only whether it has been completed by the beginning of a given time period.[2]

Nahar and Inder (2002) attempt to overcome this shortcoming, suggesting a test for long-run convergence. Bentzen (2003) applies it to study convergence of gasoline prices in OECD countries. The idea of the Nahar–Inder test is as follows: the evolution of disparity between two locations is modeled as $(\log(P_{rst}))^2 = h(t) + \varepsilon_t$, where $h(t)$ is a long-run trend, and ε_t is a residual with standard properties. A polynomial of some degree k approximates function $h(t)$, so that $(\log(P_{rst}))^2 = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \ldots + \alpha_k t^k + \varepsilon_t$. If long-run convergence happens, then $h(t)$ is decreasing with time; hence, $dh(t)/dt < 0$ must hold for all t. To test for convergence, the authors check whether the time average of this derivative is negative:

$$\frac{1}{T}\sum_{t=0}^{T}\frac{dh(t)}{dt} = \sum_{i=1}^{k}\alpha_i\frac{i}{T}\sum_{t=0}^{T}t^{i-1} < 0.$$

However, it is not equivalent to the negativity of $dh(t)/dt$ in all points in time. Therefore, the test is not adequate. This is easy to see, considering a continuous-time counterpart of the above relationship:

$$\frac{1}{T}\int_0^T\frac{dh(t)}{dt}dt = \frac{1}{T}(h(T) - h(0)) < 0.$$

Thus, merely the fact that $h(T) < h(0)$ suffices to accept the convergence hypothesis. In the general case, this obviously does not evidence long-run convergence. For example, a U-shape path of disparity may satisfy this test. (Besides, the test does not take account of probable autocorrelation, which makes it impossible to discriminate between deterministic and stochastic trends.)

The failure of the Nahar–Inder method is due to overly general representation of the long-run trend. A way out is to restrict the function class used to model the trend to functions a priory known to satisfy relationship (2). These are asymptotically decaying functions. Adopting this approach and taking a specific asymptotically decaying function to characterize the trend, convergence of prices can be modeled as

$$p_{rt} / p_{st} = 1 + \gamma e^{\delta t}, \delta < 0. \tag{3}$$

To economize notation, the region indices for parameters (and the disturbances discussed below) are suppressed.

Parameter δ defines convergence rate; γ is the initial (at $t = 0$) value of price disparity. The sign of γ shows the direction of convergence. If $\gamma < 0$, the price in r increases more quickly than in s and catches up with the latter. If $\gamma > 0$, the price in r rises more slowly than in s. If $\gamma = 0$, Eq. (3) degenerates to Eq. (1), implying that convergence of prices has completed by the start of the time period under consideration. Hence, the law of one price holds for regions r and s.

2.2. Econometrics

To derive a testable version of relationship (3), the logarithmic representation of prices is used, and random shocks, ν_t, are taken into account. They are presumed to be a first-order autoregressive process:

$$P_{rst} = log\left(1 + \gamma e^{\delta t}\right) + \nu_t, \quad \nu_t = (\lambda + 1)\nu_{t-1} + \varepsilon_t, \tag{4}$$

where ε_t is white noise, and γ, δ, and λ are parameters to be estimated. Hereafter, $t = 1,\ldots,T$. Substituting the second equation in Eq. (4) into the first gives a nonlinear model to be estimated and tested:

$$\Delta P_{rst} = \lambda P_{rs,t-1} + log\left(1 + \gamma e^{\delta t}\right) - (\lambda + 1)\, log\left(1 + \gamma e^{\delta(t-1)}\right) + \varepsilon_t. \tag{5}$$

The tests have to answer whether time series $\{P_{rst}\}$ has no unit root, i.e. that the process is stationary, and if so, whether it contains a trend of the given form, i.e. $\gamma \neq 0$ and $\delta \neq 0$. That is, the hypotheses tested are H_λ: $\lambda = 0$ (against $\lambda < 0$), H_γ: $\gamma = 0$ (against $\gamma \neq 0$), and H_δ: $\delta = 0$ (against $\delta \neq 0$).

The joint rejection of H_λ, H_γ, and H_δ is interpreted as evidence that the time series tested fluctuates around a deterministic trend of the given form. Provided that $\delta < 0$, the trend is an asymptotically decaying one. Hence, prices in regions r and s are converging to the equality, so these regions are classified as those tending towards integration. With $\delta > 0$, the prices are deterministically diverging; thus, these regions are non-integrated.

If either H_γ or H_δ (or both) is not rejected, this means that there is no deterministic trend in the time series. In such an event, as well as in the case of nonrejection of a unit root, it is tested whether law (1) governs the process. We obtain a testable version of Eq. (1) as above:

$$P_{rst} = \nu_t, \nu_t = (\lambda + 1)\nu_{t-1} + \varepsilon_t; \tag{6}$$

combining these equation gives

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \varepsilon_t, \tag{7}$$

which is the conventional AR(1) model.

The hypothesis tested here is whether the time series has a unit root, H_λ: $\lambda = 0$ (against $\lambda < 0$). Its rejection implies that the time series

[2] In the literature on economic growth, the term "convergence" had definitely meant catching-up until Bernard and Durlauf's (1995) paper caused confusion in this term similar to that in the literature on spatial price dynamics.

fluctuates around zero, i.e. around the equality of prices in regions r and s. Therefore, such regions are classified as integrated. If H_λ is not rejected, the regions are deemed non-integrated.

Note the different roles of parameters γ and δ vs. parameter λ. The first two characterize the *long-run* behavior of the price differential path, while λ characterizes the *short-run* properties of adjustment towards this path. (In the degenerate case of AR(1), the path is a straight line along the time axis that represents the price parity.) Parameter λ is interpreted as the rate deviations from the long-run path caused by random shocks dying out. Alternatively, $t_{HLS}=\log(0.5)/\log(1+\lambda)$ defines the half-life time of these random price disparities. With a unit root, i.e. $\lambda=0$, $t_{HLS}=\infty$. Thus, the effect of random shocks is permanent, preventing the price differential from returning to a long-run path; hence, no long-run path exists. With no autocorrelation, i.e. $\lambda=-1$, the return to the long-run path is instantaneous: $t_{HLS}=0$. Parameter δ is the rate the deterministic price disparity tends to zero. Similarly to the half-life time of random price disparities, the half-life time of the deterministic price disparity can be defined as the time the disparity takes to halve: $t_{HLL}=\log(0.5)/\delta$.

There is a peculiarity of price dynamics in Russia that complicates the above analysis: a number of regional price time series contain a structural break caused by the August 1998 financial crisis in the country. The break point θ is not uniform across regions, varying from 1998:08 through 1999:02. Accounting for this peculiarity produces a number of additional models that are modifications of Eqs. (5) and (7). Under such modification, the dummy variable $B_{\theta t}$, with $B_{\theta t}=1$ if $t<\theta$ and zero otherwise, models the structural change.

Incorporating the structural change dummy into Eq. (5), we obtain

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \log\left(1 + (\gamma + \gamma_B B_{\theta t})e^{\delta t}\right) - (\lambda + 1)\log\left(1 + (\gamma + \gamma_B B_\theta, t-1)e^{\delta(t-1)}\right) + \varepsilon_t. \quad (5^*)$$

In Eq. (5*), the initial price disparity is $\gamma+\gamma_B$. Its sign shows the direction of convergence before the break point. The sign of γ shows the convergence direction from the break point. If the signs of γ and γ_B are the same, the break causes a price jump towards parity; and opposite signs imply the jump away from parity, provided that $|\gamma|>|\gamma_B|$. (The opposite inequality produces an exotic case of “overshooting.” The break crosses the price parity line, reversing the direction of convergence after the break point. Aside from insignificant γs, there are no such cases among estimates obtained.) In addition to the hypotheses tested for Model (5), one more hypothesis is tested for Model (5*): H_B: $\gamma_B=0$ (against $\gamma_B\neq0$), checking whether there is a structural break in a tested series. In the case of joint rejection of H_λ, H_γ, H_B, and H_δ regions r and s are classified as those tending towards integration if $\delta<0$, or as non-integrated regions if $\delta>0$.

In contrast to Eq. (5), the case of $\gamma=0$ in Eq. (5*) does not always imply the absence of the trend if there is a structural break. Such a case may indicate that prices in regions r and s have become equal from the date of the break point onward, i.e. that the regions have become integrated. This leads to the following equation:

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \log\left(1 + \gamma_B B_{\theta t}e^{\delta t}\right) - (\lambda + 1)\log\left(1 + \gamma_B B_\theta, t-1e^{\delta(t-1)}\right) + \varepsilon_t. \quad (5^{**})$$

It is seen that this model is a combination of Eqs. (5) and (7). The price differential dynamics are characterized by Eq. (5) when $t<\theta$; and by Eq. (7) on the time interval from θ to T. The sign of δ in Eq. (5**) does not matter, as the behavior of prices after the break is of interest here. However, the case of $\delta>0$ would be strange and seems hardly probable in practice. (Not one such case occurred among estimates obtained.)

Augmenting Eq. (7) to allow for a structural break, we have

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \gamma_B\left(B_{\theta t} - (\lambda + 1)B_{\theta,t-1}\right) + \varepsilon_t.^{3}$$

To make the values of estimates comparable across models, we transform the above equation into an equivalent form:

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \log(1 + \gamma_B B_{\theta t}) - (\lambda + 1)\log\left(1 + \gamma_B B_{\theta,t-1}\right) + \varepsilon_t \quad (7^*)$$

Note that the break dummy $B_{\theta t}$ is constructed so that the break in this model is always directed towards parity. This is done to test whether regions r and s have become integrated after the date of structural change. This is the case when both hypotheses H_λ and H_B are rejected. Given $\gamma_B>0$, the crisis caused price-cutting in region r as compared to s. It otherwise increased the relative price in r.

Making inferences regarding Eqs. (7*) and (5), two traps are to be avoided. The first is that of a spurious break. Let the path of the price differential be stepwise so that $P_{rst}=\gamma+\gamma_B$ with $t<\theta$, and $P_{rst}=\gamma$ with $t\geq\theta$. As model (7*) assumes $\gamma=0$, it can give a statistically significant estimate of γ_B (with rejection of H_λ), taking a typical random shock for the structural break. Hence, it is to be checked whether $\gamma=0$ indeed holds. The second trap is due to the fact that Eq. (5) can approximate a stepwise path by a deterministic trend, seemingly suggesting that regions r and s are tending towards integration, while they are in fact non-integrated, if $\gamma\neq0$ in the stepwise path, or integrated, if $\gamma=0$ in it. Thus, we have to discriminate between these three cases. The following auxiliary equation helps to avoid both traps:

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \log(1 + \gamma + \gamma_B B_{\theta t}) - (\lambda + 1)\log\left(1 + \gamma + \gamma_B B_{\theta,t-1}\right) + \varepsilon_t. \quad (7^{**})$$

(Note that it is equivalent to $\Delta P_{rst}=\lambda P_{rs,t-1}+\gamma+\gamma_B(B_{\theta t}-(\lambda+1)B_{\theta,t-1})+\varepsilon_t$, except for numerical values of γ and γ_B.)

Hypotheses H_λ, H_γ, and H_B are tested using Eq. (7**). We may turn to Eq. (7*) only when H_B is rejected and H_γ is not. When all the three hypotheses are rejected, regions r and s are non-integrated, provided that Eq. (5) is rejected.

If both Eqs. (7**)/(7*) and (5) appear acceptable (H_λ, H_γ, and H_B are rejected for Eq. (7**), or H_B is rejected and H_γ is not for it with rejection of H_λ and H_B for Eq. (7*), and H_λ, H_γ, and H_δ are rejected for Eq. (5)), the following specification test based on the Monte Carlo method is performed to choose between them. Denote H_1: Eq. (5) is the true specification and H_2: Eqs. (7**)/(7*) is the true specification. In the first stage of the test, suppose hypothesis H_1 to hold for a given pair (r, s) and generate N simulations of Model (5) (in the empirical work reported in Section 3, N was equal to 100,000). That is, compute N series of P_{rst} through Eq. (5) with λ, γ, δ, and σ_ε estimated on the actual data and $\varepsilon_t \sim N(0,\sigma_\varepsilon^2)$. For each simulation, estimate Eqs. (5) and (7**)/(7*) and calculate their simulated log likelihood ratio (LLR). Having obtained the set of N estimated LLRs, calculate the empirical distribution of LLR, and use this as the basis for inference in judging H_1 against H_2. The second stage of the test is similar, reversing the roles of H_1 and H_2. If the first stage of the test does not reject H_1 and the second stage rejects H_2, Eq. (5) is accepted. If the first stage rejects H_1 and the

[3] This specification is derived from Eq. (6) in which the first equation is augmented with the break dummy. This differs from the classical Perron (1990) specification. The common use of two dummies to characterize the break – level dummy and pulse dummy – is superfluous. The latter, equaling 1 if $t=\theta$, and 0 otherwise, can be represented as $B_{\theta t}-B_{\theta,t-1}$. The Perron-type equation is a linear approximation of the proposed specification, allowing the coefficients on $B_{\theta t}$ and $B_{\theta,t-1}$ to be independent. This leads to parameter estimates that, while consistent, are not asymptotically efficient. For this reason the use of more adequate nonlinear specification provides a more powerful unit root test. See Gluschenko (2005) for details.

second stage does not reject H_2, Eqs. (7**)/(7*) is accepted. In the case that the inferences are inconsistent across the stages, rejecting both hypotheses or neither of them, the J test is performed.

The above set of models may seem involved. In fact, it has a simple and transparent logical structure and can be derived from only Eq. (5*). This model encompasses all the rest of models, generating three levels of nesting with setting some subset of its (structural) parameters to zero. Imposing restrictions $\gamma=0$, or $\delta=0$, or $\gamma_B=0$ on Eq. (5*), we get the first level consisting of three mutually nonnested models (5**), (7**), and (5), respectively. Restrictions $\delta=0$ and $\gamma=0$, or $\delta=0$ and $\gamma_B=0$ on Eq. (5*) generate the second level of nesting that contains Eq. (7*) and a model omitted in our set, a conventional AR(1) model with constant $\alpha=-\lambda\log(1+\gamma)$. Equivalently, Eq. (7*) is a result of imposing restriction $\delta=0$ on Eq. (5**) or restriction $\gamma=0$ on Eq. (7**); restriction $\gamma_B=0$ on Eq. (7**) or restriction $\delta=0$ on Eq. (5) produces the AR(1) model with a constant. At last, Eq. (7) represents the third level of nesting. It obtains by restricting three parameters in Eq. (5**): $\gamma=0$, $\gamma_B=0$ and $\delta=0$. This model can also be generated by the restriction $\gamma_B=0$ on Eq. (7*) or $\gamma=0$ on the AR(1) with a constant. Fig. 2 clarifies the considered relationships. Table 1 summarizes the correspondence between models characterizing price dynamics in a pair of regions and types of the regions from this pair.

The AR(1) model with a constant is superfluous for our purposes. Were it accepted for some regions r and s, this would imply that they are non-integrated, as there is a permanent price disparity γ between them. But Eq. (7) gives the same answer for these r and s. Since the model of P_{rst} is misspecified due to omitted constant, a unit root will not be rejected in Eq. (7), again evidencing non-integration of r and s.

Seemingly, if one of the structural parameters in Eq. (5*) proves to be insignificant, we would have to turn to a respective model of the next level. However, this is true only for the case of nonrejection of H_γ that leads to Eq. (5**). But the nonrejection of H_δ is not a sign that Eq. (5) is not valid, and the nonrejection of H_B does not guarantee invalidity of Eq. (7**). As noted above, these two models are competitive in characterizing price dynamics, while Eq. (5**) does not compete with them. At any rate, every time that Eq. (5**) appeared acceptable, a specification test similar to that described above easily rejected specifications Eqs. (5) and (7**) in favor of Eq. (5**).

Based on the above considerations, the procedure of analyzing each time series $\{P_{rt}\}$ is as follows:

Step 1. Model (5*) is estimated and tested. If hypotheses H_λ, H_γ, H_B, and H_δ are jointly rejected, regions r and s are deemed to be tending to integration in the case of $\delta<0$, or non-integrated in the case of $\delta>0$, $\{P_{rst}\}$ containing a structural break. Then analysis finishes. Otherwise, if H_B and H_δ are rejected, the analysis moves to Step 2, while if this is not the case, the analysis continues at Step 3.

Step 2. Model (5**) is estimated and tested. If hypotheses H_λ, H_B, and H_δ are jointly rejected, r and s are deemed integrated, the analysis finishes. Otherwise, the analysis moves to Step 3.

Step 3. Model (7**) is estimated and tested. If hypotheses H_λ, H_γ, and H_B are jointly rejected, model (7**) is potentially accepted. The analysis continues at Step 5 except for the case of nonrejection of H_γ, when it moves to Step 4.

Step 4. Model (7*) is estimated and tested. If hypotheses H_λ and H_B are jointly rejected, model (7*) is potentially accepted. The analysis continues to Step 5 in any case.

Step 5. Model (5) is estimated and tested. If hypotheses H_λ, H_γ, H_B, and H_δ are jointly rejected and neither Eqs. (7**) nor (7*) has been potentially accepted, r and s are deemed to be tending to integration, given that $\delta<0$, or non-integrated, given that $\delta>0$, the analysis finishes. If these hypotheses are rejected but there is a potentially accepted alternative model, the analysis continues to Step 6. Given insignificant estimates in Eq. (5) and no potentially accepted model, the analysis moves to Step 7. If there is such a model, it turns from potentially to actually accepted and the analysis finishes. (In the case that Eq. (7**) is accepted, r and s are deemed non-integrated; accepting Eq. (7*) implies that they are integrated, $\{P_{rst}\}$ containing a structural break in both cases.)

Step 6. The specification test is performed, choosing between models (7**)/(7*) and (5). Depending on its results, regions r and s are deemed non-integrated, integrated, or tending towards integration—if Eqs. (7**) or (5) with $\delta>0$, or Eq. (7*), or Eq. (5) with $\delta<0$ is accepted, correspondingly. Then analysis finishes.

Step 7. Model (7) is estimated and tested. If the unit root hypothesis, H_λ, is rejected, r and s are deemed to be integrated and non-integrated otherwise.

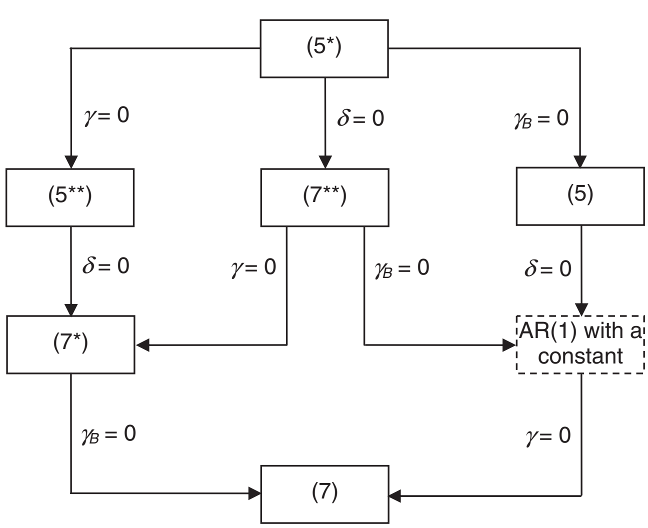


Fig. 2. Structure of the model set.

Table 1
Models vs. region types.

Model	Type of region
(7), (7*), and (5**)	Integrated
(5) with $\delta<0$, and (5*) with $\delta<0$	Tending towards integration
(7**), (5) with $\delta>0$, (5*) with $\delta>0$, and none	Non-integrated

Let us consider some technical details of estimations. For testing the unit root hypotheses, H_λ, the t-statistic of λ is used. The distributions of this statistic for regressions (5), (5*), (5**), (7*), and (7**) not only are nonstandard, but they also differ from the Dickey–Fuller distributions and have not been documented in the literature. Denote the t-statistics for the respective regressions by τ_{NL}, $\tau_{NL}(\theta)$, $\tau^*_{NL}(\theta)$, $\tau_0(\theta)$, and $\tau_c(\theta)$; argument θ indicates that the statistics depend on the break point, θ (τ_0 and τ_c with no argument stand for the Dickey–Fuller τ-statistic for Eq. (7) and the AR(1) with a constant, respectively). To derive p-values of the unit root tests, the empirical distributions of these statistics under the null hypothesis of random walk have been estimated with the use of the Monte Carlo method with 1,000,000 simulations. Appendix Table A1 reports some results of this work, tabulating selected critical values of the τ-statistics.

To test for a unit root, two tests are employed, which are the Phillips–Perron test and ADF test in the case of Eq. (7) and their modifications for other regressions. The unit root hypothesis, H_λ, is deemed rejected if both tests reject it. In the Phillips–Perron test, the

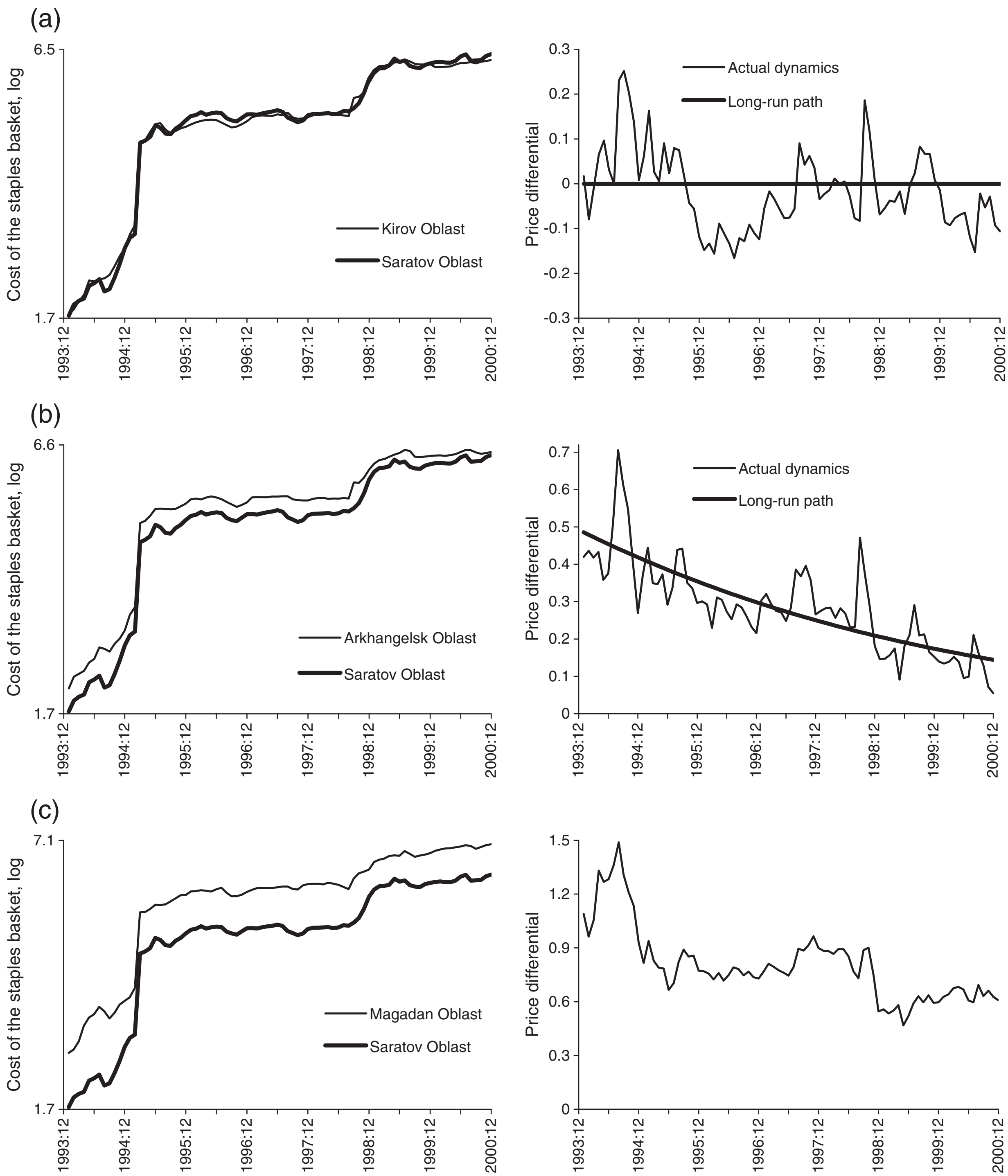


Fig. 3. Behavior of actual time series: (a) integrated regions; (b) regions tending towards integration; (c) non-integrated regions.

Phillips (1987) transformation is applied to relevant $\hat{\tau}$, using the Newey and West (1994) automatic bandwidth selection method with the Bartlett spectral kernel. The adjusted value of the τ-statistic determines p-value of the test through $p(\tau)$, the respective estimated distribution. (Given Eq. (7), this is the Dickey–Fuller distribution of τ_0.) In the ADF test, the Schwarz information criterion serves for choosing the optimal lag length. In doing so, the lag length varies from 0 to $K_{\max}=[12(T/100)^{1/4}]$, where $[\cdot]$ stands for integer part, while the number of included observations remains constant and equals $T-1-K_{\max}$ (Ng and Perron, 2005). Having found the optimal lag length, reestimating the relevant regression on the actual sample yields the adjusted value of the τ-statistic, which in turn determines p-value of the ADF test.

To find the break point, Eqs. (5*) and (7**) are estimated for each possible point, $\theta=$ 1998:08,…,1999:02. Then θ that yields the least sum of squared residuals is taken. Eqs. (5**) and (7*) inherit estimated θ from Eqs. (5*) and (7**), respectively. (While experimenting with θ estimated in each of the four regressions independently, for the most part the estimates of θ proved to be the same across the models.)

Table 2
Summary of estimations and unit root tests.

Region	Unit root test *p*-values (PP/ADF)	λ		Initial disparity, γ		Structural break, γ_B		Convergence rate, δ	
I. Northern economic area									
1. Rep. of Karelia	0.008/0.007	−0.422	(0.091)	0.436	(0.060)***			−0.012	(0.003)***
2. Rep. of Komi[d]	0.002/0.000	−0.497	(0.098)	0.207	(0.084)**	0.266	(0.071)***	−0.013	(0.004)***
3. Arkhangelsk Obl.	0.022/0.011	−0.389	(0.090)	0.625	(0.074)***			−0.017	(0.003)***
4. Vologda Obl.	0.008/0.010	−0.143	(0.055)						
5. Murmansk Obl.	0.057/0.076	−0.238	(0.072)	0.727	(0.146)***			−0.009	(0.004)**
II. Northwestern Economic Area									
6. St. Petersburg City	0.132/0.076	−0.069	(0.040)						
7. Novgorod Obl.	0.032/0.012	−0.141	(0.055)						
8. Pskov Obl.	0.005/0.003	−0.194	(0.063)						
9. Kaliningrad Obl.	0.002/0.002	−0.217	(0.069)						
III. Central economic area									
10. Bryansk Obl.[b]	0.040/0.027	−0.167	(0.069)			−0.073	(0.030)**		
11. Vladimir Obl.	0.000/0.000	−0.298	(0.077)						
12. Ivanovo Obl.	0.003/0.056	−0.215	(0.067)						
13. Kaluga Obl.	0.003/0.003	−0.205	(0.067)						
14. Kostroma Obl.	0.001/0.001	−0.257	(0.074)						
15. Moscow City [b]	0.064/0.078	−0.220	(0.069)	0.951	(0.314)***	−0.478	(0.240)**	−0.011	(0.005)**
16. Oryol Obl.[b]	0.036/0.053	−0.134	(0.057)			−0.098	(0.035)***		
17. Ryazan Obl.	0.009/0.006	−0.150	(0.054)						
18. Smolensk Obl.[b]	0.001/0.001	−0.401	(0.091)	0.056	(0.030)*	−0.109	(0.035)***		
19. Tver Obl.	0.004/0.002	−0.213	(0.068)						
20. Tula Obl.[b]	0.040/0.029	−0.234	(0.072)	0.076	(0.038)*	−0.113	(0.042)***		
21. Yaroslavl Obl.	0.012/0.047	−0.147	(0.055)						
IV. Volga-Vyatka economic area									
22. Rep. of Mariy El	0.045/0.042	−0.100	(0.050)						
23. Rep. of Mordovia[d]	0.050/0.030	−0.239	(0.074)	−0.127	(0.027)***	0.071	(0.031)**		
24. Chuvash Rep.	0.027/0.012	−0.150	(0.059)						
25. Kirov Obl.	0.001/0.001	−0.256	(0.075)						
26. Nizhni Novgorod Obl.	0.024/0.017	−0.339	(0.083)	0.353	(0.207)*			−0.114	(0.059)*
V. Central Black-Soil economic area									
27. Belgorod Obl.	0.010/0.004	−0.194	(0.066)						
28. Voronezh Obl.	0.015/0.013	−0.368	(0.087)	−0.258	(0.076)***			−0.051	(0.020)**
29. Kursk Obl.	0.002/0.001	−0.239	(0.070)						
30. Lipetsk Obl.	0.010/0.006	−0.183	(0.065)						
31. Tambov Obl.[b]	0.005/0.004	−0.223	(0.068)			−0.080	(0.024)***		
VI. Volga-region economic area									
32. Rep. of Kalmykia	0.000/0.000	−0.349	(0.083)						
33. Rep. of Tatarstan	0.046/0.045	−0.078	(0.039)						
34. Astrakhan Obl.	0.000/0.015	−0.326	(0.081)						
35. Volgograd Obl.	0.002/0.016	−0.247	(0.073)						
36. Penza Obl.	0.011/0.006	−0.176	(0.063)						
37. Samara Obl.	0.077/0.093	−0.086	(0.041)						
38. Saratov Obl.	(Benchmark region)								
39. Ulyanovsk Obl.	0.018/0.018	−0.313	(0.077)	−0.274	(0.047)***			−0.009	(0.004)**
VII. Northern Caucasus economic area									
40. Rep. of Adygeya	0.000/0.000	−0.319	(0.081)						
41. Rep. of Dagestan	0.000/0.004	−0.376	(0.085)						
42. Kabardian-Balkar Rep.	0.006/0.005	−0.170	(0.059)						
43. Karachaev-Cirkassian Rep.[c]	0.004/0.005	−0.249	(0.076)			0.056	(0.031)*		
44. Rep. of Northern Ossetia	0.003/0.001	−0.235	(0.071)						
45. Krasnodar Krai	0.000/0.030	−0.394	(0.089)						
46. Stavropol Krai	0.000/0.000	−0.401	(0.089)						
47. Rostov Obl.	0.000/0.000	−0.321	(0.083)						
VIII. Urals economic area									
48. Rep. of Bashkortostan	0.001/0.019	−0.215	(0.066)						
49. Udmurt Rep.	0.001/0.001	−0.229	(0.068)						
50. Kurgan Obl.	0.003/0.004	−0.476	(0.095)	0.475	(0.110)***			−0.090	(0.023)***
51. Orenburg Obl.	0.002/0.002	−0.541	(0.099)	0.337	(0.088)***			−0.077	(0.023)***
52. Perm Obl.	0.009/0.009	−0.376	(0.085)	0.370	(0.067)***			−0.027	(0.006)***
53. Sverdlovsk Obl.	0.020/0.017	−0.348	(0.085)	0.338	(0.062)***			−0.014	(0.005)***
54. Chelyabinsk Obl.	0.003/0.002	−0.511	(0.098)	0.228	(0.040)***			−0.016	(0.005)***
IX. Western Siberian economic area									
55. Rep. of Altai[e]	0.000/0.000	−0.444	(0.091)			0.148	(0.024)***		
56. Altai Krai[e]	0.000/0.000	−0.553	(0.096)	−0.075	(0.016)***	0.124	(0.020)***		
57. Kemerovo Obl.[e]	0.001/0.001	−0.511	(0.093)			0.300	(0.047)***	−0.013	(0.005)**
58. Novosibirsk Obl.[e]	0.012/0.010	−0.244	(0.066)	0.113	(0.036)***	0.077	(0.041)*		
59. Omsk Obl.[e]	0.000/0.000	−0.405	(0.090)			0.044	(0.018)**		
60. Tomsk Obl.[c]	0.000/0.000	−0.577	(0.097)			0.170	(0.016)***		
61. Tyumen Obl.[d]	0.065/0.054	−0.199	(0.067)	0.115	(0.051)**	0.106	(0.056)*		
X. Eastern Siberian economic area									
62. Rep. of Buryatia[a]	0.005/0.003	−0.415	(0.092)	0.226	(0.092)**	0.184	(0.068)***	−0.011	(0.005)**
63. Rep. of Tuva[d]	0.001/0.001	−0.427	(0.092)	0.236	(0.033)***	0.176	(0.040)***		

Table 2 *(continued)*

Region	Unit root test *p*-values (PP/ADF)	λ		Initial disparity, γ		Structural break, γ_B		Convergence rate, δ	
X. Eastern Siberian economic area									
64. Rep. of Khakasia[c]	0.000/0.000	−0.534	(0.097)	0.141	(0.023)***	0.061	(0.028)**		
65. Krasnoyarsk Krai[c]	0.000/0.000	−0.561	(0.099)	0.045	(0.020)**	0.133	(0.024)***	0.008	(0.005)*
66. Irkutsk Obl[c]	0.000/0.000	−0.598	(0.102)	0.132	(0.029)***	0.223	(0.038)***		
67. Chita Obl.	0.001/0.001	−0.606	(0.101)	0.721	(0.048)***			−0.015	(0.002)***
XI. Far Eastern economic area									
68. Rep. of Sakha (Yakutia)[c]	0.000/0.000	−0.446	(0.092)	0.765	(0.063)***	0.575	(0.084)***		
69. Jewish Autonomous Obl.[c]	0.005/0.004	−0.397	(0.089)	0.336	(0.088)***	0.238	(0.062)***	−0.008	(0.003)**
70. Primorsky Krai	0.027/0.023	−0.327	(0.083)	0.869	(0.098)***			−0.010	(0.003)***
71. Khabarovsk Krai[d]	0.016/0.015	−0.324	(0.083)	0.469	(0.128)***	0.239	(0.085)***	−0.007	(0.004)*
72. Amur Obl.[e]	0.005/0.003	−0.311	(0.074)	0.176	(0.042)***	0.225	(0.052)***		
73. Kamchatka Obl.[d]	0.000/0.000	−0.509	(0.097)	0.776	(0.054)***	0.489	(0.070)***		
74. Magadan Obl.	0.234/0.235	−0.011	(0.010)						
75. Sakhalin Obl.	0.280/0.280	−0.012	(0.012)						

Notes: 1. PP and ADF stand for the Phillips–Perron test and augmented Dickey–Fuller test, respectively; 2. Standard errors are in parentheses; 3. Significance at 1% (***), 5% (**), and 10% (*); 4. Numbers of nonintegrated regions are marked with bold italic; 5. 'Obl.' stands for Oblast and 'Rep.' stands for Republic.

[a] Break in 1998:08.
[b] Break in 1998:09.
[c] Break in 1998:11.
[d] Break in 1998:12.
[e] Break in 1999:01.

2.3. Data

The subjects of the Russian Federation are taken as regions. The price data were collected in capital cities of the regions. The sample covers 75 of Russia's 89 regions. Data are lacking for ten autonomous *okrugs*, the Chechen Republic, and the Republic of Ingushetia. Two other regions are omitted; the City of Moscow is simultaneously a separate subject of the Russian Federation ("city-region") and the capital city of the surrounding Moscow Oblast. The same holds for St. Petersburg and the Leningrad Oblast. This explains why these city-regions are present in the sample, while their surrounding *oblasts* are not.

Reporting results below, Russian regions are grouped by economic area, *ekonomicheskiy rayon*, as in Russian statistical publications prior to June 2000, except the Kaliningrad Oblast which is added here to the Northwestern Economic Area. (The economic areas are economic-geographical units rather than formal administrative-territorial units.)

The price representative for the analysis is the cost of a basket of 25 basic food goods defined as the standard by the Russian statistical agency, Goskomstat (now Rosstat), between January 1997 and June 2000. This basket covers about one third of foodstuffs involved in the Russian CPI. But unlike the CPI, the staples basket has constant weights across regions and time. Goskomstat (1996) provides a description of the basket composition. The costs of the basket (including those for the second half of 2000 and retrospectively calculated for 1994–1996) were obtained directly from Goskomstat (available at: http://econom.nsu.ru/staff/chair_et/gluschenko/Research/Data/Basket-25.xls). A more detailed description of this data set is given in Gluschenko (2003).

The data are monthly, spanning 84 months, from January 1994 to December 2000. There are missing observations in the time series used. Most occur in 1994, which has 42 missing observations (4.7% of the yearly total) in 17 regional time series. The remainder of the data set lacks only 9 observations. To fill the gaps, missing prices are approximated by the food component of the regional monthly CPIs. The interpolated value of p_{rt} is the arithmetic mean of the nearest known preceding price inflated to the required time point, t, and the nearest known succeeding price deflated to t.

Fig. 3 shows actual time series data for representative regions of types (a), (b), and (c), anticipating things to be reported in the next section. (The working paper version, Gluschenko, 2010b, provides additional plots for all "sub-types" according to the first column of Table 1.) Plots in Fig. 3(a) and (b) are counterparts of plots in Fig. 1(a) and (b), although in logarithmic terms. The long-run trend in Fig. 3(b) is computed with the use of estimated γ and δ reported in Table 2 in the next section. As is seen, the actual data do tend to exhibit the stylized behavior depicted in Fig. 1. Fig. 3(c) additionally demonstrates a case of non-integration. For this region pair, the Saratov and Magadan *oblasts*, no one of our models rejects unit root.

3. Empirical results

The 75 series of regional prices in the data set used yield 2775 region pairs. Therefore, we need to reduce such a mass of pairwise comparisons. On the other hand, only 74 out of the pairs are independent, which makes the reduction of the number of pairs to 74 imminent. The standard approach in the literature on the law of one price and PPP is to pick some region as a benchmark, using its price as a numeraire. Unfortunately, there is no obvious evidence for a priori choosing a proper benchmark among regions under consideration.

To solve this problem, the estimations were run by taking each region as the benchmark in order to select the "best" one.[4] (Thus, this did involve all 2775 pairs). Appendix Table A2 supplies summary of these results. The Saratov Oblast was chosen as the final benchmark among three regions that generate the highest numbers of integrated pairs (40 to 42). One region, the Kaliningrad Oblast, was discarded because of a greater number of non-integrated pairs. One more region, the Kabardian-Balkar Republic, has a small advantage, yielding the number of integrated pairs greater by one with the same number of pairs tending towards integration. But the Kabardian-Balkar Republic seems poorly representative, being a small North-Caucasian region. For this reason, it was also discarded. Integration of each region with the Saratov Oblast is analyzed below. Thus, index s in the above models is fixed and corresponds to this

[4] In doing so, a simplified way of choosing between Models (7**)/(7*) and (5) by comparison of their estimated log likelihoods has been used rather than the computationally intensive specification test based on the Monte Carlo method. Thorough testing might change some of these choices. However, a random inspection for a number of benchmark regions suggests that such changes are few in number. For example, in the actual pattern for the Saratov Oblast, the number of regions tending towards integration decreases by one, thus increasing by one the number of non-integrated regions.

region. Throughout this study, the 10% significance level is adopted in all cases.

Table 2 reports the final estimation results, i.e. estimates of a model selected for a given region as well as results of unit root tests for this model. (For the full set of estimates and results of specification tests, see Gluschenko, 2010b.) The selected model determines a set of parameters reported in the table. Given all parameters λ, γ, γ_B, and δ, this means the acceptance of Eq. (5*). Reporting λ, γ_B, and δ implies that Eq. (5**) is accepted; λ, γ, and δ correspond to Model (5); and λ, γ, and γ_B correspond to Eq. (7**) . If there are only λ and γ_B in a given row, then Eq. (7*) is accepted; and the only parameter λ is reported when Eq. (7) is accepted. The latter case may also imply that no model is selected provided that a unit root is not rejected in Eq. (7). Bold italic marks the numbers of non-integrated regions. Recall that the correspondence between the models and region types is tabulated in Table 1. If there is a structural break in a given time series (γ_B is reported), a footnote to the table provides its point in time.

Out of 74 regions, 40 are integrated with the Saratov Oblast, 18 are tending towards integration with it, and 16 are neither integrated nor tending towards integration. Thus, considering the period of 1994–2000, more than a half (54%) of region pairs exhibit market integration and about a quarter (24%) of them move to this state, while only slightly more than a fifth (22%) of pairs do not show evidence of integration. Out of the latter, four pairs include difficult-to-access regions (the Republic of Sakha and the Kamchatka, Magadan and Sakhalin *oblasts*). They are remote Far-Eastern regions lacking railway and road communication with other regions. In these regions, arbitrage can hardly be bilateral since goods are imported only. Therefore, the difficult-to-access regions are reasonably expected to be non-integrated and to remain such in the foreseeable future. The pattern obtained fundamentally differs from the patterns of poor market integration in Russia found for the very early years of transition by Berkowitz et al. (1998), Gardner and Brooks (1994), and Goodwin et al. (1999).

Among integrated region pairs, Eq. (7) describes price dynamics in 32 cases. Model (7*) is valid for seven pairs, and Eq. (5**) is valid in the only case of the Kemerovo Oblast. This implies that eight regions had been non-integrated before the structural breaks caused by the 1998 financial crisis and became integrated after the breaks. Thus, the 1998 crisis facilitated price equalizing among Russian regions, improving the pattern of market integration. (The reasons for this will be discussed later.) In three region pairs, the break was upward, suggesting increases in prices relative to the benchmark region; the remaining five cases are those of price-cutting. The half-life times in the group of integrated regions, t_{HLS}, vary from 0.8 to 8.5 months with the average equaling 3.1 months.

The evolution of prices among region pairs tending towards integration is characterized by Eq. (5) in 13 cases and by the model with break, Eq. (5*), in five cases. In two regions only, the Voronezh and Ulyanovsk *oblasts*, prices rose in the course of convergence to the benchmark price. Although both have almost the same (estimated) starting disparity, about 25% below the benchmark, their convergence rates considerably differ. Expressed as a percentage, $|e^{\delta}-1|\cdot 100$, the convergence rate equals 5% per month in the Voronezh Oblast and 0.9% per month in the Ulyanovsk Oblast, which yields the disparity half-lives, t_{HLL}, equaling 1.1 and 6.4 years, respectively. A very probable reason is that the government of the Ulyanovsk Oblast maintained low prices in the region by price regulations and subsidies over many years, until the beginning of 2001, so decelerating price convergence. (Regarding this region, see also Berkowitz and DeJong, 1999, and Gardner and Brooks, 1994.) In the reminder of this region group, the starting disparity is on average 51% above the benchmark and varies from 21% to 87%. The convergence rate has a band of 0.7% to 10.8% per month with an average of 2.8%. This corresponds to t_{HLL} from 0.5 to 7.8 years, 4.1 years on average. There is a modest negative correlation, –0.383, between positive starting disparities and convergence rates. This suggests that convergence has a weak propensity to be slower, the greater the initial disparity. Except for Moscow, the structural breaks decreased price disparities, thus playing again in favor of more integration.[5] Regarding half-lives of random deviations from the long-run paths, t_{HLS}, their average over all 18 region pairs of this group is equal to 1.5 months with the variation from 0.7 to 2.8 months.

It is interesting to note that among regions tending towards integration, four can be deemed as becoming integrated by the end of the time span covered because of practically completed convergence. These are the Nizhni Novgorod, Voronezh, Kurgan, and Orenburg *oblasts*. In January 2000, their estimated disparities, $\gamma e^{\delta\cdot 72}$, had values of 0.01%, −0.64%, 0.07%, and 0.13% of the benchmark price, respectively.

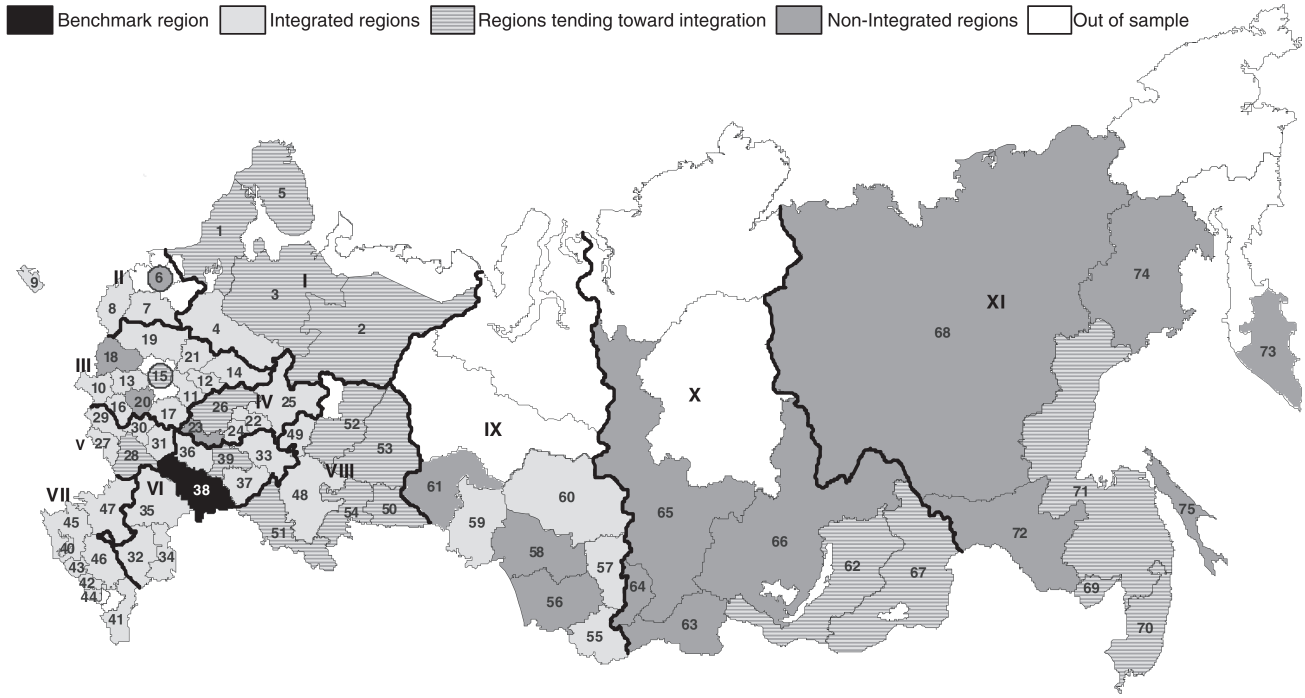
The only case of deterministic divergence, Eq. (5*) with $\delta>0$, exists among non-integrated regions. Three price differentials in this region group contain unit root (in fact, the AR(1) with a constant and no unit root would be valid for one of them). The rest of the 12 region pairs have a stepwise path of the price differential that is characterized by Eq. (7**). Thus, non-integration was predominantly due to constant (apart from random shocks) price disparities, with one-shot switches, rather than to deterministic or stochastic divergence of prices. Price disparities increased as a result of the 1998 crisis in four out of those 12 region pairs and decreased in eight pairs. (With the only exception, the former are pairs with regions from the European part of Russia, and the latter contain regions from Siberia and the Far East.) This suggests that differences in prices between Russian regions became for the most part smaller after the crisis. Not one case is found where a region has been integrated before the crisis and become non-integrated after it. The half-lives of random deviations, t_{HLS}, among region pairs characterized by Eq. (7**) vary from 0.8 to 3.1 months with the average of 1.6 months.

Overall, the 1998 crisis strongly affected regional price dynamics. It caused a structural break in about a third of the time series under consideration. The only break is detected in the first month of the crisis, August 1998. The rest of the breaks are almost uniformly distributed among September, November, and December 1998, and January 1999. Not one break is found in October 1998 and February 1999. All early breaks, those in September 1998, occurred in the European part of Russia. In its Asian part, the crisis affected price dynamics with a delay, starting to provoke structural breaks since November 1998 (except for the Republic of Buryatia, where the very early break occurred).

One aspect of the crisis was dramatic devaluation of the Russian currency. By the beginning of 1999, it was devaluated 3.3-fold relative to the end of July 1998. The $/ruble exchange rate increased by 27% during August and by more 103% during September 1998. In October, the exchange rate was more or less stable (which could explain the absence of structural breaks in this month) and rose again during November and December, by 12% and 15%. As a result, domestic goods were quickly displacing those imported from abroad.

A surge of inflation accompanied the devaluation of ruble. After a modest (for Russia of that time) 8.1% rise in consumer prices over January to August 1998, it jumped to 38.4% in September 1998, varying from 14.3% to 55.4% across regions of the country. Because of this, the crisis initially brought the threat to market integration in Russia. In order to preserve region's population from rise in prices (or, at least, to smooth the rise), governments of a number of regions erected trade barriers, restricting exportation of agricultural and food products from the region. (This can partly explain that great dispersion of inflation rates across the regions in September 1998.) These measures, however,

[5] The case of Moscow appears strange in general. There is abundant evidence of a special position of Moscow as "a country within a country" (see, e.g., Gluschenko, 2010a). Its market is partitioned off from the Russian market by barriers erected by both the city government and organized crime. Therefore, there are strong grounds to expect Moscow not to move towards integration with any other region. Possibly, the shape of the Moscow price differential path has become by chance (maybe, due to structural break) such that it lends to fitting to Model (5*). However, the question of whether the Moscow prices do exhibit convergence to something else can be answered only by exploring their evolution beyond 2000.



Notes: Thick lines are borders of economic areas; see Table 2 for numerical designations of economic areas and regions.

Fig. 4. Geographical pattern of market integration in Russia.

had a very short-term effect. Being against Russian law, they were abolished after a short time by regional prosecutors. Thus, the new-erected barriers were not able to prevent expansion of inter-regional trade caused by the displacement of foreign goods by domestic ones, which, in turn, facilitated improvements in market integration in the country. Besides, this is a reason for prices in many non-integrated regions to become closer to the benchmark price. As Gluschenko (2003) documents, market segmentation peaked in September 1998, but it started decreasing by next month. Re-integration of Russia's market was so quick that the market reached a fairly stable degree of integration as early as in the beginning of 1999.

The spatial structure of market integration is graphically presented in Fig. 4. There are only four non-integrated regions in the European part of Russia; the rest of them are in Siberia and the Far East. The farthest integrated regions lie in Western Siberia; there is none eastward of it. Nonetheless, there are five regions tending towards integration with the benchmark region in Eastern Siberia and the Far East. In the latter, four of five non-integrated regions are difficult-to-access ones. However, one more region labeled by Gluschenko (2003) as difficult-to-access, the Murmansk Oblast (in the European part of the country), proves to be tending towards integration.

Fig. 4 provides no evidence of a correlation between non-integration and the Red Belt regions as they are defined by Berkowitz and DeJong (1999). Curiously enough, our benchmark region itself, the Saratov Oblast, lies in the Red Belt. Out of 30 Red Belt regions (excluding the Saratov Oblast), 19, or 63%, turn out to be integrated with the benchmark, six, or 20%, are tending towards integration with it, and five, or 17%, are non-integrated. The proportion of integrated regions in the Red Belt is greater than that in the rest of the country. Among 44 regions outside the Red Belt, 48% are comprised of integrated regions and 27% are comprised of regions tending towards integration; 25% of regions are non-integrated. It may seem that this difference is caused by belonging the benchmark region to the Red Belt. But the use of the "second-best" benchmark, the Kaliningrad Oblast, which is not a Red Belt region, yields a qualitatively similar result.

At the same time, Gluschenko's (2010a) results corroborate the findings of Berkowitz and DeJong (1999), suggesting that the Red Belt considerably contributed to segmentation of the Russian market. Considering consequences of the 1998 crisis resolves this ostensible contradiction. Among eight regions that have become integrated due to structural breaks, as Eqs. (7*) and (5**) suggest, six are those from the Red Belt. The crisis caused a 1.5-fold increase in the proportion of integrated regions in the Red Belt. Before the crisis, there were 37% of non-integrated regions in the Red Belt as compared to 30% among the rest of regions. Note moreover that anti-market policy in some Red Belt regions can impede market integration without an influence on our classification of regions. An example is the small convergence rate in the above-discussed Ulyanovsk Oblast. On the other hand, as Gluschenko (2010a) found, the role of anti-integration forces, such as regional protectionism, progressively shrank over time. Moreover, after 1996, a number of Red Belt regions (recall that that they were classified as such based on the 1996 data) "abandoned" their anti-market policies.

In general, the extent of market integration in Russia in 1994–2000 seems not to differ much from that in long-standing market economies. For instance, Ceglowski (2003) investigates the law of one price across 25 Canadian cities (with the country's capital as the benchmark) for each of 45 individual goods, applying the AR(1) model with a constant. Averaging data reported in Ceglowski's (2003) Table 2 over these 45 goods markets, the percentage of time series for which unit root can be rejected at the 10% significance level (in our terms, the percentage of integrated city pairs) equals 55%, which is close to the figure for Russia.[6]

4. Conclusion

Using the cost of the basket of 25 basic food goods as the price representative, the spatial pattern of market integration in Russia in 1994–2000 was analyzed. It was found that over a half of Russian

[6] Ceglowski (2003) obtains the average (over goods) of median half-lives of random deviations, t_{HLS}, equaling 0.5 years, while the median t_{HLS} is equal to 0.2 years (2.8 months) for Russian integrated regions. In fact, these figures should be closer, since the half-lives for Canada are computed from λs estimated in the ADF equations which yield, as a rule, a smaller absolute value of λ as compared to our Eq. (7) because of additional lags.

regions (54%) could be deemed as integrated with the benchmark region over 1994–2000, and about a quarter of regions (24%) could be classified as tending towards integration with the benchmark. Among the latter, four regions exhibited convergence completed by the end of the time span under consideration. Slightly more than one-fifth of the regions (22%) were found non-integrated. However, the latter assessment may be overstated, since the strict version of the law of one price was used as an indication of integration. It does not allow for such an irremovable market friction as spatial separation of regions, i.e. price disparities caused by transportation costs only.

The introduction of the concept of regions tending towards integration has proven to be fruitful in revealing the features of the transition process. Omitting the relevant models, only six out of 18 region pairs recognized as tending towards integration can be characterized by Model (7) or (7*). Thus, if the traditional approach to the time series analysis of market integration were used, 46 regions (or 62% of the total) would be deemed as integrated with the benchmark, and 28 regions (38%) would be non-integrated. Such a pattern is not encouraging and suggests no indications of its further improvement.

The results obtained shed light on reasons behind the patterns of the evolution of market integration in Russia presented in Berkowitz and DeJong (2001, 2003) and Gluschenko (2003). The improvement in market integration during 1994–2000 can be measured in several ways: an increasing aggregated degree of integration (Berkowitz and DeJong, 2001, 2003) and a decreasing aggregated degree of segmentation (Gluschenko, 2003). These can be assigned to a considerable proportion of regions that tended towards integration. At the same time, non-integrated regions did not cause a rise in market segmentation, exhibiting, with only one exception, no price divergence. The changes in the degrees of integration/segmentation accelerated within several months after the 1998 financial crisis in Russia. Judging from the results obtained here, this is due to the fact that structural breaks induced by the crisis in inter-regional price differentials were asynchronous across regions and distributed over a few months.

Overall, the results unambiguously suggest that the Russian market has been moving towards closer integration in 1994–2000, despite anti-integration forces (such as regional protectionism and organized crime; see Gluschenko, 2010a) and anti-market policies in a considerable number of regions (predominantly in the Red Belt regions; see Berkowitz and DeJong, 1999). Among non-integrated regions, four are difficult-to-access. Logically, access difficulties present insurmountable market frictions, so the lack of integration of these regions is more likely due to geographical realities than a particular economic policy, either national or regional. The pattern obtained appears encouraging and fundamentally differs from the pattern of poor market integration observed in a few initial years of the Russian transition by Berkowitz et al. (1998), Gardner and Brooks (1994), and Goodwin et al. (1999). What is more, as the comparison with Canada in the end of the previous section shows, the extent of market integration in Russia in 1994–2000 is comparable to that in long-standing market economies.

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Appendix A

Table A1
Critical values of the unit root test τ-statistics.

Significance level	No break	Break point, θ						
		1998:08	1998:09	1998:10	1998:11	1998:12	1999:01	1999:02
τ_{NL} and $\tau_{NL}(\theta)$ for Eqs. (5) and (5*), respectively								
0.1%	−5.553	−4.807	−4.805	−4.795	−4.795	−4.793	−4.788	−4.789
1%	−4.365	−4.068	−4.068	−4.064	−4.064	−4.061	−4.059	−4.058
5%	−3.512	−3.385	−3.385	−3.384	−3.384	−3.381	−3.379	−3.377
10%	−3.129	−3.038	−3.038	−3.038	−3.038	−3.035	−3.032	−3.032
20%	−2.707	−2.640	−2.640	−2.640	−2.640	−2.637	−2.635	−2.634
$\tau^*_{NL}(\theta)$ for Eq. (5**)								
0.1%		−5.276	−5.287	−5.271	−5.255	−5.210	−5.219	−5.179
1%		−4.078	−4.067	−4.048	−4.051	−4.033	−4.030	−4.012
5%		−2.995	−2.986	−2.985	−2.988	−2.986	−2.986	−2.983
10%		−2.458	−2.455	−2.458	−2.459	−2.461	−2.464	−2.465
20%		−1.840	−1.839	−1.847	−1.853	−1.855	−1.858	−1.864
τ_c and $\tau_c(\theta)$ for the AR(1) with a constant and Eq. (7**), respectively								
0.1%	−4.251	−4.373	−4.368	−4.375	−4.372	−4.368	−4.373	−4.369
1%	−3.511	−3.676	−3.676	−3.674	−3.670	−3.668	−3.665	−3.661
5%	−2.897	−3.002	−3.000	−3.000	−2.996	−2.995	−2.993	−2.991
10%	−2.586	−2.656	−2.656	−2.656	−2.654	−2.654	−2.652	−2.651
20%	−2.223	−2.262	−2.263	−2.262	−2.262	−2.262	−2.262	−2.262
τ_0 and $\tau_0(\theta)$for Eqs. (7) and (7*), respectively								
0.1%	−3.363	−3.693	−3.701	−3.703	−3.703	−3.710	−3.714	−3.723
1%	−2.593	−2.902	−2.906	−2.913	−2.922	−2.925	−2.930	−2.937
5%	−1.945	−2.083	−2.091	−2.092	−2.099	−2.100	−2.106	−2.111
10%	−1.614	−1.670	−1.675	−1.674	−1.678	−1.682	−1.684	−1.686
20%	−1.228	−1.240	−1.239	−1.239	−1.241	−1.242	−1.242	−1.244

Notes: 1. Sample size = 84 (1994:01 through 2000:12); 2. MacKinnon's (1996) critical values are reported for τ_c and τ_0; 3. Data for the AR(1) with a constant, τ_c, are supplied for comparison only.

Table A2
Summary of estimation results across different benchmarks, number of time series (region pairs).

Benchmark region	Integrated	Tending towards integration	Non-integrated	Model characterizing dynamics								
				(5*), $\delta>0$	(5*), $\delta<0$	(5**)	(7**)	(7*)	(5), $\delta>0$	(5), $\delta<0$	(7)	None
I. Northern economic area												
1. Rep. of Karelia	10	35	29	3	15	1	21	6	0	20	3	5
2. Rep. of Komi	14	34	26	1	18	9	17	3	1	16	2	7
3. Arkhangelsk Obl.	10	44	20	3	26	2	12	3	0	18	5	5
4. Vologda Obl.	27	24	23	1	11	3	16	11	0	13	13	6
5. Murmansk Obl.	3	42	29	1	27	0	17	1	0	15	2	11
II. Northwestern economic area												
6. St. Petersburg City	16	21	37	1	15	0	21	7	1	6	9	14
7. Novgorod Obl.	22	23	29	2	12	2	24	10	0	11	10	3
8. Pskov Obl.	17	29	28	0	9	3	25	4	0	20	10	3
9. Kaliningrad Obl.	42	7	25	1	2	0	19	15	0	5	27	5
III. Central economic area												
10. Bryansk Obl.	21	33	20	0	13	1	15	6	0	20	14	5
11. Vladimir Obl.	22	23	29	1	11	1	24	7	0	12	14	4
12. Ivanovo Obl.	21	23	30	0	11	2	25	5	0	12	14	5
13. Kaluga Obl.	38	12	24	0	5	2	15	9	0	7	27	9
14. Kostroma Obl.	18	17	39	5	6	2	28	4	1	11	12	5
15. Moscow City	3	16	55	14	16	2	32	1	0	0	0	9
16. Oryol Obl.	18	51	5	0	14	2	3	4	0	37	12	2
17. Ryazan Obl.	23	15	36	0	9	2	29	7	0	6	14	7
18. Smolensk Obl.	21	27	26	0	14	10	25	8	0	13	3	1
19. Tver Obl.	24	12	38	3	4	4	30	7	0	8	13	5
20. Tula Obl.	23	30	21	0	16	3	19	8	0	14	12	2
21. Yaroslavl Obl.	18	27	29	1	16	3	24	6	1	11	9	3
IV. Volga-Vyatka economic area												
22. Rep. of Mariy El	15	5	54	10	2	0	22	1	0	3	14	22
23. Rep. of Mordovia	13	8	53	4	3	0	38	1	1	5	12	10
24. Chuvash Rep.	16	17	41	3	10	3	23	3	0	7	10	15
25. Kirov Obl.	34	6	34	7	2	0	22	7	1	4	27	4
26. Nizhni Novgorod Obl.	18	18	38	2	3	2	33	2	0	15	14	3
V. Central Black-Soil economic area												
27. Belgorod Obl.	27	36	11	0	7	1	7	6	0	29	20	4
28. Voronezh Obl.	13	51	10	0	16	4	4	2	0	35	7	6
29. Kursk Obl.	25	40	9	0	9	1	7	4	0	31	20	2
30. Lipetsk Obl.	24	35	15	0	16	0	12	4	0	19	20	3
31. Tambov Obl.	28	24	22	0	12	4	19	13	0	12	11	3
VI. Volga-region economic area												
32. Rep. of Kalmykia	26	21	27	0	12	5	25	9	0	9	12	2
33. Rep. of Tatarstan	13	33	28	2	16	0	23	0	0	17	13	3
34. Astrakhan Obl.	26	28	20	3	9	5	12	3	1	19	18	4
35. Volgograd Obl.	27	18	29	3	5	4	24	3	0	13	20	2
36. Penza Obl.	26	28	20	0	8	1	11	6	0	20	19	9
37. Samara Obl.	17	17	40	2	9	1	25	9	1	8	7	12
38. Saratov Obl.	40	19	15	1	5	1	11	7	0	14	32	3
39. Ulyanovsk Obl.	5	68	1	0	36	0	0	0	0	32	5	1
VII. Northern Caucasus economic area												
40. Rep. of Adygeya	17	44	13	0	19	2	10	3	0	25	12	3
41. Rep. of Dagestan	29	24	21	1	11	1	16	5	0	13	23	4
42. Kabardian-Balkar Rep.	41	19	14	1	2	2	5	4	0	17	35	8
43. Karachaev-Cirkassian Rep.	23	16	35	1	4	3	24	11	0	12	9	10
44. Rep. of Northern Ossetia	29	33	12	1	6	2	6	2	0	27	25	5
45. Krasnodar Krai	21	24	29	1	6	4	23	5	0	18	12	5
46. Stavropol Krai	21	27	26	1	11	1	21	4	0	16	16	4
47. Rostov Obl.	27	22	25	1	8	1	21	6	0	14	20	3
VIII. Urals economic area												
48. Rep. of Bashkortostan	28	20	26	1	6	0	23	4	0	14	24	2
49. Udmurt Rep.	25	14	35	4	5	1	27	8	0	9	16	4
50. Kurgan Obl.	16	19	39	8	3	1	23	6	3	16	9	5
51. Orenburg Obl.	29	12	33	8	0	1	21	4	2	12	24	2
52. Perm Obl.	18	31	25	3	10	9	20	3	1	21	6	1
53. Sverdlovsk Obl.	9	34	31	3	13	1	19	5	0	21	3	9
54. Chelyabinsk Obl.	20	30	24	4	6	2	18	7	1	24	11	1
IX. Western Siberian economic area												
55. Rep. of Altai	30	20	24	1	3	2	20	17	0	17	11	3
56. Altai Krai	20	9	45	1	6	1	36	11	0	3	8	8
57. Kemerovo Obl.	23	25	26	3	14	7	20	11	1	11	5	2
58. Novosibirsk Obl.	12	26	36	6	13	1	27	6	0	13	5	3
59. Omsk Obl.	27	26	21	3	8	2	13	9	0	18	16	5
60. Tomsk Obl.	29	17	28	3	10	12	21	12	0	7	5	4
61. Tyumen Obl.	20	26	28	0	2	1	16	11	0	24	8	12
X. Eastern Siberian economic area												
62. Rep. of Buryatia	25	23	26	1	8	3	22	16	0	15	6	3

(continued on next page)

Table A2 (*continued*)

Benchmark region	Integrated	Tending towards integration	Non-integrated	Model characterizing dynamics								
				(5*), $\delta>0$	(5*), $\delta<0$	(5**)	(7**)	(7*)	(5), $\delta>0$	(5), $\delta<0$	(7)	None
X. Eastern Siberian economic area												
63. Rep. of Tuva	7	20	47	7	8	0	35	2	1	12	5	4
64. Rep. of Khakasia	15	18	41	7	4	0	22	6	1	14	9	11
65. Krasnoyarsk Krai	27	12	35	6	5	3	21	18	0	7	6	8
66. Irkutsk Obl.	20	12	42	1	5	1	35	10	0	7	9	6
67. Chita Obl.	6	48	20	2	25	0	15	1	0	23	5	3
XI. Far Eastern economic area												
68. Rep. of Sakha (Yakutia)	3	14	57	2	13	0	48	0	0	1	3	7
69. Jewish Autonomous Obl.	8	41	25	2	30	0	21	3	0	11	5	2
70. Primorsky Krai	2	32	40	3	14	1	25	1	0	18	0	12
71. Khabarovsk Krai	3	42	29	3	27	0	23	0	0	15	3	3
72. Amur Obl.	12	27	35	2	18	0	32	8	0	9	4	1
73. Kamchatka Obl.	2	7	65	19	6	0	46	0	0	1	2	0
74. Magadan Obl.	1	17	56	0	2	0	12	0	0	15	1	44
75. Sakhalin Obl.	3	38	33	0	23	0	16	0	0	15	3	17

Notes: 1. To choose between Models (7**)/(7*) and (5), comparison of their estimated log likelihoods was applied rather than the Monte Carlo based specification test; 2. 'Obl.' stands for Oblast and 'Rep.' stands for Republic.

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