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Integration of the Russian Market

Empirical Analysis

Konstantin Gluschenko

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The paper analyzes a spatial pattern of goods market integration in Russia, and characterizes the movement of the national market as a whole to integration. By the spatial pattern is meant a state of each individual region of the country: whether it is integrated, and if not, whether it moves towards integration. Time series of the cost of the basket of 25 basic foods across 75 regions of Russia for 1994-2000 with monthly frequency are used as the empirical stuff. With the use of nonlinear cointegration relationship that includes asymptotically subsiding trend capturing movement towards integration, 36% of Russian regions are found to be integrated with the national market; 44% of them are non-integrated, but are tending to integration with the national market; and 20% of regions are non-integrated having no such a trend. Analyzing distribution dynamics, σ-convergence is found to take place; and the shape of the across-region distribution of prices tends to be more regular over time. To characterize intra-distribution mobility, a stochastic kernel (the generalization of a transition probability matrix, pioneered by Danny T. Quah) is estimated. Such a kernel is also used to estimate the long-run limit of the price distribution. This limit is unimodal, predicting that "price convergence clubs" will not arise in the long run.

Keywords. Russia, market integration, law of one price, price dispersion, convergence, Russian regions.

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Konstantin Gluschenko
Institute of Economics and Industrial Engineering
Siberian Branch of the Russian Academy of Sciences
Laventieva pr. 17, 630090 Novosibirsk, Russia
Tel.: +7(3832) 30 25 48
Fax: +7(3832)30 25 80
E-mail: glu@nsu.ru

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NON-TECHNICAL SUMMARY

Results of previous researches suggest that after a period of growing disconnectedness of the Russian market, the improvement of market integration started in 1994. Nevertheless, the market still is not near to completely integrated. This paper aims to reveal the spatial pattern of goods market integration in Russia, and to characterize the movement of the national market as a whole to integration. By the spatial pattern is meant a state of each individual region of the country: whether it is integrated over the 1994-2000 span, and if not, whether it moves towards integration. The source data for the empirical analysis are time series of the cost of a staples basket across 75 regions of Russia with monthly frequency, the cost for Russia as a whole being used as a representative of the national market.

It is hypothesized that the Russian goods market should eventually come to the final steady state of complete integration, that is, to the equality of prices across all regions. Currently, the market may be believed to be in transition towards this steady state. Hence, it is expected that three groups of regions may exist at present: (a) integrated regions, *i.e.*, those being in the steady state of equality of prices; (b) non-integrated regions tending to integration, *i.e.*, those in which prices are catching up with each other; and (c) non-integrated regions having no such a trend. (For brevity, hereafter regions from the second group are referred to as “regions tending to integration”, and regions from the third group are referred to as simply “non-integrated regions.”)

Differences between prices in regions and in Russia as a whole are analyzed, thus dealing with integration of regions with the entire national market. A region is deemed as integrated, if the price in it fluctuates about equality with the Russian price. When regional price converges to the Russian one (the price difference has a non-linear subsiding trend), the region is classed with ones tending to integration. Otherwise, *i.e.*, if the regional and Russian prices diverge or have a persistent difference, the region is deemed as non-integrated. Of 75 Russian regions, 36% are found integrated with the national market over 1994-2000; 44% are non-integrated regions tending to integration with it (the speed of convergence of regional prices to the Russian level varying from 0.7% to 8.9% per month); and 20% have no such a trend.

Analyzing the extensiveness of integration linkages between regions (with the use of Granger causality test), it is found that, on average, price disturbances are transmitted – in either direction – between a given region and 62% of the rest ones, thus evidencing rather high degree of regional connectedness. Isolated groups of regions (price convergence clubs) are not detected.

Since there are both regions tending and not tending to integration, the resulting trend of the entire national market is *a priori* unclear. Examining the behavior of price dispersion across regions sheds light on the issue: the dispersion diminishes over time, implying that, despite the presence of regions not tending to integration, the predominant trend is the improvement in market integration. Besides that, the pattern obtained evidences that non-integration is predominantly due to persistent

differences in prices rather than price divergence. To obtain more detailed properties of the integration evolution, the entire cross-sectional distribution of prices is estimated for a sequence of points in time. Its shape tends to be more regular and narrower over time, however, keeping a long right-hand tail that is due to difficult-to-access regions. Moreover, the distribution shape corroborates the absence of price convergence clubs.

Having obtained this sequence of distributions, the transition process between them, *i.e.*, price mobility of regions, is studied. The contribution of relative mobility (changes in order of regions along the scale of relative prices) and absolute mobility (transition of regions between levels of prices, *i.e.,* price classes) to changes in price dispersion is traced. It is found that the decrease in the price dispersion almost is not due to relative mobility. The main contribution belongs to absolute mobility. The estimated transition function (which characterizes probability to transit from a given price at some point in time to a certain price at the next time point) corroborates this finding. The long-run limit of the price distribution is derived from this function. It predicts that no price convergence clubs are to be expected in the long run.

The results obtained evidence poor market integration over 1994-2000, since only about one third of Russian regions can be deemed as integrated with the national market. However, they unambiguously suggest that the Russian market moved towards integration until about the end of 1999. It seems that by that time price convergence in Russia completed, having reached a “natural” limit of market integration. A comparison demonstrates that price dispersion across Russia in the last years is comparable with that across US, the economy that is deemed as highly integrated.

1. INTRODUCTION

The fast switch in the early 1990s from the centrally planned economy to that governed by the market principles, along with the political changes of that time, gave rise to dramatic regional fragmentation of the economic space of Russia. (Berkowitz and DeJong (2003) as well as Gluschenko (2003) discuss this process in more detail.) Therefore the creation – or recovery, if one would prefer to say so – of its single economic space became a severe problem challenging the country. It is even believed that a progress in solving this problem can be deemed as an important indication of successfulness of the Russian market reforms in general.

A “core” of the single economic space is goods market integration. Results of studies by Gluschenko (2002a, 2003) suggest that after a period of growing disconnectedness of the Russian market, the improvement of market integration started in 1994. Nevertheless, the market still is not near to completely integrated. Gluschenko (2002a) reveals a number of region-specific economic forces impeding integration, and Berkowitz and DeJong (2001, 2003) find macroeconomic and some other region-specific “anti-integration” forces.

These papers find the temporal pattern of market integration in Russia, but they do not provide an insight into its spatial set-up, since, exploiting the cross-sectional approach, the results are averaged across regions of the country. It is to reveal the spatial pattern of goods market integration in Russia with the use of time-series analysis that is the main object of this study. By the spatial pattern is meant a state of each individual region of the country: whether it is integrated over a certain span of time, and if not, whether it moves towards integration. One more object is to characterize the movement of the national market as a whole to integration in some additional – as compared to earlier papers – aspects. Dynamics of cross-sectional distribution of regional prices receives the study for this. The source data for the empirical analysis are time series of the cost of a staples basket across 75 regions of Russia for 1994-2000 with monthly frequency, the cost for Russia as a whole being used as a representative of the national market.

The logical order of the study is as follows. With the use of nonlinear cointegration analysis, Russian regions are divided into three groups: (a) regions integrated with the national market; (b) non-integrated regions tending to integration with the national market; and (c) non-integrated regions without such a trend. As this pattern remains open the issue of the presence of price convergence clubs among regional markets, it is supplemented with the analysis of Granger causality across region pairs, characterizing the extensiveness of integration linkages between regions, and answering the question of whether the national market is fragmented to a few isolated submarkets. When there are both regions tending and not tending to integration, the resulting trend of the entire market is *a priori* unclear. Examining the behavior of price dispersion (analyzing σ-convergence) sheds light on the issue. Besides that, it verifies the above division of regions into groups, and reveals whether non-integration is due to price divergence or, predominantly, to persistent differences in prices. To obtain more detailed properties of the integration evolution, the entire cross-sectional distribution of prices is estimated for a sequence of points in time. Multimodality of the distribution is an indication that there may be price convergence clubs. Having obtained this sequence of distributions, the transition process between them, *i.e.*, price mobility of regions, is studied. The contribution of relative mobility (changes in order of regions along the scale of relative prices) and absolute mobility (transition of regions between levels of prices, *i.e.,* price classes) to changes in price inequality is traced as well as a stochastic kernel – a generalization of a transition probability matrix – is estimated. At last, this kernel is used to derive the long-run limit of the price distribution in order to judge whether price convergence clubs are expected to arise in the long run.

Of 75 Russian regions, 36% are found integrated with the national market over 1994-2000; 44% are non-integrated regions tending to integration with it (the speed of convergence of regional prices to the Russian level varying from 0.7% to 8.9% per month); and 20% have no such a trend. Granger causality tests suggest that, on average, price disturbances are transmitted – in either direction – between a given region and 62% of the rest ones, thus evidencing rather high degree of regional connectedness; isolated submarkets are not found. Being represented by region, the results of the time series analysis are temporally averaged. Therefore, they supplement the results of Gluschenko (2002a, 2003). Taken jointly, these results provide a comprehensive, "two-dimensional" – across time and space – pattern of market integration in Russia.

It is found that σ-convergence of regional prices takes place, implying that, despite the presence of regions not tending to integration, the predominant trend is the improvement in market integration. The shape of the cross-sectional distribution of prices tends to be more regular and narrower over time, however, keeping a long right-hand tail that is due to difficult-to-access regions. The distribution is unimodal, suggesting the absence of price convergence clubs. Using the Gini correlation coefficient as a measure of relative mobility, it is found that the decrease in the price inequality almost is not due to relative mobility. The main contribution belongs to absolute mobility; the estimated stochastic kernel corroborates this finding. The long-run limit of the price distribution is unimodal, so predicting no price convergence clubs in the long run.

The issue of market integration in transition economies has been the subject of a number of studies. Using cointegration analysis, Gardner and Brooks (1994), Goodwin *et al.* (1999), and Berkowitz *et al.* (1998) examine price dispersion among Russian cities in the early years of the transition (up to 1995). They find the Russian market weakly integrated, yet having encouraging signs of the improvement. (An early version of the paper by Berkowitz *et al.* (1998) is even titled "Transition in Russia: It's Happening".) Subsequently, Berkowitz and DeJong (1999) reveal the "Red Belt" as a culprit behind the fragmentation of the Russian market; and then Berkowitz and DeJong (2001, 2003) estimate a segment of the integration trajectory for Russia (which is corroborated by Gluschenko (2003) who applies a different methodology). Cointegration and threshold relationships are analyzed across 7 regions of Western Siberia in Gluschenko (2001a), and across 11 aggregated economic territories of Russia in Gluschenko (2002b); both integrated and non-integrated region/territory pairs are found. However, these results should be treated with caution. A caveat is that regional CPIs were used as a price representative; but as found later by Gluschenko (2001b, c), they are sufficiently biased, overstating inter-regional differences.

Conway (1999), using data from 1993–1996 for three commodities, examines price convergence among four market locations within Kiev, Ukraine. He finds significant evidence of price convergence due to arbitrage by buyers and sellers at these markets, but sizeable and sustained divergences from the law of one price have remained as well. Cushman *et al.* (2001) examine the law of one price with 5 food prices over an 11-month period in Kiev, during the early 1991–1992 period of Ukraine's transition to independence. They compare these prices with the prices of similar goods in the US. Cointegration between Ukrainian and US price time series with a (linear) trend is deemed as an evidence of price convergence. Although the law of one price did not hold during the period, the commodity real exchange rates are found to have possessed deterministic trends that were in the direction of closing the initial considerable price gap.

This paper also relates to papers analyzing internal market integration in advanced market economies, such as Engel and Rogers (1996), Parsley and Wei (1996), and Rogers (2002). More distantly, it relates as well to countless papers on analysis of the law of one price in the international context, and purchasing power parity, most sufficient of which were surveyed by Rogoff (1996), and Sarno and Taylor (2002). Noteworthy is also a relationship with the literature on empirics of economic growth (which is voluminous, too, see Durlauf and Quah, 1999). On the one hand, methodology of examining convergence in the economic growth context is applied here to price dynamics,[1] and, on the other hand, the time-series method of analyzing price convergence that is put forward in the paper seems to be useful to analyze, *e.g.*, income convergence.

The remainder of the paper is organized as follows. In the next section, methodology of the analysis and the data used are described. In Section 3, empirical results of the time series and price distribution dynamics analysis are presented. Conclusions are drawn in Section 4.

2. METHODOLOGY AND DATA

2.1. Strategy of the analysis

Time series analysis. Perfect integration of a spatially separated goods market implies that there are no impediments to the movement of goods between all its spatial segments, *i.e.*, regions of the country. In other words, perfectly integrated market operates like a single market despite its spatial

[1] Michael Beenstock has pointed out the resemblance of the convergence problem in economic growth and the problem of price dynamics.

separation. Then the price of a (tradable) good across regions is uniform, *i.e.*, the law of one price holds, inter-regional arbitrage maintaining the law to hold. Thus, the law of one price can be used as a theoretical benchmark for empirical analyzing internal market integration.

As mentioned in Introduction, there are two stages in the evolution of market integration in Russia, namely, the early stage of progressive disintegration beginning in January 1992, and the late stage of improvement in integration beginning in about 1994. It is the late stage that is of interest in this study. It is hypothesized that the Russian goods market should eventually come to the final steady state of complete integration, that is, to the equality of prices across all regions. Currently, during the late stage of the integration evolution, the market may be believed to be in transition towards this steady state. Hence, it is expected that three groups of regions may exist at present: (a) integrated regions, *i.e.*, those being in the steady state of equality of prices; (b) non-integrated regions tending to integration, *i.e.*, those in which prices are catching up with each other; and, maybe, (c) non-integrated regions having no such a trend. For brevity, hereafter regions from the second group are referred to as “regions tending to integration”, and regions from the third group are referred to as simply “non-integrated regions.”

Testing for equality of prices (or price levels) is the conventional exercise in studies of the law of one price and purchasing power parity. Using a (predominantly linear) cointegration relationship, a relative-price time series is classified as stationary or non-stationary. However, providing the “all or nothing” answer, this traditional approach is impotent in revealing a transitional case, that is, the case when some time series is not stationary over a given time span, but is tending to become a stationary one with time. In order to overcome such a difficulty, a cointegration relationship with nonlinear trend is used in this study.

Let p_{rt} and p_{st} be the price of a good in regions r and s, correspondingly, at time t. To model convergence of prices to equality, the time series of the relative price is taken to have the asymptotically subsiding trend of deviations from the equality,

$$p_{rt}/p_{st} = 1 + \gamma e^{\delta t},\ \delta<0 \qquad (1)$$

(to economize notations, the region indices for parameters – as well as for disturbances below – are omitted). With $\gamma = 0$, Equation (1) takes the form

$$p_{rt}/p_{st} = 1, \qquad (2)$$

which means that convergence of prices has been completed by the beginning of the time span under consideration, hence, the law of one price holds for regions r and s.

Equations (1) and (2) imply convergence to the absolute price parity, *i.e.*, to perfect integration which is not a common instance in the real world. (For example, Engel and Rogers (1996) as well as Parsley and Wei (1996) find price dispersion among US cities to depend strongly on distance.) Therefore, there may be a persistent difference in prices between r and s that is induced by “natural”, irremovable impediments to inter-regional trade such as physical distance and difficult access to a number of regions. And so, it would be more realistic to relax the criterion for market integration, allowing for such market frictions. Then convergence to the relative price parity would be tested, that is, to an arbitrary constant ratio of prices, α, instead of 1 in (1) and (2). Such a relaxation has been implemented in Gluschenko (2002a, 2003). The trouble is that this α should reflect the effect of "natural" market frictions only, and not that of artificial ones impeding market integration. But in the context of pairwise time series analysis, there is no way to separately identify these effects. That is why the strict version of the law of one price is adopted as the benchmark of integration, any deterministic difference in prices interpreting as an indication of non-integration. Certainly, the degree of Russia's market integration may be understated to some extent because of this. And so, the aim of the further lines of the analysis is not only to obtain additional aspects of the pattern, but also to verify results based on the above models.

To derive a testable version of the theoretical relationship (1), stochastic disturbances, ν_t, are taken into account, supposing them to be a (first-order) autoregressive process:

$$P_{rst} = \ln(1 + \gamma e^{\delta t}) + \nu_t, \quad \nu_t = (\lambda + 1)\nu_{t-1} + \varepsilon_t, \tag{3}$$

where $P_{rst} \equiv \ln(p_{rt}/p_{st})$ is the price differential, ε_t is white noise, and γ, δ, and λ are parameters to be estimated. Substituting the second equation in (3) into the first one gives the nonlinear model to be estimated and tested:

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \ln(1 + \gamma e^{\delta t}) - (\lambda + 1)\ln(1 + \gamma e^{\delta(t-1)}) + \varepsilon_t. \tag{4}$$

It is tested whether time series $\{P_{rst}\}$ has no unit root, *i.e.*, that the process is stationary around the trend, and if so, whether the time series does have a subsiding trend, *i.e.*, $\gamma \neq 0$ and $\delta < 0$. That is, the hypotheses tested are H_1: $\lambda = 0$ (against $\lambda < 0$); H_2: $\gamma = 0$ (against $\gamma \neq 0$); and H_3: $\delta \geq 0$ (against $\delta < 0$). Throughout the paper, the 10% significance level is adopted.

To test hypothesis H_1, the Phillips-Perron test is performed, which eliminates serial correlation from the residuals, using the Newey-West (1994) automatic bandwidth selection method with the Bartlett spectral kernel. (This test is chosen in order not to lose degrees of freedom through adding additional lags to the regression itself.) However, the test statistic (which is the t-ratio of λ) for an AR(1) process of the form (4) is not documented in the literature. Therefore, to derive p-values of the test, the empirical distribution of this statistic under the null hypothesis was estimated, implementing a large set of simulations. Appendix A provides details as well as results obtained.

If the unit root in (4) is rejected, hypotheses H_2 and H_3 are tested; provided the stationarity of the time series, the ordinary t-test is valid for this. If either of them is not rejected, this means that there is no deterministic trend of the given form in the time series (or – when $\delta > 0$ – that the trend is not subsiding). In such an event, as well as in the case of non-rejection of unit root, it is tested whether the process is governed by law (2), as described below.

The joint rejection of H_1, H_2 and H_3 is interpreted as evidence that the time series has asymptotically subsiding trend, fluctuating around it. Hence, prices in *r* and *s* are converging to equality, and these regions are classed with ones tending to integration. Coefficient δ defines the convergence speed. The sign of γ shows the direction of convergence: with $\gamma < 0$, prices in *r* catch up with prices in *s*, increasing over time faster that those in *s*; with $\gamma > 0$, the prices in *r* are rising slower than in *s*. (*Per se*, γ is the initial – at $t = 0$ – deviation of prices from parity.) Coefficient λ is interpreted as an indicator of the speed of dying out deviations from trajectory (1) that are caused by random shocks; $\theta = \ln(0.5)/\ln(1 + \lambda)$ defines the half-life time of the deviations. (With $\lambda = 0$, *i.e.* in the case of unit root, $\theta = \infty$, meaning that the effect of random shocks is permanent; hence, there is no return to trajectory (1). With $\lambda = -1$ implying the absence of autocorrelation, $\theta = 0$; hence, the return to trajectory (1) is instantaneous).

Using the same way as above, a testable version of (2) is arrived at:

$$P_{rst} = \nu_t, \quad \nu_t = (\lambda + 1)\nu_{t-1} + \varepsilon_t, \tag{5}$$

or

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \varepsilon_t, \tag{6}$$

which is the conventional AR(1) model.

The hypothesis tested is whether the time series has unit root, H'_1: $\lambda = 0$ (against $\lambda < 0$). The same procedure as for testing H_1 is used, taking MacKinnon's (1996) p-values for regression without intercept and trend. The rejection of the unit root is interpreted as evidence that the time series fluctuates around zero, that is, around equality of prices in *r* and *s* (θ defining the half-life time of the deviations from the equality). Therefore, these regions are classed with integrated ones. If unit root is not rejected, regions are deemed as non-integrated.

Noteworthy are different roles of parameters γ and δ *vs.* parameter λ. The first two characterize the *long-run* behavior of a relative price trajectory, while λ defines the *short-run* properties of adjustment toward this trajectory (which is, in the degenerate case of AR(1), the straight line along the time axis, representing the price parity).

There is a peculiarity in price dynamics in Russia: a number of regional price time series contain a structural break caused by the August 1998 financial crisis. The period of break is not uniform across regions, varying from 1998:08 to 1999:02. With such a break, the time series might appear to have a (spurious) deterministic trend, so biasing the inference towards non-rejection of a trend in (4), and towards non-rejection of a unit root in (6). To avoid this, (4) and (6) are augmented for breaks, taking the forms

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \ln(1 + (\gamma + \gamma_B B_t(t^*))e^{\delta t}) - (\lambda + 1)\ln(1 + (\gamma + \gamma_B B_{t-1}(t^*))e^{\delta(t-1)}) + \varepsilon_t, \tag{4*}$$

and

$$\Delta P_{rst} = \lambda P_{rs,t-1} + \gamma_B(B_t(t^*) - (\lambda + 1)B_{t-1}(t^*)) + \varepsilon_t, \tag{6*}$$

where $B_t(t^*)$ is the structural change dummy such that $B_t(t^*) = 1$ if $t < t^*$, and zero otherwise. The period of break is found by estimating (4^*) and (6^*) for t^* = 1998:08,…,1999:02, and choosing its value that yields the least sum of squared residuals.[2]

In (4^*), the sign of $\gamma + \gamma_B$ shows the direction of convergence before the break, and that since the break is shown by the sign of γ. This time γ can equal zero; such an event implies that prices in *r* and *s* have become close to equal from the break on. 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 jump crosses the price parity line, thus changing the direction of convergence since the break. There are no such cases among estimates obtained except for insignificant γs.) Equation (6^*) is constructed so that the price jump is always parity-directed, in order to test whether *r* and *s* have become integrated since the period of structural change. Given $\gamma_B > 0$, the crisis caused price-cutting in *r*; otherwise, it increased the relative price in the region. The hypotheses tested for (4^*) are the same as for (4) but H_2 which is substituted for H^*_2: $\gamma_B = 0$ (against $\gamma_B \neq 0$). For (6^*), the analogous hypothesis denoted $H^{*\prime}_2$ is tested in addition to H'_1. Hypotheses H_1 and H'_1 are tested through the same procedure as above, however, using estimated empirical distributions of the unit root test statistic for time series with breaks; see Appendix A.

Thus, each time series $\{P_{rt}\}$ is analyzed as follows:

Step 1. Model (4^*) is estimated and tested. If hypotheses H_1, H^*_2, H_3 and are jointly rejected, regions *r* and *s* are deemed as tending to integration, $\{P_{rst}\}$ containing a structural break. Otherwise, if the structural break is rejected, the analysis comes to Step 2, and if it is not (and H_1 or/and H_3 is not rejected), the analysis continues from Step 3.

Step 2. Model (4) is estimated and tested. If hypotheses H_1, H_2, and H_3 are jointly rejected, *r* and *s* are deemed as tending to integration. Otherwise, the analysis comes to Step 3.

Step 3. Model (6^*) is estimated and tested. If there is no structural break (hypothesis $H^{*\prime}_2$ is not rejected), the analysis comes to Step 4. Otherwise, if the unit root is rejected, *r* and *s* are deemed as integrated (since the period of the break), and if it is not, they are deemed as non-integrated, $\{P_{rst}\}$ containing a structural break.

Step 4. Model (6) is estimated and tested. If the unit root is rejected, *r* and *s* are deemed as integrated; otherwise, they are deemed as non-integrated.

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[2] Specification (6^*) is derived from (5), augmenting the first equation in (5) with the break variable. It differs from the classical regression for testing for structural break in AR(1), like, *e.g.*, in Perron and Vogelsang (1992), which includes two dummies, a pulse one and a level one. It is readily seen that the second term in (6^*) combines their properties. Given unit root ($\lambda = 0$), it produces a pulse at t^*; given no autocorrelation ($\lambda = -1$), we have a step spanning $1,\ldots, t^*-1$ (i.e., a one-time jump in the intercept from γ_B to 0 at t^*); with $-1 < \lambda < 0$, a superposition of the pulse and step is produced. But the cost is nonlinearity of the regression with respect to coefficients, and the need to specially estimate the distribution of unit root test statistic for this specification.

There are 75 series of regional prices for Russia, yielding 2775 region pairs. A standard way of reducing such a mass of pairwise comparisons in the literature on purchasing power parity and the law of one price is to take one of locations as a benchmark, as, *e.g.*, in Parsley and Wei (1996), and Gardner and Brooks (1994), to name a few. It is this way that is exploited in the current line of the analysis. The national market as a whole is chosen as the benchmark (since, in the intra-national context, such a benchmark is believed to be natural and much more reasonable than an arbitrary region). Thus, integration of each region with the entire national market is analyzed, using only region-Russia pairs. That is, index s in the above relationships is fixed, and is set to $s = 0$, p_{0t} denoting the price in Russia as a whole. (This price is close to the mean of prices across all regions, however, does not coincide with it; see the next section. For brevity, nevertheless, it will be referred to as "average Russian price"). And so, s is omitted hereafter; *i.e.*, P_{rt} denotes percentage difference in prices between region r and Russia as a whole: $P_{rt} \equiv \ln(p_{rt}/p_{0t})$.

Certainly, so reducing the set of pairs, the pattern becomes rougher and looses many details. However, it is believed to be in good agreement with the detailed pattern, based on Gluschenko (2002b), where results of analysis across pairs of Russian economic territories are compared with those across the territory-Russia pairs. Theoretically, if two regions are integrated (or tending to integration) with the national market, then they should be integrated (tending to integration) with one another. Practically, this might fail, but only because of low power of unit root tests. There is a caveat though. There may be integration or price convergence between two (and more) regions without integration with, or convergence to, the national market. Such a fact would imply that there are "price convergence clubs" among regional markets, an analog of convergence clubs in economic growth (see, *e.g.*, Barro and Sala-i-Martin, 1992). Using comparison with the benchmark rather than all pairwise comparisons, this issue remains open. It is to be clarified by additional analyses.

One of them is the Granger causality analysis that does involve inter-regional comparisons. By conducting the Granger causality test, it is sought whether price disturbances are transmitted across regions. To avoid spurious causality resulting from the presence of trends in both tested time series, the series are detrended and debreaked (the latter is done to eliminate approximation of structural break by a trend). Letting P'_{rt} denote detrended and debreaked P_{rt}, the bivariate regression

$$\begin{aligned} P'_{rt} &= \varphi_{0(r)} + \varphi_{1(r)}P'_{r,t-1} + \ldots + \varphi_{m(r)}P'_{r,t-m} + \psi_{1(r)}P'_{s,t-1} + \ldots + \psi_{m(r)}P'_{s,t-m} + \varepsilon_{(r)t} \\ P'_{st} &= \varphi_{0(s)} + \varphi_{1(s)}P'_{s,t-1} + \ldots + \varphi_{m(s)}P'_{s,t-m} + \psi_{1(s)}P'_{r,t-1} + \ldots + \psi_{m(s)}P'_{r,t-m} + \varepsilon_{(s)t} \end{aligned} \quad (7)$$

is estimated across t for region pair (r, s), and hypotheses $\psi_{1(r)} = \ldots = \psi_{m(r)} = 0$ ($\mathbf{P}'_s$ does not Granger cause $\mathbf{P}'_r$) and $\psi_{1(s)} = \ldots = \psi_{m(s)} = 0$ ($\mathbf{P}'_r$ does not Granger cause $\mathbf{P}'_s$) are tested. If a hypothesis, say, the first one, is rejected, this suggests that prices in s are responsive to changes in prices in r, evidencing in favor of the existence of integration linkages between these regions.

Having run the Granger causality test for every region pair, the results can be summarized in an $R\times R$ – where R is the number of regions – matrix $\mathbf{C} = (C_{sr})$ such that $C_{sr} = 1$ if $\mathbf{P}'_r$ Granger causes

$\mathbf{P}'_s$, and $C_{sr} = 0$ otherwise; $C_{rr} \equiv 1$. In fact, this is the adjacency matrix of a "causality graph" displaying direct price linkages between regions. Regions r and s are linked indirectly if $C_{sr} = 0$, but $C_{sq} = 1$ and $C_{qr} = 1$. This means that there is a path from r to s in the graph represented by **C**. (In this case, the path length is 2.) The $(R - 1)$-th power of **C** provides a pattern of all direct and indirect linkages; its zero rs-th element implies that there are no any linkages between r and s. This pattern answers the question of whether the national market is fragmented to a few isolated submarkets. If rows and columns of $\mathbf{C}^{R-1}$ can be reordered so that it becomes a block diagonal matrix, then this is the case. It is such submarkets that may potentially be the price convergence clubs.

In addition, spatial Granger causality is analyzed in order to examine effects of spatial lags, proceeding from Rey and Montouri (1999). A region's spatial lag, $P'_{\text{“}r\text{-}1\text{”},t}$, is a weighted average of (detrended and debreaked) prices in its neighboring regions, with the weights being obtained from the simple contiguity matrix normalized so that its column sums are all 1. Using (7) with $\mathbf{P}'_s$ replaced by $\mathbf{P}'_{\text{“}r\text{-}1\text{”}}$, it is tested whether $\mathbf{P}'_{\text{“}r\text{-}1\text{”}}$ Granger cause $\mathbf{P}'_r$.

Analyzing distribution dynamics. When there are both regions tending to integration and non-integrated regions, the resulting trend of the entire market is *a priori* unclear. Then the behavior of the entire cross-section distribution of prices can shed light on the issue. It is reasonable to believe that if prices converge over time to some common level, then the market as a whole is moving towards integration. A simple testable version is known in the economic growth literature – *e.g.*, Sala-i-Martin (1996) – as σ-convergence.

Reformulated in terms of prices, it is defined as follows: regional prices are converging, if their dispersion tends to decrease over time, that is,

$$\sigma(P_t)/\sigma(P_{t-\tau}) < 1, \qquad (8)$$

where $\sigma(P_t)$ is the standard deviation of prices P_{rt} over $r = 1,\ldots, R$ at a given point in time. The occurrence of σ-convergence in the case when the existence of non-integrated regions has been detected is evidence that the trend to convergence of prices prevails over the trend to divergence induced by those regions. Along with analyzing σ-convergence for the entire set of regions, it is also applied to each of three region groups obtained through the time series analysis in order to verify this separation. The group of regions tending to integration is expected to display σ-convergence; and the group of integrated regions is expected to have near-constant σ. The group of non-integrated regions would show σ-divergence if non-integration is due to random walking or deterministic price divergence. However, if the reason of non-integration is constant persistent differences in prices, a near-constant σ is to be expected.

One more concept of convergence in the economic growth literature is β-convergence. If a cross-sectional regression

$$P_{rt} = \alpha + \beta_{t-\tau,t}P_{r,t-\tau} + \varepsilon_r \qquad (9)$$

yields $\beta_{t-\tau,t} < 1$ then it is said that the data set exhibits β-convergence (Sala-i-Martin, 1996). Wodon and Yitzhaki (2001) show that there is a relationship between these types of convergence:

$$\sigma(P_t)/\sigma(P_{t-\tau}) = \beta_{t-\tau,t}/\rho, \qquad (10)$$

where ρ is the correlation coefficient between $P_{t-\tau}$ and P_t. If (8) holds, then it must be that there is β-convergence, because $\rho < 1$. But the reverse is not true for the same reason. Thus, β-convergence does not necessarily imply σ-convergence (hence, σ-convergence is a sufficient – but not necessary – condition for β-convergence).

Being merely one of characteristics of the price distribution, the evolution of $\sigma(P_t)$ provides rather poor information on features of price dynamics. To reveal more detailed properties of the integration evolution, the behavior of distribution of regional prices as such, $f_t(P)$, is analyzed. The cross-section distributions are non-parametrically estimated in a number of points in time with the use of a kernel density estimator. The Gaussian kernel is adopted; formally, the estimate of a probability density looks like

$$\hat{f}_t(P) = \frac{1}{\sqrt{2\pi}Rh} \sum_r \exp\left(-\frac{1}{2}\left(\frac{P - P_{rt}}{h} \right)^2 \right), \tag{11}$$

where R, recall, denotes the number of regions, and h is the Silverman (1986) smoothing bandwidth. The distribution is estimated for entire Russia and for the three groups of regions. Judging from unimodality or multimodality of the distribution, the question of whether there are price convergence clubs in the evolution of market integration is to be answered.

Having obtained a sequence of distributions $\{f_t(P)\}$, the next issue is to characterize the transition process between them, *i.e.*, price mobility of regions. As Fields and Ok (2001) note in their survey, the very notion of mobility is not well-defined; the mobility literature does not provide a unified discourse of analysis (nor is there a unified terminology). Nonetheless, there is agreement regarding two main concepts of mobility in the economical and sociological literature. The first one is relative (or rank) mobility which concerns changes in ranking of, in our case, regions by the price level. The second concept is absolute (or quantity) mobility concerning changes in regions' price levels themselves. Both concepts are used in the below analysis.

To measure relative mobility, the approach proposed by Yitzhaki and Wodon (2001) is adopted (their notation changed to correspond). The dispersion of prices, or price inequality, is measured by the Gini coefficient:

$$G_t = \frac{2\,\mathrm{Cov}(p_t, k_t)}{R\bar{p}_t}, \tag{12}$$

where $p_t = \{p_{rt}\}$, and $k_t = \{k_{rt}\}$ is regions' ranks in ascending prices p_{rt}. Here, as the Gini coefficient needs arguments to be positive, the (relative) prices themselves are used rather than their logarithms.

The Gini symmetric index of mobility is defined as:

$$S_t = \frac{G_{t-\tau} M_{t,t-\tau} + G_t M_{t-\tau,t}}{G_{t-\tau} + G_t}; \tag{13}$$

that is, as a weighted average of asymmetric mobility indices quantifying mobility in forward and reverse directions in time:

$$M_{t-\tau,t} = (1 - \Gamma_{t-\tau,t})/2,\ M_{t,t-\tau} = (1 - \Gamma_{t,t-\tau})/2. \tag{14}$$

In turn, Γs are the Gini correlation coefficients:

$$\Gamma_{t-\tau,t} = \frac{\mathrm{Cov}(p_{t-\tau}, k_t)}{\mathrm{Cov}(p_{t-\tau}, k_{t-\tau})},\ \Gamma_{t,t-\tau} = \frac{\mathrm{Cov}(p_t, k_{t-\tau})}{\mathrm{Cov}(p_t, k_t)}. \tag{15}$$

These mobility indices can vary from 0 and 1. (The original Yitzhaki and Wodon (2001) index is bounded between 0 and 2; for easier interpretation, this range is normalized to [0, 1] in (14) by division by 2). If $S_{t-\tau,t} = M_{t-\tau,t} = M_{t,t-\tau} = 0$, there is no mobility. If $S_{t-\tau,t} = M_{t-\tau,t} = M_{t,t-\tau} = 1$, mobility is "perfect", *i.e.*, there is a total reversal in the ranks. The case of $S_{t-\tau,t} = M_{t-\tau,t} = M_{t,t-\tau} = 0.5$ implies random mobility, meaning that $p_{t-\tau}$ and p_t are statistically independent. Notice that Γs are not sensitive to monotonic transformations of distributions in $t - \tau$ and t, and so, such changes as a shift of the median or/and, *e.g.*, a decrease of the variance – which just mean convergence of prices – are not captured by the Gini mobility indices (indicating the absence of mobility).

It is absolute mobility that is responsible for such changes. One measure of absolute mobility that has a rather wide use in the mobility literature is an estimate of $\beta_{t-\tau,t}$ in (9); see, *e.g.*, Jarvis and Jenkins (1998), and Beenstock (2003).[3] A possible modification is to estimate it from a Gini regression (Olkin and Yitzhaki, 1992), regressing P_{rt} on $k_{r,t-\tau}$ rather than $P_{r,t-\tau}$ in (9). In fact, such an estimate, denoted by $\beta^*_{t-\tau,t}$, is an instrumental variable estimate in which price in $t - \tau$ is instrumented by rank. Then, as shown by Wodon and Yitzhaki (2001), the measures of relative and absolute mobility can be related with one another:

$$\frac{G_t}{G_{t-\tau}} = \frac{\beta^*_{t-\tau,t}\,\bar{p}_{t-\tau}}{\Gamma_{t,t-\tau}\,\bar{p}_t}. \tag{16}$$

For more transparent interpretation, the ratio of average prices in (16) may be replaced with unity (as it is close to 1 because of normalizing to the price in Russia as a whole). Then it is seen that convergence of prices occurs if absolute mobility exceeds relative mobility. The equality of these kinds of mobility would keep the Gini coefficient unchanged; and the predominance of relative mobility over absolute one would lead to price divergence. Benefiting from the Wodon-Yitzhaki relationship, $\beta^*_{t-\tau,t}$ is simply calculated from (16) in this paper rather than estimated from a Gini regression.

One more way of analyzing absolute mobility is exploited in the paper, following Quah (1996). Let $\mathrm{M}_{(t-\tau,t)}(P^{(i)},P^{(j)})dP$ be the fraction of regions being in (infinitesimal) price class i with prices from $P^{(i)}$

[3] If $\beta = 1$, there is no mobility; $\beta < 1$ implies a movement towards the mean (downward mobility among the high-price regions, and upward mobility among the low-price ones), which is equivalent to β-convergence; $\beta > 1$ implies a movement away from the mean, which is equivalent to β-divergence. Thus, the greater $|\beta - 1|$, the higher mobility.

to $P^{(i)} + dP$ at $t - \tau$, and in price class j with prices from $P^{(j)}$ to $P^{(j)} + dP$ at t. Covering all classes, $P \in (-\infty, \infty)$, $\mathbf{M}_{(t,t-\tau)}$ is an operator mapping the price distribution from period $t - \tau$ to period t:

$$f_t(P) = \mathbf{M} \cdot f_{t-\tau}(P). \tag{17}$$

This operator is a stochastic kernel,[4] or a transition probability function which is the generalization of a transition probability matrix. ($\mathbf{M}$ may be viewed as such a matrix with infinite number of rows and columns, $\{i\}$ and $\{j\}$ being continuous.) It is readily seen that the stochastic kernel is a probability density of prices at t conditional on prices at $t - 1$: $\mathbf{M} = f(P_t | P_{t-\tau})$. Then (17) can be written as

$$f_t(P_t) = \int_{-\infty}^{\infty} f(P_t | P_{t-\tau}) f_{t-\tau}(P_{t-\tau}) dP_{t-\tau} . \tag{18}$$

The stochastic kernel is estimated in a manner like the univariate distributions are; see (11):

$$\hat{f}(P_t | P_{t-\tau}) = \frac{\dfrac{1}{2\pi R h_{t-\tau} h_t} \sum_r \exp\left(-\dfrac{1}{2}\left(\dfrac{P_t - P_{rt}}{h_t}\right)^2\right) \exp\left(-\dfrac{1}{2}\left(\dfrac{P_{t-1} - P_{r,t-\tau}}{h_{t-1}}\right)^2\right)}{\hat{f}_{t-\tau}(P_{t-\tau})} . \tag{19}$$

(The numerator in (19) is the estimate of the joint distribution of $P_{t-\tau}$ and P_t, and the denominator is the estimate – by Formula (11) – of the marginal distribution.)

Under the assumption of time-invariance of the stochastic kernel, *i.e.*, of the underlying transition mechanism, the application of transformation (17) to $f_t(P)$ n times yields a distribution for $t + n\tau$, that is,

$$f_{t+n\tau}(P) = \mathbf{M}^n \cdot f_t(P). \tag{20}$$

Taking $n \to \infty$ yields the ergodic distribution, $f_\infty(P)$, *i.e.*, such that

$$f_\infty(P) = \mathbf{M}_\infty \cdot f_\infty(P), \tag{21}$$

where $\mathbf{M}_\infty$ is the limit of $\mathbf{M}^n$ with $n \to \infty$. The ergodic distribution is the long-run limit of the distribution of prices. Depending on unimodality or multimodality of the ergodic distribution, it can be judged whether the existence of convergence clubs is to be expected in the long run.

To estimate $\mathbf{M}_\infty$, relationship (20) is applied, with numerically integrating in (18). Since $\mathbf{M}_\infty$ degenerates into $f(P_t | P_{t-\tau}) = f_\infty(P_t)$ for each $P_{t-\tau}$, the fulfillment of this condition accurate to 10^{-7} is used as a criterion of convergence of $\mathbf{M}^n$ to $\mathbf{M}_\infty$.

2.2. Data

The cost of the basket of 25 food goods (defined as the standard by Goskomstat between January 1997 through June 2000) is used as a price representative for the analysis. This basket covers about one third of foodstuffs involved in the Russian CPI; but unlike the CPI, it has constant weights

[4] Quah (1996) as well as Durlauf and Quah (1999) provide much more general formalization.

across regions and time; Goskomstat (1996) describes its composition.[5] The costs of the basket were obtained directly from Goskomstat.

The information has been collected in capital cities of the Russian regions; 75 of the 89 regions of Russia are covered. The data are lacking for 10 autonomous *okrugs*, the Chechen Republic, and the Republic of Ingushetia. Besides that, two more regions are omitted. The city of Moscow is a "city-region", being a separate subject of the Russian Federation, and at the same time it is the capital city of the surrounding Moscow Oblast; the same holds for St. Petersburg and the Leningrad Oblast. Therefore only these "cities-regions" are present in the sample, while the relevant surrounding *oblasts* are not. The data are monthly, spanning January 1994 through December 2000 (though the data set begins in 1992, the early stage of the market integration evolution is discarded). Thus, the number of the time observations equals 84.

The cost of the basket for Russia as a whole is calculated by Goskomstat as the weighed average of regional costs (using the ratio of region's population in the population of Russia as the regional weight). Thus, the average Russian price does not coincide with the average over regions, though they are rather close to one another. This implies that the mean of relative prices p_{rt}/p_{0t} can deviate – to some extent – from unity, and the mean of their logarithms can deviate from zero.

There are missing observations in the time series used. The most of them occur in 1994. For this year, there are 42 missing observations (4.7% of the yearly total) in 17 regional time series. The remainder of the data set has only 9 missing observations. To fill the gaps, the missing prices are approximated, using the food component of the regional monthly CPIs. The interpolated value of price p_{rt} is the arithmetic mean of the nearest known preceding price inflated to t, and the nearest known succeeding price deflated to t; see Gluschenko (2003). For example, if an observation for one month is missed, its restored value looks like $p_{rt} = (p_{r,t-1}\cdot\pi_{rt} + p_{r,t+1}/\pi_{r,t+1})/2$, where $\pi_{r\tau}$ is the food CPI for month τ in region r.

At last, a caveat with the data used should be mentioned. As regional wholesale prices are not available, retail prices are analyzed, which embody region-specific distribution costs. Varying across regions, they may cause violation of the law of one price even if wholesale prices do obey the law. There are two ways of dealing with the problem as suggested by Gluschenko (2002a). The first is to produce proxies of wholesale prices from retail prices. However, given monthly price time series, this way is not proper here, since data on distribution costs and retail-wholesale margins are available only on a yearly basis. Thus, the second way is forced to follow, interpreting the spatial variation of distribution costs as an additional indication of poor integration. In fact, this means extending the notion of market integration, considering integration of the goods market as such in conjunction with integration of the related markets

[5] The basket includes: rye-wheat bread, wheat bread, flour, rice, millet, vermicelli, potatoes, cabbages, carrots, onions, apples, sugar, beef, poultry, cooked sausage, partially smoked sausage, frozen fish, milk, sour cream, butter, cottage cheese, rennet cheese, eggs, margarine, and vegetable oil.

for distribution services and labor in retail trade.[6] (Indeed, organized crime responsible for a sufficient portion of inter-regional price dispersion in Russia acts both on the inter-regional level, forcing wholesale prices to rise, and on the local level, causing additional traders' expenses raising distribution costs.) On the other hand, basing on results reported by Gluschenko (2002a, 2003), it may be believed that patterns for retail and proxied wholesale prices would not sufficiently deviate from each other.

3. EMPIRICAL RESULTS

3.1. Spatial pattern of market integration

Table 1 summarizes results on integration of each individual region with the entire national market, which are obtained with the use of models (4^*), (4), (6^*), and (6). For a given region, the table reports results for one of these models, depending on which of them is accepted as describing the price behavior in this region. Reporting all parameters – λ, γ, γ_B, and δ – means acceptance of model (4^*); reporting λ, γ, and δ implies that (4) is accepted; thus, the region is deemed as tending to integration. If there are only λ and γ_B in the table, model (6^*) is accepted; and the only parameter λ is reported for (6). In the last two cases, the region is deemed as integrated if the unit root is rejected (the p-value of the Phillips-Perron test is less than, or equal to, 0.1); otherwise the region is deemed as non-integrated.

Results for each model are provided in Appendix B. In Table 1 as well as in Tables B1 and B2 of Appendix B, standard deviations are in parentheses; ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively; p-values of the Phillips-Perron test (denoted "p(λ=0)" in the tables of Appendix B) exceeding 10% are marked with bold italics. The horizontal borders in Table 1 separate the economic territories (*ekonomicheskiy rayon*) from one another. The composition of these territories and their names can be seen from the map in Figure 1 below. Regions are arranged geographically in the table, accordingly to their traditional ordering in Goskomstat's publications until July 2000 (except for the Kaliningrad Oblast which is added to the Northwestern Territory).

Of all the 75 regions, 27, or 36%, are deemed as integrated with the national market; and there are 15 (20%) non-integrated regions having no trend to integration. The minimum p-value of the unit root test among regions for which the unit root is not rejected in model (6) or (6^*) equals 0.158, and the rest of them exceed 0.2. Thus, the results of testing can be believed as rather reliable in spite of low power of the unit root test.

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[6] Such a component of distribution costs like rent does not fit in with this. However, rent does not play a noticeable role in costs of the Russian trade, coming to about 1% in retail prices of goods (as Appendix A in Gluschenko (2002a) evidences).

Table 1. Summary of time-series estimations and unit root tests

Region	Phillips-Perron test p-value	λ	γ	Structural break (γ_B)	δ
1. Rep. of Karelia	0.002	-0.423 (0.091)	0.186 (0.030)***		-0.011 (0.004)***
2. Rep. of Komi[d]	0.002	-0.439 (0.092)	0.005 (0.058)	0.227 (0.072)***	-0.017 (0.006)***
3. Arkhangelsk Obl.[d]	0.006	-0.428 (0.093)	0.195 (0.049)***	0.119 (0.039)***	-0.014 (0.003)***
4. Vologda Obl.	0.001	-0.347 (0.089)		-0.043 (0.010)***	
5. Murmansk Obl.	*0.233*	-0.013 (0.009)		-0.207 (0.036)***	
6. Saint Petersburg City	*0.420*	-0.028 (0.024)		-0.183 (0.036)***	
7. Novgorod Obl.	0.000	-0.677 (0.106)		-0.034 (0.007)***	
8. Pskov Obl.	0.027	-0.181 (0.069)		-0.088 (0.021)***	
9. Kaliningrad Obl.	0.017	-0.173 (0.063)		-0.125 (0.030)***	
10. Bryansk Obl.[a]	0.066	-0.274 (0.083)	-0.385 (0.108)***	0.147 (0.088)*	-0.018 (0.004)***
11. Vladimir Obl.	0.030	-0.175 (0.067)		-0.122 (0.018)***	
12. Ivanovo Obl.	0.002	-0.301 (0.084)		-0.090 (0.012)***	
13. Kaluga Obl.	0.035	-0.239 (0.073)	-0.236 (0.075)***		-0.042 (0.017)**
14. Kostroma Obl.	*0.422*	-0.078 (0.053)		-0.090 (0.028)***	
15. Moscow City[a]	*0.788*	-0.003 (0.013)		-0.070 (0.028)**	
16. Oryol Obl.	0.015	-0.328 (0.085)	-0.313 (0.029)***		-0.017 (0.003)***
17. Ryazan Obl.	0.019	-0.153 (0.060)		-0.083 (0.019)***	
18. Smolensk Obl.	0.000	-0.534 (0.101)	-0.090 (0.036)**	-0.133 (0.032)***	-0.009 (0.004)**
19. Tver Obl.	0.000	-0.344 (0.082)		-0.118 (0.013)***	
20. Tula Obl.	0.009	-0.299 (0.072)	-0.145 (0.053)***	-0.082 (0.044)*	-0.016 (0.005)***
21. Yaroslavl Obl.	0.000	-0.388 (0.088)		-0.077 (0.009)***	
22. Rep. of Mariy El	*0.330*	-0.014 (0.015)			
23. Rep. of Mordovia	*0.282*	-0.015 (0.014)		0.125 (0.039)***	
24. Chuvash Rep.[b]	*0.661*	-0.012 (0.018)		-0.070 (0.027)**	
25. Kirov Obl.	*0.386*	-0.050 (0.040)		-0.125 (0.030)***	
26. Nizhni Novgorod Obl.[c]	0.085	-0.129 (0.057)		-0.099 (0.024)***	
27. Belgorod Obl.	0.000	-0.470 (0.095)	-0.261 (0.027)***		-0.012 (0.003)***
28. Voronezh Obl.[a]	0.000	-0.524 (0.098)	-0.646 (0.142)***	0.249 (0.129)*	-0.029 (0.003)***
29. Kursk Obl.	0.000	-0.471 (0.097)	-0.245 (0.025)***		-0.015 (0.003)***
30. Lipetsk Obl.	0.002	-0.468 (0.095)	-0.391 (0.071)***	0.134 (0.059)**	-0.015 (0.003)***
31. Tambov Obl.[b]	0.004	-0.362 (0.082)	-0.176 (0.046)***	-0.068 (0.033)**	-0.007 (0.003)**
32. Rep. of Kalmykia[b]	0.000	-0.548 (0.103)	-0.045 (0.038)	-0.117 (0.037)***	-0.012 (0.005)**
33. Rep. of Tatarstan	0.000	-0.614 (0.101)	-0.363 (0.058)***	0.077 (0.045)*	-0.008 (0.002)***
34. Astrakhan Obl.	0.000	-0.701 (0.106)	-0.181 (0.020)***		-0.025 (0.005)***

Region	Phillips-Perron test p-value	λ	γ	Structural break (γ_B)	δ
35. Volgograd Obl.[d]	0.000	-0.354 (0.084)		-0.099 (0.015)***	
36. Penza Obl.	0.026	-0.279 (0.078)	-0.227 (0.027)***		-0.010 (0.003)**
37. Samara Obl.	0.000	-0.376 (0.087)			
38. Saratov Obl.	0.014	-0.316 (0.082)	-0.178 (0.035)***		-0.010 (0.005)**
39. Ulyanovsk Obl.	0.000	-0.577 (0.098)	-0.600 (0.068)***	0.152 (0.057)***	-0.013 (0.002)***
40. Rep. of Adygeya	0.000	-0.772 (0.108)	-0.366 (0.068)***	0.118 (0.059)**	-0.018 (0.003)***
41. Rep. of Dagestan	0.000	-0.574 (0.101)	-0.122 (0.023)***		-0.012 (0.005)**
42. Kabardian-Balkar Rep.	0.000	-0.231 (0.040)	-0.828 (0.079)***		-0.093 (0.017)***
43. Karachaev-Cirkassian Rep.	*0.158*	-0.080 (0.044)			
44. Rep. of Northern Ossetia	0.002	-0.445 (0.093)	-0.243 (0.032)***		-0.025 (0.005)***
45. Krasnodar Krai	0.000	-0.619 (0.105)	-0.430 (0.157)***	0.234 (0.140)*	-0.020 (0.005)***
46. Stavropol Krai	0.000	-0.554 (0.100)	-0.165 (0.016)***		-0.009 (0.003)***
47. Rostov Obl.	0.000	-0.679 (0.106)	-0.185 (0.012)***		-0.007 (0.002)***
48. Rep. of Bashkortostan[d]	0.006	-0.240 (0.073)		-0.126 (0.024)***	
49. Udmurt Rep.[c]	0.017	-0.185 (0.064)		-0.129 (0.022)***	
50. Kurgan Obl.[c]	0.007	-0.131 (0.042)		-0.099 (0.031)***	
51. Orenburg Obl.[b]	0.020	-0.167 (0.060)		-0.110 (0.040)***	
52. Perm Obl.	0.003	-0.372 (0.082)	0.160 (0.074)**		-0.084 (0.039)**
53. Sverdlovsk Obl.	0.020	-0.292 (0.081)	0.119 (0.044)***		-0.021 (0.012)*
54. Chelyabinsk Obl.	0.000	-0.698 (0.105)			
55. Rep. of Altai	0.000	-0.401 (0.088)			
56. Altai Krai	*0.506*	-0.023 (0.024)		0.077 (0.039)*	
57. Kemerovo Obl.[e]	0.000	-0.310 (0.069)		0.038 (0.015)**	
58. Novosibirsk Obl.[e]	0.000	-0.306 (0.070)		0.033 (0.013)**	
59. Omsk Obl.[e]	0.000	-0.578 (0.101)	-0.910 (0.296)***	0.667 (0.282)**	-0.034 (0.005)***
60. Tomsk Obl.	0.000	-0.252 (0.071)			
61. Tyumen Obl.	0.033	-0.138 (0.056)		0.068 (0.024)***	
62. Rep. of Buryatia	0.005	-0.232 (0.073)		0.118 (0.022)***	
63. Rep. of Tuva	*0.331*	-0.073 (0.046)		0.118 (0.044)***	
64. Rep. of Khakasia[e]	0.017	-0.200 (0.068)		0.038 (0.018)**	
65. Krasnoyarsk Krai	0.014	-0.196 (0.066)		0.070 (0.026)***	
66. Irkutsk Obl.[f]	0.001	-0.342 (0.085)		0.147 (0.026)***	
67. Chita Obl.	0.001	-0.450 (0.091)	0.298 (0.076)***	0.106 (0.054)*	-0.012 (0.003)***
68. Rep. of Sakha (Yakutia)	*0.513*	-0.007 (0.013)			

Region	Phillips-Perron test p-value	λ	γ	Structural break (γ_B)	δ
69. Jewish Autonomous Obl.[f]	0.003	-0.422 (0.091)	0.183 (0.045)***	0.148 (0.035)***	-0.010 (0.003)***
70. Primorsky Krai	0.040	-0.282 (0.081)	0.545 (0.060)***		-0.008 (0.002)***
71. Khabarovsk Krai[d]	0.000	-0.571 (0.104)	0.298 (0.048)***	0.143 (0.034)***	-0.007 (0.002)***
72. Amur Obl.[c]	0.006	-0.216 (0.063)		0.170 (0.028)***	
73. Kamchatka Obl.[d]	*0.790*	-0.005 (0.014)		0.179 (0.063)***	
74. Magadan Obl.[d]	*0.478*	-0.008 (0.010)		0.155 (0.051)***	
75. Sakhalin Obl.[d]	*0.535*	-0.010 (0.014)		0.137 (0.055)**	

[a] Break in 1998:08; [b] Break in 1998:10; [c] Break in 1998:11; [d] Break in 1998:12; [e] Break in 1999:01; [f] Break in 1999:02. Not marked breaks are in 1998:09.

Comparing with Table B2 of Appendix B, one can see that taking the structural break into account sufficiently increases the number of integrated regions: there are eight of them, for which the unit root is not rejected in (6) while it is rejected in (6*). Recalling that the break dummy equals 1 before the period of break, and 0 since it, this implies that these regions became integrated since the break. Hence, the 1998 financial crisis facilitated price equalizing among Russian regions, so it improved the pattern of regional integration. There is the only opposite case, in Saint Petersburg City, where unit root is rejected in (6*), and is not in (6). The 1998 crisis caused persistent rise in prices there, as compared to the average Russian price, thus it called forth non-integration with the national market.

The structural break is not rejected for 23 of 27 integrated regions. Of them, 15 regions have an upward break, *i.e.*, the crisis forced rise in relative prices in these regions. All of them are from the European part of Russia. For eight regions, all from the Asian part of Russia (Siberia and the Far East), the break is downward, implying decline in relative prices. The same pattern is valid for non-integrated regions (of which, the structural break is rejected only for three), with the only exception of the Republic of Mordovia. Thus, a consequence of the 1998 crises was coming prices in the Asian and European parts of Russia together.

The number of regions deemed as tending to integration with the national market is 33, or 44% of the total. For the most part (24 regions of 33, or 73%), convergence is “upward”, *i.e.,* catching-up the average Russian level by regions with low prices. The lowest starting price level, 0.17 ($=1 + \gamma + \gamma_B$), among them has the Kabardino-Balkar Republic; the highest, 0.88, have the Republic of Dagestan. There are nine regions (or 27% of 33 regions) with “downward” convergence from the starting values of 1.12 in the Sverdlovsk Oblast and 1.54 in the Primorsky Krai as the low and high ends. All these are regions from the Northern Territory, Ural, Siberia, and the Far East. The only region with “upward” convergence on these territories is the Omsk Oblast (from Western Siberia). The convergence speed expressed as a percentage (*i.e.*, $|e^{\delta} - 1|$) varies from 0.7% (in the Tambov Oblast, Rostov Oblast, and Khabarovsk Krai) to 8.9% (in the Kabardino-Balkar Republic) per month. Both values occur in regions with “upward” convergence; the range for “downward” convergence is 0.7% to 8.1%. There is strong positive correlation between the starting price gap, $|\gamma + \gamma_B|$, and the convergence speed, in the case of upward convergence: the correlation coefficient equals 0.79. However, the pattern is reverse for the downward convergence: the greater the gap, the slower convergence, the correlation coefficient equaling –0.52.

The structural break is rejected for about a half of regions tending to integration, namely, for 16, and is not for 17. The latter, in turn, are divided almost in half into those nine in which the break accelerated convergence (γ and γ_B have the same signs), having pushed prices towards the Russian average, and into eight regions where the break pushed prices away from the average Russian price (γ and γ_B with opposite signs), thus slowing convergence down. There are two regions, the republics of Komi and Kalmykia, with statistically insignificant γ, implying that prices there became near to the average Russian price since the break on. Thus, these regions might be equally well classed as integrated. Comparison of Tables B1 and B2 in Appendix B suggests that neglecting the structural break would markedly distort the pattern. There are 12 cases, where the break is spuriously treated as a trend in (4). Then the relevant regions would be deemed as tending to integration while they are, in fact, either integrated or non-integrated without a trend towards integration.

At last, there are 15, or 20% of the total, non-integrated regions having no trend to integration with the national market. While using model (6) augmented for the constant term, the unit root is not rejected only in three of these time series, namely, in those for the Republic of Sakha, Magadan Oblast, and Sakhalin Oblast. (However, the structural break was not taken into account in such estimations.) This suggests that the reason of non-integration is, for the most part, a constant nonzero difference of prices in a relevant region from the average Russian price rather than deterministic or stochastic price divergence. However, as discussed in Section 2.1, the existence of such a difference is taken as an indication of non-integration, since there is no way – in the context of the current analysis – to part irremovable price differences from removable ones caused by transitory impediments to integration.

Overall, the 1998 crisis strongly affected across-region price dynamics. Nevertheless, the behavior of prices remained intact in a number of regions; the break is rejected for 23 regions (31% of all the 75). In these regions, the crisis caused a price spike, after which relative prices returned to the previous trajectory.

The spatial pattern of market integration is presented in Figure 1. From this figure, about a half of non-integrated regions are seen to concentrate in Central Russia. (In particular, non-integrated are all but one regions of the Volga-Vyatka Territory.) The pattern is rather surprising, as these are small regions with relatively short distances between them; besides that, this part of the country has developed transport infrastructure. It can be surmised that it is the atomistic administrative-territorial division of Central Russia that causes market segmentation: the more regional borders and governors, the more possibilities to impede inter-regional trade and to diversify price policy across space. Curiously, the Ulyanovsk Oblast which maintained price regulations and subsidizing as long as up to the beginning of 2001 turns out to be tending to integration with the national market. The time series of Moscow prices has an "almost confident" unit root with its $\lambda = -0.003$.

No correlation was found between non-integration and belonging to the “Red Belt” reported by Berkowitz and DeJong (1999), even in the European part of Russia.

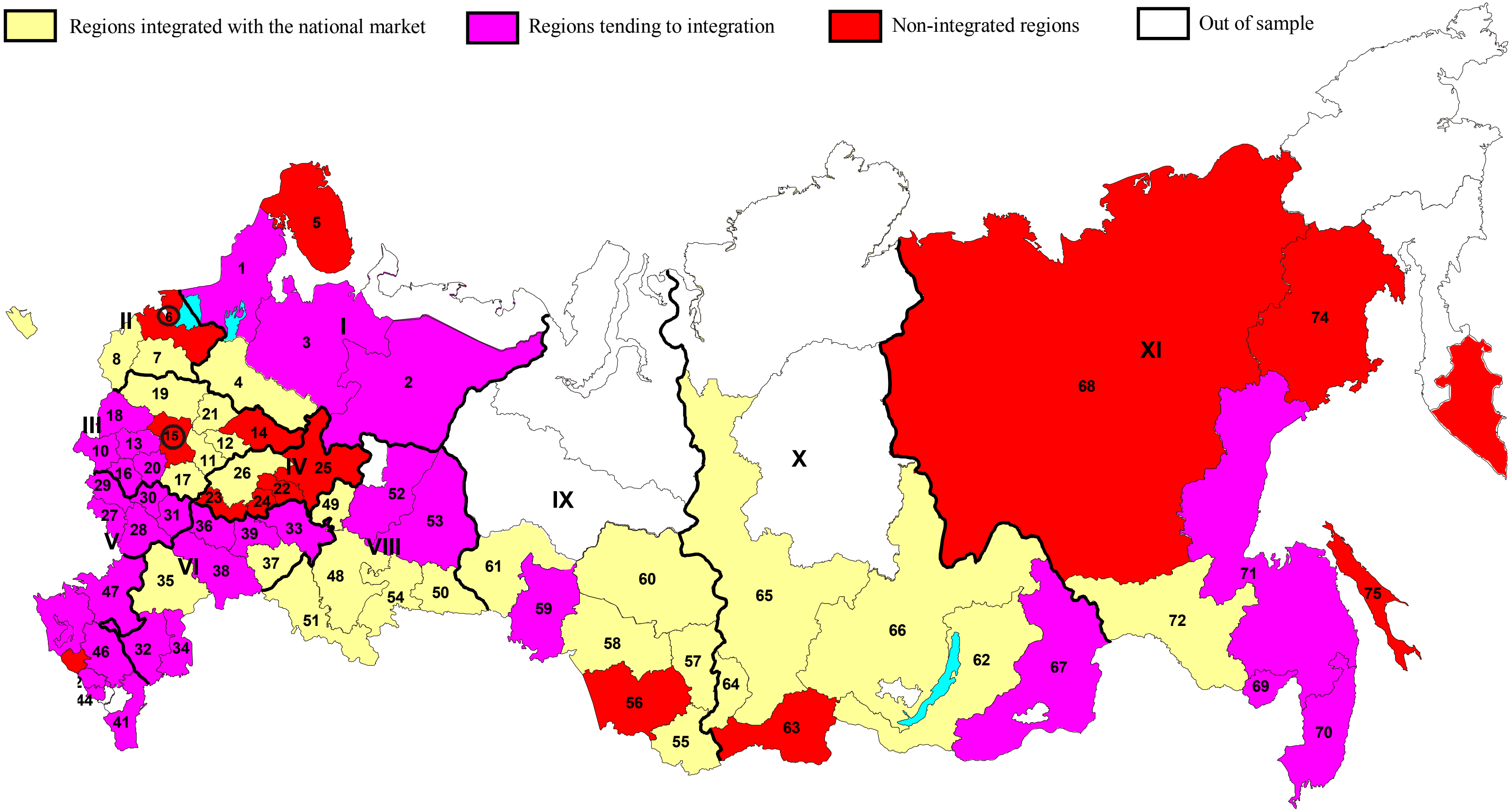
On the other hand, non-integrated regions are few in number in Siberia and the Far East. This corroborates a finding by Gluschenko (2003) that the Asian part of Russia excluding difficult-to-access regions is more integrated than European Russia. Another evidence seen in Figure 1 is the fact that all difficult-to-access regions (the Murmansk, Magadan, Sakhalin, and Kamchatka *oblasts*, and the Republic of Yakutia) are not integrated with the national market, a result that could be expected. It also supports findings by Gluschenko (2002a, 2003) that these regions markedly contribute to the overall disconnectedness of regional markets.

Turning to Appendix B containing the full set of estimates, the unit root in (6) or/and (6^*) is rejected for 20 regions recognized as tending to integration. Thus, if the traditional approach to the time series analysis of integration were used, 47 regions, or 63%, would be classed as integrated with the national market, and 28 regions (37%) would fall into non-integrated ones.

Among the estimates of Model (4) in Table B1, there are 13 non-subsiding trends ($\delta > 0$) implying divergence of prices, of which 10 have statistically insignificant δ, and two have insignificant factor γ. The only significant non-subsiding trend has Moscow. Taking account of the structural break (see Table B2), the number of positive estimates of δ increases to 20 in Model (4^*), seven of them being for the same regions as in (4). Of these 20, 13 are insignificant, two are accompanied with non-rejection of the unit root in the model, and one is with insignificant factor $\gamma + \gamma_B$. This time, δ for Moscow turns out insignificant, but instead, there are four significant non-subsiding trends for other regions. For two of relevant regions, the unit root is rejected in (6^*), and then only two cases of price divergence remain. This pattern gives grounds to believe that the trend to convergence of prices is predominant in the Russian market.

The pattern of spatial linkages of regions presented in Table 2 supports this belief. The table summarizes results of Granger causality tests for 2775 region pairs, using 6 lags; see (7) in Section 2.1. The second column of the table is the percentage proportion of regions in which prices are Granger caused by prices in the region named in a given row, $N_{r->}$; similarly, the third column is the proportion of regions that cause prices in a given one, $N_{r<-}$; the forth column is $N_{r<->}$, the proportion of regions that both cause the given region and are caused by it; and the last but one column is $N_r = N_{r->} + N_{r<-} - N_{r<->}$, describing the total extent of region’s price linkages with the rest of the country. The last column reports p-values of the hypothesis that region’s spatial lag does not Granger cause prices in the region; the number of neighboring regions in the lag is in parenthesis; the p-values exceeding the 10-percent significance level are marked with bold italics.

While analyzing Granger causality, it was experimented with different number of lags, namely, taking $l = 3$, 6, and 12 in (7). By and large, the results for these lags proved to be similar, having no sufficient qualitative differences. (Appendix C reports a comparison of results obtained with different number of lags.) On this basis, the results for 6 lags are taken as a basic stuff, having long enough sequence of lags with reasonably small loss in the degrees of freedom.



For numerical designations of regions, see Table

Thick lines are borders of economic territories, Roman numerals labelling the territories:

I Northern Territory
II Northwestern Territory
III Central Territory
IV Volga-Vyatka Territory
V Central Black-Earth Territory
VI Volga Region Territory
VII North-Caucasian Territory
VIII Ural Territory
IX Western-Siberian Territory
X Eastern-Siberian Territory
XI Far-Eastern Territory

Fig. 1. Geographical pattern of market integration

Table 2 evidences that the extent of inter-regional interaction is high: on average, price disturbances are transmitted between a region and 46 other regions (or 62% of their total number). This figure varies across regions from 26 regions (35%) to 65 regions (88%). The stable across tried lags group of regions having rather weak price linkages with the rest of the country includes the Irkutsk and Vladimir *oblasts*. Such a group for the strongest linkages includes the Republic of Sakha (Yakutia), and Saratov and Orenburg *oblasts*.

The range of $N_{r->}$ is 8 regions to 47 regions. The low-end group consists of the Republic of Tuva and Irkutsk Oblast; and the Krasnodar and Khabarovsk *krais* are in the high-end group. The value of $N_{r<-}$ varies from 7 regions to 58 regions with Moscow stably entering into the low-end group. The high-end group is not stable enough across different numbers of lags; however, the Republic of Yakutia is close to belong to it. The number of bi-directional linkages, $N_{r<->}$, varies between 1 region and 32 regions, with the Irkutsk Oblast, Moscow, and Republic of Buryatia as the low-end group, and the Belgorod Oblast as the high-end one.

Surprisingly, the extent of price linkages does not depend on whether regions are integrated with the national market, or are tending to integration, or are not integrated. The averages over each of these three region groups are close to those over all regions: the group averages of $N_{r->}$ fall in the range 31.2% to 36.2%; those of $N_{r<-}$ have the range 37.5% to 41.5%; the range is 15.7% to 16.8% for $N_{r<->}$; and the group averages of the total index, N_r, lie in the range 60.2% to 62.3%. One more surprising thing is the high extent of price linkages of the difficult-to-access regions. Their N_r equals 50.0% to 87.8%, the Republic of Yakutia having the maximum value of it across all Russian regions.

Table 2. Results of Granger causality tests

Region *r*	Percentage of regions Granger caused by *r*	Percentage of regions Granger causing *r*	Percentage of bi-directional causality	Total	P-value of spatial Granger causality test (“*r*–1” causes *r*)	
1. Rep. of Karelia	24.3	17.6	4.1	37.8	*0.545*	(2)
2. Rep. of Komi	52.7	48.6	25.7	75.7	0.026	(1)
3. Arkhangelsk Obl.	28.4	50.0	16.2	62.2	*0.103*	(2)
4. Vologda Obl.	24.3	45.9	14.9	55.4	0.058	(4)
5. Murmansk Obl.	41.9	52.7	17.6	77.0	0.076	(1)
6. Saint Petersburg City	23.0	17.6	2.7	37.8	*0.603*	(5)
7. Novgorod Obl.	31.1	33.8	10.8	54.1	0.037	(3)
8. Pskov Obl.	16.2	31.1	5.4	41.9	*0.971*	(3)
9. Kaliningrad Obl.	20.3	20.3	1.4	39.2	*0.719*	(1)
10. Bryansk Obl.	25.7	24.3	8.1	41.9	0.021	(4)
11. Vladimir Obl.	27.0	16.2	8.1	35.1	*0.417*	(4)
12. Ivanovo Obl.	36.5	18.9	8.1	47.3	*0.302*	(4)

Region *r*	Percentage of regions Granger caused by *r*	Percentage of regions Granger causing *r*	Percentage of bi-directional causality	Total	P-value of spatial Granger causality test (“*r*–1” causes *r*)	
13. Kaluga Obl.	40.5	45.9	17.6	68.9	*0.851*	(4)
14. Kostroma Obl.	33.8	45.9	16.2	63.5	*0.109*	(4)
15. Moscow City	29.7	12.2	5.4	36.5	*0.795*	(7)
16. Oryol Obl.	47.3	37.8	23.0	62.2	0.002	(4)
17. Ryazan Obl.	33.8	18.9	6.8	45.9	*0.862*	(7)
18. Smolensk Obl.	56.8	50.0	31.1	75.7	0.001	(4)
19. Tver Obl.	41.9	44.6	20.3	66.2	0.001	(4)
20. Tula Obl.	35.1	45.9	21.6	59.5	*0.117*	(5)
21. Yaroslavl Obl.	29.7	9.5	2.7	36.5	*0.851*	(4)
22. Rep. of Mariy El	45.9	47.3	17.6	75.7	0.003	(3)
23. Rep. of Mordovia	35.1	41.9	18.9	58.1	0.003	(5)
24. Chuvash Rep.	36.5	55.4	18.9	73.0	0.014	(5)
25. Kirov Obl.	41.9	20.3	10.8	51.4	*0.616*	(7)
26. Nizhni Novgorod Obl.	45.9	43.2	17.6	71.6	0.083	(5)
27. Belgorod Obl.	62.2	62.2	43.2	81.1	*0.444*	(1)
28. Voronezh Obl.	33.8	18.9	5.4	47.3	*0.514*	(6)
29. Kursk Obl.	62.2	31.1	18.9	74.3	*0.518*	(5)
30. Lipetsk Obl.	37.8	29.7	6.8	60.8	*0.292*	(6)
31. Tambov Obl.	35.1	47.3	21.6	60.8	0.015	(5)
32. Rep. of Kalmykia	35.1	24.3	2.7	56.8	*0.172*	(3)
33. Rep. of Tatarstan	54.1	43.2	20.3	77.0	*0.376*	(6)
34. Astrakhan Obl.	58.1	28.4	17.6	68.9	*0.597*	(3)
35. Volgograd Obl.	54.1	39.2	24.3	68.9	*0.311*	(5)
36. Penza Obl.	44.6	37.8	17.6	64.9	0.057	(5)
37. Samara Obl.	39.2	37.8	8.1	68.9	*0.200*	(4)
38. Saratov Obl.	48.6	68.9	29.7	87.8	0.007	(6)
39. Ulyanovsk Obl.	40.5	31.1	9.5	62.2	0.033	(6)
40. Rep. of Adygeya	31.1	12.2	5.4	37.8	0.050	(1)
41. Rep. of Dagestan	45.9	50.0	23.0	73.0	0.019	(2)
42. Kabardian-Balkar Rep.	33.8	40.5	17.6	56.8	*0.352*	(3)
43. Karachaev-Cirkassian Rep.	36.5	37.8	12.2	62.2	*0.132*	(3)
44. Rep. of Northern Ossetia	47.3	44.6	24.3	67.6	0.021	(2)
45. Krasnodar Krai	63.5	27.0	17.6	73.0	*0.914*	(4)
46. Stavropol Krai	37.8	40.5	13.5	64.9	*0.192*	(7)

Region *r*	Percentage of regions Granger caused by *r*	Percentage of regions Granger causing *r*	Percentage of bi-directional causality	Total	P-value of spatial Granger causality test (“*r*–1” causes *r*)	
47. Rostov Obl.	41.9	39.2	17.6	63.5	0.063	(4)
48. Rep. of Bashkortostan	48.6	44.6	18.9	74.3	*0.739*	(4)
49. Udmurt Rep.	37.8	31.1	9.5	59.5	*0.337*	(3)
50. Kurgan Obl.	29.7	59.5	21.6	67.6	*0.535*	(3)
51. Orenburg Obl.	44.6	73.0	35.1	82.4	*0.240*	(3)
52. Perm Obl.	20.3	31.1	6.8	44.6	*0.201*	(3)
53. Sverdlovsk Obl.	25.7	36.5	14.9	47.3	*0.211*	(5)
54. Chelyabinsk Obl.	47.3	52.7	23.0	77.0	*0.302*	(4)
55. Rep. of Altai	47.3	62.2	31.1	78.4	*0.172*	(1)
56. Altai Krai	48.6	36.5	17.6	67.6	0.052	(3)
57. Kemerovo Obl.	43.2	52.7	20.3	75.7	0.062	(5)
58. Novosibirsk Obl.	47.3	43.2	17.6	73.0	*0.560*	(4)
59. Omsk Obl.	29.7	41.9	8.1	63.5	*0.605*	(2)
60. Tomsk Obl.	29.7	23.0	8.1	44.6	*0.806*	(3)
61. Tyumen Obl.	43.2	52.7	24.3	71.6	0.005	(3)
62. Rep. of Buryatia	28.4	13.5	2.7	39.2	*0.551*	(2)
63. Rep. of Tuva	10.8	39.2	5.4	44.6	*0.232*	(2)
64. Rep. of Khakasia	45.9	58.1	32.4	71.6	*0.202*	(3)
65. Krasnoyarsk Krai	35.1	62.2	27.0	70.3	0.098	(5)
66. Irkutsk Obl.	12.2	27.0	1.4	37.8	*0.633*	(3)
67. Chita Obl.	32.4	48.6	20.3	60.8	0.002	(2)
68. Rep. of Sakha (Yakutia)	40.5	78.4	31.1	87.8	0.085	(1)
69. Jewish Autonomous Obl.	41.9	29.7	9.5	62.2	*0.123*	(2)
70. Primorsky Krai	47.3	14.9	6.8	55.4	*0.522*	(3)
71. Khabarovsk Krai	60.8	37.8	28.4	70.3	0.033	(4)
72. Amur Obl.	48.6	44.6	23.0	70.3	*0.119*	(3)
73. Kamchatka Obl.	14.9	41.9	6.8	50.0	*0.537*	(1)
74. Magadan Obl.	51.4	36.5	23.0	64.9	*0.110*	(1)
75. Sakhalin Obl.	58.1	59.5	33.8	83.8	0.002	(1)
Minimum	10.8	9.5	1.4	35.1		
Maximum	63.5	78.4	43.2	87.8		
Average	38.9	38.9	16.2	61.7		

Matrix $\mathbf{C}^{R-1}$ has no one zero element, suggesting that there are no isolated regions or clusters of regions. Eventually, each region is linked with all others either directly or through some chains of regions. (In fact, three exponentiations have sufficed for the matrix to have no zero elements; hence, each region is linked with any other one through no more that two regions.) This may be considered as an indirect evidence of the absence of price convergence clubs.

Constructing spatial lags, $\mathbf{P'}_{\text{“}r\text{-}1\text{”}}$, to analyze spatial Granger causality, the actual transport communication between regions is taken into account rather than their physical contiguity. For example, the Kaliningrad Oblast, being an exclave, shares common border with no other region of Russia (Saint Petersburg is deemed as its “trade neighbor”). Another example is the Kamchatka and Magadan *oblasts* having a common border, but having no trade through it (for the both, the Primorski Krai is taken as their “trade neighbor”, since delivery of goods to these regions comes through Vladivostok, the capital of the Primorski Krai).

The last column of Table 2 suggests widespread spatial autocorrelation: a little less than two thirds of regions (namely, 46 ones) are Granger caused by their spatial lags at the 10-percent level. There are a number of interesting cases of the absence of it. Spatial autocorrelation is strongly rejected for Moscow. This conforms with low value of its $N_{r<-}$, evidencing that the Moscow prices are hardly influences by prices in other regions. (On the other hand, the impact of Moscow prices on other regions' prices is not too strong; its $N_{r->}$ is well below the average.) The same, although a bit weaker, is valid for Saint Petersburg. Prices in the Kamchatka and Magadan *oblasts* are not caused by those in the Primorski Krai, their only “trade neighbor”, while being rather sufficiently caused by prices in different regions. A possible explanation is that the Primorski Krai is – for the most part – a trans-shipment point for delivery of goods to these regions, and not a region of origin of the goods. The pattern is different for the rest three difficult-to-access regions (the Republic of Yakutia, Sakhalin and Murmansk *oblasts*) that have only one “trade neighbor” as well: spatial autocorrelation is accepted for them.

3.2. Price distribution dynamics

Having considered the state of market integration in 1994-2000, the evolution of integration during this period is turned to. The first issue is that of σ-convergence. Figure 2 plots the dynamics of price dispersion measured as σ_t, the standard deviation of prices normalized to the Russian average. The trajectory of σ_t demonstrates that price dispersion over all regions has been almost permanently decreasing, at least till the middle of 1999. This is a clear evidence of σ-convergence in 1994-2000, suggesting that the Russian market is moving towards integration.

Additional trajectories for region groups provide insight into the structure of changes in price dispersion. For comparability, standard deviations for region groups are computed with the use of the mean over all regions rather than that over a given group, *i.e.*, price dispersion is measured relative whole of country; hence, it is not a within-group dispersion. With this, price dispersion over all Russian regions is a weighted average of group dispersions, $\sigma_t = (R_1/R)\sigma_{t1} + (R_2/R)\sigma_{t2} + (R_3/R)\sigma_{t3}$, the weight being the share of the group in the total number of regions (σ_{ti} denotes standard deviation of prices in region group *i*). The share of integrated regions is 0.36, that of non-integrated regions is 0.20, and that of regions tending to integration is 0.44.

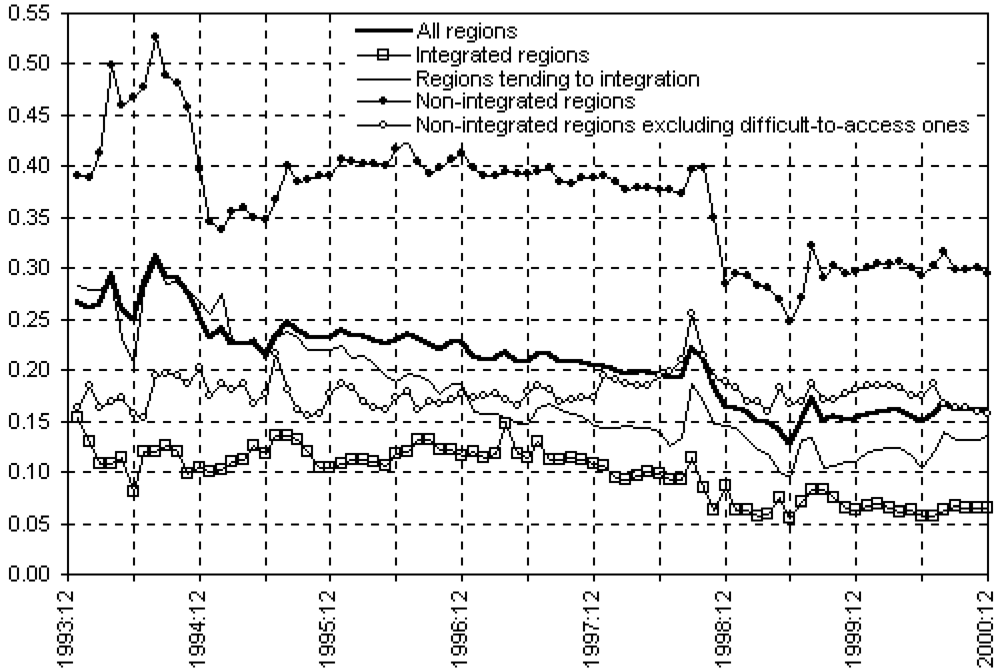
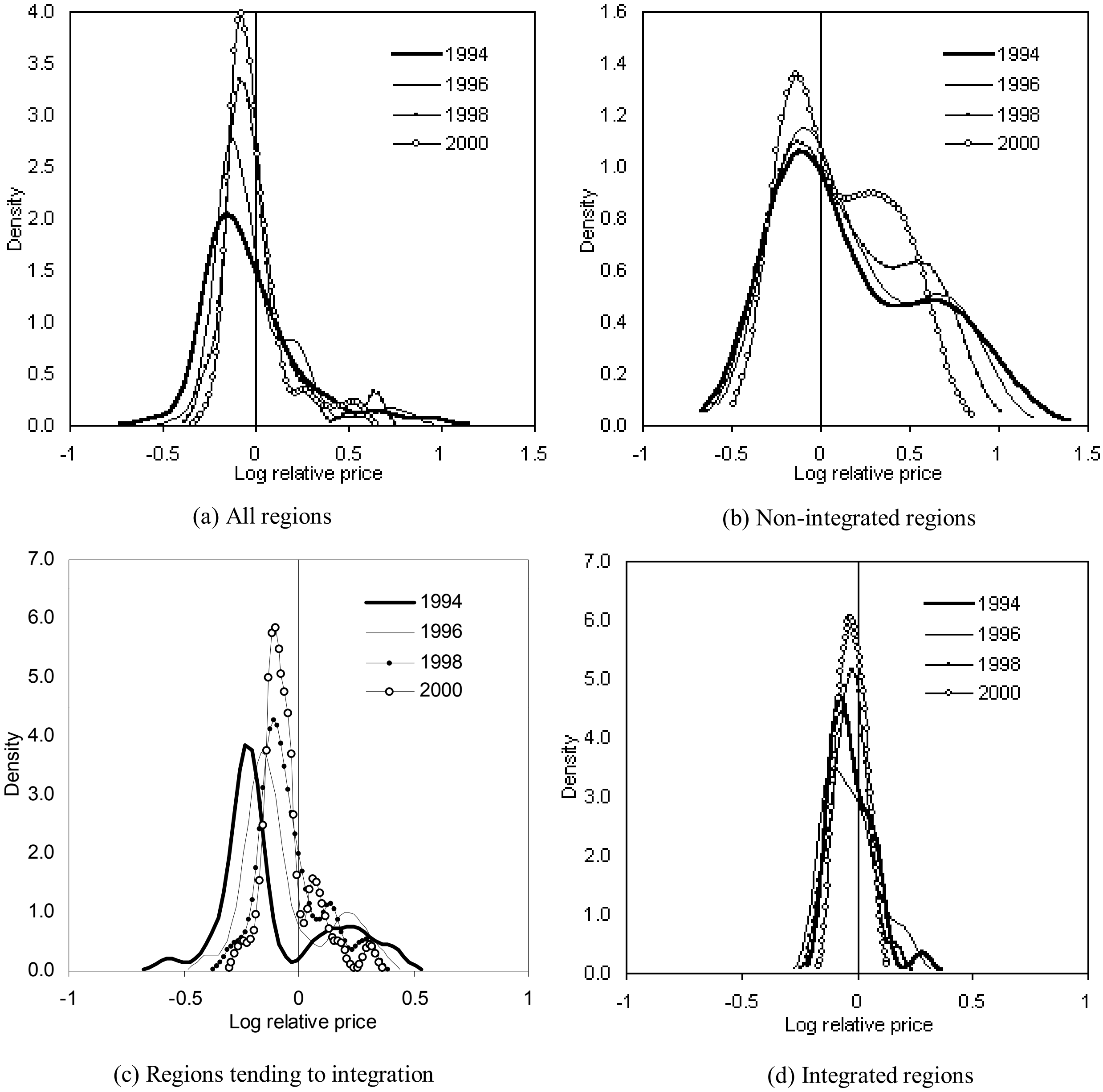


Fig. 2. Standard deviations of the log relative cost of the 25-food basket

The structural break caused by the August 1998 financial crisis is pronounced on the trajectories of σ. Its evident effect is reducing price dispersion. As expected, the main contribution to the decrease of price dispersion is due to regions tending to integration. Starting with σ roughly equaling the country one in the beginning of the period, the gap between them quickly widens over time. For integrated regions, price dispersion is the lowest and is near-constant, fluctuating around the level of 0.11 before the break, and around the level of 0.07 since January 1999.

The most price dispersion is inherent in non-integrated regions. The trajectory for this group has the most pronounced structural break reducing the group σ by about a quarter. However, the main contribution to this is due to difficult-to-access regions. Being computed for non-integrated regions excluding difficult-to-access ones, the trajectory of σ appears to have no break. Contrary to the theoretical expectations this subgroup does not exhibit increasing price dispersion. The reason is the fact that there is almost no price divergence in the Russian market (indeed, the estimation results in Appendix B provide only two clear evidences of price divergence). Regions deemed as non-integrated are for the most part those having a persistent difference from the average Russian price, as mentioned in Section 3.1.

To gain further insight into behavior of prices, dynamics of the entire cross-section distribution of regional prices is to be considered. At first, the issue of interest is the degree to which the shape of the price distribution changed over time. To assess these changes, probability densities have been non-parametrically estimated using Formula (8) for each year from 1994 through 2000. The estimated densities are reported in Figure 3 for selected years. The distributions have been estimated using cross sections averaged over each year in order to smooth accidental changes occurring in instantaneous distributions. Appendix D reports results for all years in comparison with instantaneous distributions for January 1994 and each December of 1994 through 2000.



(a) All regions

(b) Non-integrated regions

(c) Regions tending to integration

(d) Integrated regions

Fig. 3. Selected estimates of the price distributions

The densities in the figure reveal several features in the distribution shape dynamics over the 7-year period of 1994 to 2000. Turning to the sample of all regions, Figure 3a, the "main" mode of the distribution is shifting from negative *P* to zero, or, in terms of prices, from the cost of the 25-food basket below the Russian average to the national average. Along with this, the left-hand tail of the distribution shortens with time. But the long right-hand tail is persistent during the entire period, and prevents the distribution from becoming symmetric by the end of the period. Likewise, a small secondary mode in this tail is persistent. However, the right-hand tail somehow shortened, the high-price mode shifting towards zero. Referring to Figure D1 in Appendix D, it is seen that the most prominent shift occurs between 1997 and 1998, which can be assigned to the 1998 financial crisis. For the most part, prices generating the high-price mode are those in the difficult-to-access and a few more Far-Eastern regions. The share of foods imported from abroad was smaller in this part of the country (as well as in the Asian part a Russia at all) than in its Western part. Therefore the sharp devaluation of ruble in August 1998 lowered (relative) prices in most of the "high-price mode regions". It is in this way that the 1998 crisis narrowed the price gap between the Far East and the rest of Russia.

As the group of non-integrated regions contains all difficult-to-access regions, it demonstrates similar properties as regarding the right-hand tail (Figure 3b). There are two main differences from the entire-country distribution. Firstly, the main mode does not shift with time, having the peak at almost the same value of *P*. Secondly, the right-hand tail of the distributions is much heavier. It comes as no surprise, as it is non-integrated "expensive" regions that concentrate in this tail. The distribution for non-integrated regions has the following statistics in 2000 as compared to those for Russia as a whole (in parentheses): the mean: 0.104 (–0.009), the median: –0.100 (–0.042), the standard deviation: 0.281 (0.157).

The main mode of the distribution of regions tending to integration (Figure 3c) sufficiently shifts to higher prices over time. This distribution has a small secondary mode in the area of prices above the national average; this mode did not vanish after 1998. The distribution has the following statistics in 2000: the mean: –0.050, the median: –0.076, the standard deviation: 0.111.

At last, a few words about the distribution for integrated regions (Figure 3d). It tends towards a symmetric one; its mean and median are close to one another and to zero: they are –0.023 and –0.032, respectively, in 2000. The distribution is much narrower than that for Russia as a whole; the standard deviation of the former equals 0.055 (while that of the latter is equal to 0.157). Besides that, the distribution for integrated regions tends to normality. For example, the hypothesis of normality has significance of 64% (by the Jarque-Bera statistic) in 2000.

Overall, it can be concluded that the distribution of prices in regions tending to integration has a tendency of coming closer to the distribution of integrated regions (both in shape and position), so corroborating their classification through the time series analysis. However, the distribution for non-integrated regions almost does not change over time, except for its right-hand tail. (The reason for the change in the tail was the 1998 crisis). Because of this, the distribution for entire Russia has the long right-hand tail as well; the distribution remains to be bimodal with the secondary mode (yet, very low) in this tail. Since the end of 1996, almost all of regions in the tail are remote ones except for Moscow. In 1999 and 2000, the right part of the tail, where prices are more than 15% above the national average, includes all difficult-to-access regions, the Khabarovsk Krai and the Primorsky Krai (the almost easternmost regions of Russia), and Moscow. Their prices – at least, all of them –

can be hardly believed to lower so that the right-hand tail becomes similar to the left-hand one. Nevertheless, there are a number of regions which left this part of the tail during the period under consideration. However, this is the subject of the next line of the analysis, namely, the analysis of the intra-distribution mobility.

At first, the method proposed by Yitzhaki and Wodon (2001) is used; see Formulae (12) to (15) in Section 2.1. Figure 4 compares dynamics of price inequality measured by the Gini coefficient, G_t, and relative mobility measured by the Gini symmetric index of mobility, S_t. To control for effect of the difficult-to-access regions' peculiarity, G_t and S_t are computed for both entire Russia and excluding difficult-to-access regions. However, as seen from the figure, this does not affect the qualitative pattern. Price inequality is less in the latter case, and mobility is greater in quantitative terms, but the behavior of both G_t and S_t is very close in these two cases. The asymmetric (directional) mobility indices, $M_{t-1,t}$ and $M_{t,t-1}$, turned out to be very close to S_t, for the most part practically coinciding with it. For this reason, they are not plotted in Figure 4.

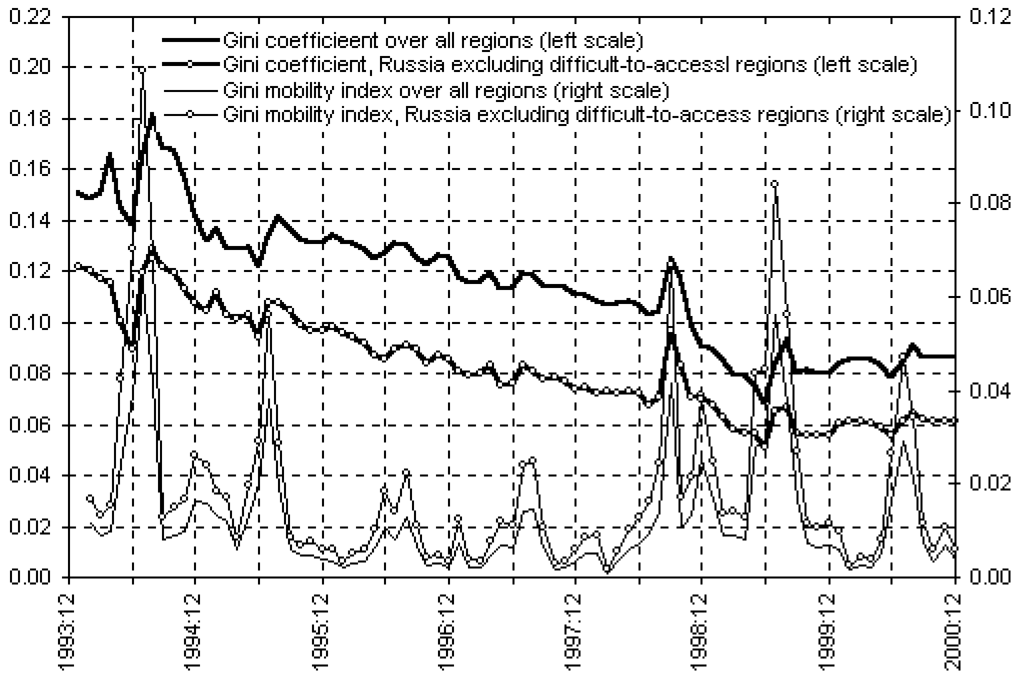


Fig. 4. Price inequality and relative mobility

It worth noting that the Gini coefficient is practically the same measure of price dispersion (inequality) like the standard deviation of log prices, σ_t. Figure E1 in Appendix E provides a comparison of σ_t from Figure 2 and G_t from Figure 4 (the both are over all regions). Being different in values, these indicators have the same behavior over changes in distributions; their trajectories coincide to a high degree of accuracy.

As Figure 4 suggests, relative mobility affects only on local properties of price inequality dynamics, and does not have any pronounced effect on the global trend to the decrease of inequality. Spikes of mobility correlate only with transitory rises in inequality. (Surprisingly, mobility does not act at all in favor of decrease of inequality.) Except these spikes, relative mobility remains to be very low, not exceeding 0.015.

As for the spikes themselves, they occurs very regularly, having peaks, as a rule, in July – or near it – of each year. They are thus seen to be a seasonal phenomenon. In summer, the rate of rise in prices for many items covered by the 25-food basket (see Section 2.2) decreases dramatically, not infrequently to negative values. However, this process is non-synchronous across regions of Russia, depending on natural conditions in a given region and its agricultural specialization. As a consequence, rather extensive changes in ranks of the cost of the food basket across regions happen, and then the ranking returns to its original (or close to original) state within a few months. There are two deviations from this regularity. In 1998, the summer spike was continued further (peaking in September of that year) by the financial crisis. Inflation induced by the crisis turned out to be chaotic across regions, as their delays in responding to the crisis were different. The same is valid for December 1998, when a new burst of inflation occurred.

A possible reason for low relative mobility might be the fact that very short-run transitions are considered. Usually, the distribution of prices changes gradually, and so, monthly changes could be rather small, indicating law mobility. (An indirect indication of this slowness is the proximity of the forward and reverse transition indices $M_{t-1,t}$ and $M_{t,t-1}$ to one another, which means that the shape of distributions $f_{t-1}(P)$ and $f_t(P)$ is rather similar.). At the same time, mobility over a longer period could be sufficient. This inconsistency between mobility estimated over shorter and longer transitions is a well-known problem discussed, *e.g.*, by Singer and Spilerman (1976) with reference to transition matrices.

To verify this, the relative-mobility indices are computed for longer time spans, one to six years. The results are presented in Table 3. Cross sections averaged over each year are used; results for Russia excluding difficult-to-access regions are in square brackets.

As can be expected, elimination of difficult-to-access regions decreases price inequality and increases mobility. Nevertheless, mobility is very low, the mobility indices not exceeding 0.1 (the maximum value is for the span of 1994-1999, equaling 0.95). The average of the one-year S_t is 0.027 (hereafter, the values for Russia excluding difficult-to-access regions are considered), and that of the two-year one is 0.052. For longer transitions, the averages of the mobility index are very close to one another (equaling 0.074 to 0.077), and to S_t for the 1994-2000 transition. It is clearly seen that the financial crisis of 1998 has sufficiently contributed to the increase in mobility. In general, the results in Table 3 give no clear indications, either, that there is any correlation between relative mobility and the decrease of price inequality.

However, as Formula (16) states, the total change in inequality is due to interaction between relative and absolute mobility. In Table 4, a change in the Gini coefficient is confronted with the Gini correlation coefficient, $\Gamma_{t,t-\tau}$, characterizing relative mobility, and parameter $\beta^*_{t-\tau,t}$, characterizing absolute mobility (lesser values of them correspond to greater mobility). The yearly averaged cross sections without difficult-to-access regions are used for calculations; $\beta^*_{t-\tau,t}$ are computed by Formula (16) rather than estimated through a Gini regression.

Table 3. Mobility over different time horizons

Initial and final state		Gini coefficient		Gini mobility indices		
$t-\tau$	t	$G_{t-\tau}$	G_t	$M_{t-\tau,t}$	$M_{t,t-\tau}$	S_t
1994	1995	0.152 [0.108]	0.128 [0.098]	0.014 [0.022]	0.016 [0.024]	0.015 [0.023]
1995	1996	0.128 [0.098]	0.127 [0.088]	0.017 [0.026]	0.014 [0.023]	0.016 [0.025]
1996	1997	0.127 [0.088]	0.114 [0.077]	0.019 [0.032]	0.016 [0.028]	0.018 [0.030]
1997	1998	0.114 [0.077]	0.105 [0.072]	0.015 [0.025]	0.015 [0.025]	0.015 [0.025]
1998	1999	0.105 [0.072]	0.078 [0.056]	0.020 [0.034]	0.021 [0.034]	0.020 [0.034]
1999	2000	0.078 [0.056]	0.084 [0.059]	0.014 [0.023]	0.016 [0.024]	0.015 [0.024]
1994	1996	0.152 [0.108]	0.127 [0.088]	0.025 [0.034]	0.022 [0.034]	0.023 [0.036]
1994	1997	0.152 [0.108]	0.114 [0.077]	0.052 [0.083]	0.041 [0.069]	0.047 [0.077]
1994	1998	0.152 [0.108]	0.105 [0.072]	0.047 [0.077]	0.047 [0.080]	0.047 [0.078]
1994	1999	0.152 [0.108]	0.078 [0.056]	0.057 [0.092]	0.063 [0.101]	0.059 [0.095]
1994	2000	0.152 [0.108]	0.084 [0.059]	0.046 [0.076]	0.048 [0.078]	0.047 [0.077]
1995	1997	0.128 [0.098]	0.114 [0.077]	0.041 [0.063]	0.032 [0.055]	0.037 [0.059]
1995	1998	0.128 [0.098]	0.105 [0.072]	0.035 [0.053]	0.036 [0.061]	0.035 [0.057]
1995	1999	0.128 [0.098]	0.078 [0.056]	0.050 [0.076]	0.052 [0.084]	0.050 [0.079]
1995	2000	0.128 [0.098]	0.084 [0.059]	0.038 [0.058]	0.036 [0.059]	0.037 [0.059]
1996	1998	0.127 [0.088]	0.105 [0.072]	0.028 [0.046]	0.031 [0.052]	0.029 [0.049]
1996	1999	0.127 [0.088]	0.078 [0.056]	0.047 [0.079]	0.054 [0.087]	0.049 [0.082]
1996	2000	0.127 [0.088]	0.084 [0.059]	0.042 [0.070]	0.048 [0.077]	0.044 [0.073]
1997	1999	0.114 [0.077]	0.078 [0.056]	0.043 [0.075]	0.046 [0.074]	0.044 [0.075]
1997	2000	0.114 [0.077]	0.084 [0.059]	0.046 [0.080]	0.052 [0.084]	0.049 [0.082]
1998	2000	0.105 [0.072]	0.084 [0.059]	0.025 [0.042]	0.026 [0.042]	0.029 [0.042]

Table 4. Interaction between relative and absolute mobility

Initial and final state		$G_t/G_{t-\tau}$	$\Gamma_{t,t-\tau}$	$\beta^*_{t-\tau,t}$
$t-\tau$	t			
1994	1995	0.903	0.952	0.869
1995	1996	0.897	0.954	0.857
1996	1997	0.877	0.944	0.836
1997	1998	0.927	0.950	0.877
1998	1999	0.779	0.932	0.726
1999	2000	1.063	0.951	1.010
1994	2000	0.545	0.845	0.468

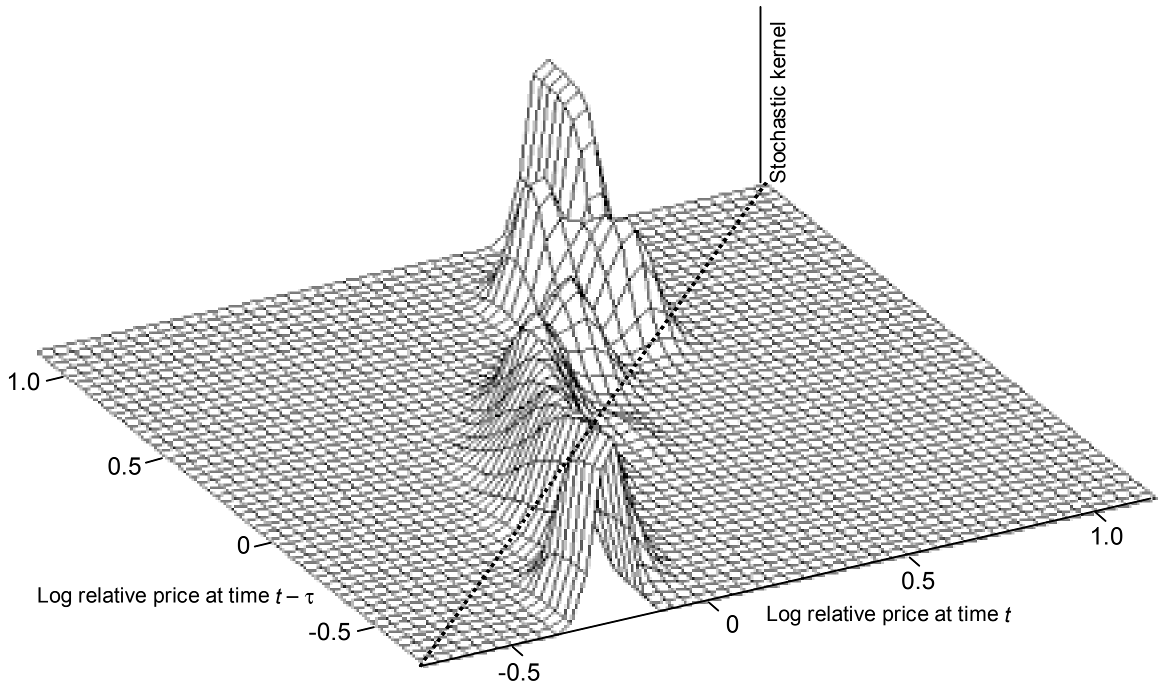
The results in the table suggest that absolute mobility prevails over relative mobility (as $\beta^*_{t-\tau,t} < \Gamma_{t,t-\tau}$), so causing price dispersion – hence, the variance of the price distribution – to decrease. The exception is the transition from 1999 to 2000, where $\beta^*_{t-\tau,t}$ indicates (slight) divergence of prices, being more than unity. As the result, price inequality slightly rises in 2000 as compared to 1999. The most pronounced pattern is provided by the transition though the entire time span, from 1994 to 2000. Here, the mobility indicators differ almost twice, thus almost halving price inequality over the time span. The same pattern takes place for month-to-month transitions, but being, of course, much less pronounced than for year-to-year ones. Figure E2 in Appendix E illustrates such a pattern with the use of cross sections over all regions.

To gain the better insight into absolute mobility, the evolution of the entire across-region distribution of prices is modeled by the stochastic kernel; see Formulae (17) through (19) in Section 2.1. From considerations of robustness of the results, the kernel is estimated in two ways. The first uses information only on the price transition of regions from the beginning to the end of the time span concerned. That is, the estimate of the stochastic kernel is $\hat{f}(P_t | P_{t-\tau}) = \hat{f}(P_{2000} | P_{1994})$. The second way makes use of information on the transitions within 1994-2000; the more distant is a transition in time, the lesser importance is attached to it. That is, the estimate of the stochastic kernel is a weighted average of the year-to-year estimates (a is a normalizing factor making the weights to sum to unity): $\hat{f}(P_t | P_{t-\tau}) = a(\hat{f}(P_{1995} | P_{1994})/6 + \hat{f}(P_{1996} | P_{1995})/5 + ... + \hat{f}(P_{2000} | P_{1999})/1)$. The kernels are estimated using yearly averaged cross sections. Figure 5 reports the three-dimensional plots of both estimates of the stochastic kernel. A line projected from a fixed $P_{t-\tau}$, parallel to the P_t axis, characterizes probability to transit to particular values of prices at t, given the value of the price at $t - \tau$.

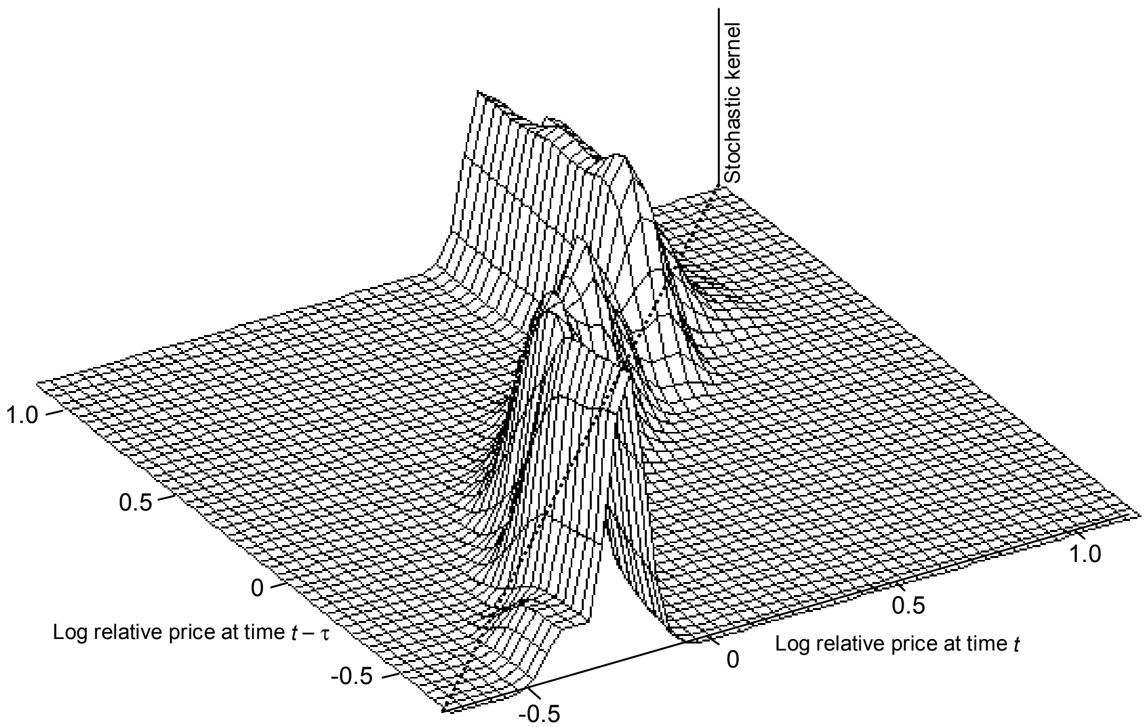
In spite of differences between the kernels obtained, they are qualitatively similar, suggesting the same features of price distribution dynamics. The dashed lines in Figures 5a and 5b mark the diagonals, *i.e.*, the lines of equal prices at $t - \tau$ and t. In other words, the diagonal is the "line of immobility". Be a most of the probability mass concentrated along this line, it would evidence low absolute price mobility. However, this is not the case; the pattern suggests that the degree of mobility is rather high. The mode line of both stochastic kernels is turned counter-clockwise, crossing the diagonal approximately at the zero point. This implies that regions with prices below the Russian average tend to transit to higher prices, and those with high prices tend to transit to lower prices; only regions with prices close to the national average are near-immobile.

As described in Section 2.1, the stochastic kernel can be used for estimating a long-run limit of the price distribution, the ergodic distribution. Figure 6 presents estimates of ergodic distributions obtained with the use of both kernels; the actual price distribution for 2000 is reported for comparison.

While estimating the ergodic distribution, 23 iterations (exponentiations) according Formulae (20) and (21) have been sufficient for kernel (a) to converge to it, and 89 iterations have been needed for kernel (b). Two estimated distributions are close to each other. They are almost symmetric except for long right-hand tail which shortens but still persists. The distribution is unimodal, thus suggesting the absence of price convergence clubs in the long run.



(a) Estimated using transition from 1994 to 2000



(b) Estimated with the use of year-to-year transitions

Fig. 5. Relative price dynamics across Russian regions: the estimated stochastic kernels

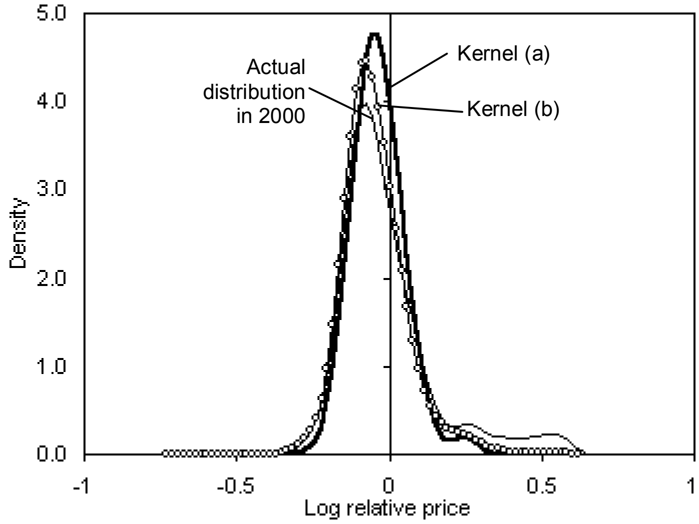


Fig. 6. Ergodic distributions of regional prices

4. CONCLUSIONS

Using the cost of the basket of 25 basic food goods as the price representative, the spatial pattern and trends of market integration in Russia in 1994-2000 have been analyzed. The results obtained evidence poor market integration: with the strict law of one price as the benchmark, only about one third of Russian regions can be deemed as integrated with the national market. Nevertheless, encouraging evidence is found of trends towards more integration. About a half of Russian regions are classed with those tending to integration. Besides that, it is inconceivable that the obtained pattern of integration overstates shortcomings of the Russian market, ignoring such an irremovable market friction as spatial separation of regions.

Overall, the results unambiguously suggest that the Russian market has been moving towards integration. (An exception is the group of the difficult-to-access regions, which is hardly involved in this movement. However, the difficult access is one more irremovable market friction; Non-integration of these regions owes to geographical features of the country rather than to some economic policy, either national or regional.) More exactly, it moved until about the end of 1999. Then why it stopped? It seems that by that time price convergence in Russia completed, having reached a "natural" limit of market integration. This is corroborated by the fact that the ergodic distributions of prices are close to the actual distribution in 2000 (see Figure 6).

Reasoning from the *theoretical benchmark* of complete integration, the situation is not brilliant, as one fifth of regions neither are integrated nor tend to become such. But let us compare it with an actual benchmark: the United States, whose market is deemed to be the most integrated. Figure 7 provides such a comparison.

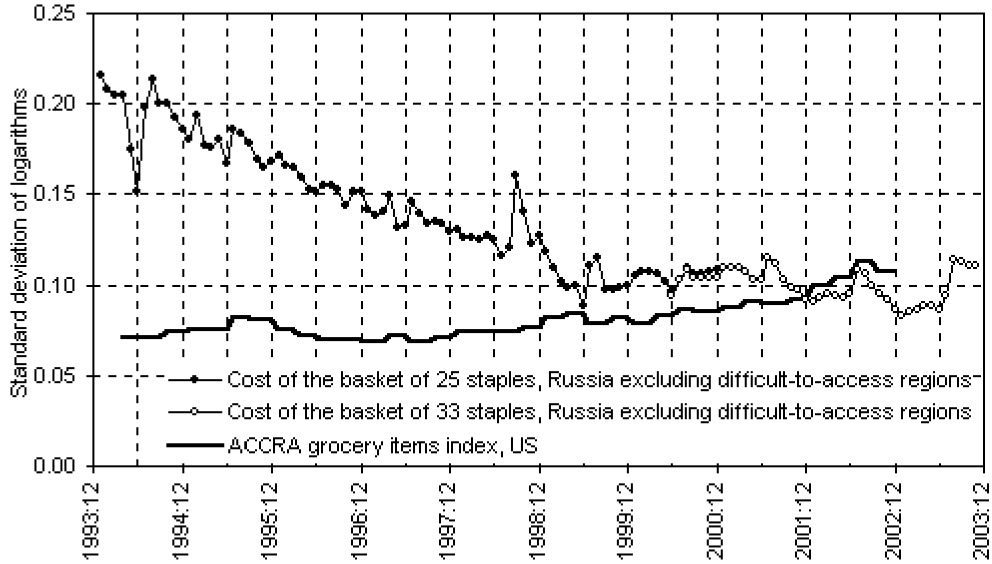


Fig. 7. Price dispersion across Russia and the US

In this figure, the data on the 25-item basket are supplemented with the data on a new, 33-item basket, introduced since June 2000; the source of the data is Goskomstat (2000-2003). The costs of the baskets are normalized to the cost for Russia as a whole. Judging from the second half of 2000, for which there are data on both baskets are available, standard deviations of their costs, calculated across Russia without difficult-to-access regions, are close to one another. ACCRA (1994-2002) data on the relative (to the US average) costs of the 27-item grocery basket across about 300 US cities with quarterly frequency are used as a US price representative (see the source for composition of the basket).

Firstly, the figure confirms the conclusion that price convergence in Russia is near to be completed: in recent years, price dispersion remains rather stable, fluctuating about the level of 0.1. And secondly – what is the most important thing – price dispersion across Russia in the last years is comparable with that across US.

This finding corroborates Shleifer and Treisman (2003) who conclude that by the late 1990s Russia has become a typical middle-income capitalist country. (As they write, “Russia’s economic and political systems remain far from perfect. However, their defects are typical of countries at its level of economic development”.) Moreover, regarding market integration, the behavior of the contemporary Russian economy is not far from that of the US economy.

APPENDICES

A. Unit root test statistics for models with nonlinear trend and/or break

To obtain p-values of the t-ratio of λ that is used in the unit root test for Equation (4), the equation has been estimated over each of 500,000 simulated random walks having $T = 84$ observations, thus obtaining the empirical distribution of this t-ratio (referred to as τ_{NL}). Denoting the number of trial as i, observations are generated as $P^{(i)}_{-(T-2)} = \varepsilon^{(i)}_{-(T-2)}$, and $P^{(i)}_t = P^{(i)}_{t-1} + \varepsilon^{(i)}_t$ for $t = -(T-3),\dots,T$, where $\varepsilon^{(i)}_t$ is a random number such that $\varepsilon^{(i)}_t \sim N(0,1)$. Discarding observations with $t \leq 0$ (to avoid initial value bias), a simulated random-walk series $\{P^{(i)}_t\}_{t=1,\dots,T}$ is obtained.

For comparison, the t-ratios of λ in conventional autoregressions with no constant term, with constant, with constant and trend, and with constant, trend and trend squared (τ_0, τ_c, τ_{ct}, and τ_{ctt} statistic, respectively) have been estimated over the same series. These regressions are

$$\Delta P_t = \lambda P_{t-1} + \varepsilon_t, \tag{A1}$$

$$\Delta P_t = \alpha + \lambda P_{t-1} + \varepsilon_t, \tag{A2}$$

$$\Delta P_t = \alpha + \lambda P_{t-1} + \beta t + \varepsilon_t, \tag{A3}$$

$$\Delta P_t = \alpha + \lambda P_{t-1} + \beta_1 t + \beta_2 t^2 + \varepsilon_t. \tag{A4}$$

Nonlinear least squares used for estimating Equation (4) finds a local minimum of the sum of squared residuals (SSR). To make this problem milder, the equation has been estimated with the use of three sets of initial values of coefficients. The first is simply $\{\lambda_0 = 0, \gamma_0 = 0, \delta_0 = 0\}$. The second set is $\{\lambda_0 = \hat{\lambda}_a, \gamma_0 = \hat{\gamma}_a, \delta_0 = \hat{\delta}_a\}$, where $\hat{\gamma}_a$ and $\hat{\delta}_a$ are the estimates of γ and δ in auxiliary equation $P_t = \ln(1 + \gamma e^{\delta t}) + \pi_t$, and $\hat{\lambda}_a$ is the estimate of λ in $\Delta\hat{\pi}_t = \lambda\hat{\pi}_{t-1} + \varepsilon_t$, $\hat{\pi}_t$ being the estimated residuals in the previous regression. The third set is $\{\lambda_0 = \hat{\lambda}_c, \gamma_0 = \exp(-\hat{\alpha}_c / \hat{\lambda}_c) - 1,\ \delta_0 = 0\}$, where $\hat{\lambda}_c$ and $\hat{\alpha}_c$ are the estimates of γ and α in (A2); that is, (4) is initially set to be equivalent to (A2). With the three estimation results for (4) over a given series, the one with minimum SSR is chosen as "true", calculating t-ratio $\tau^{(i)}_{NL} = \hat{\lambda} / \sigma(\hat{\lambda})$, where σ denotes the standard error of the estimate.

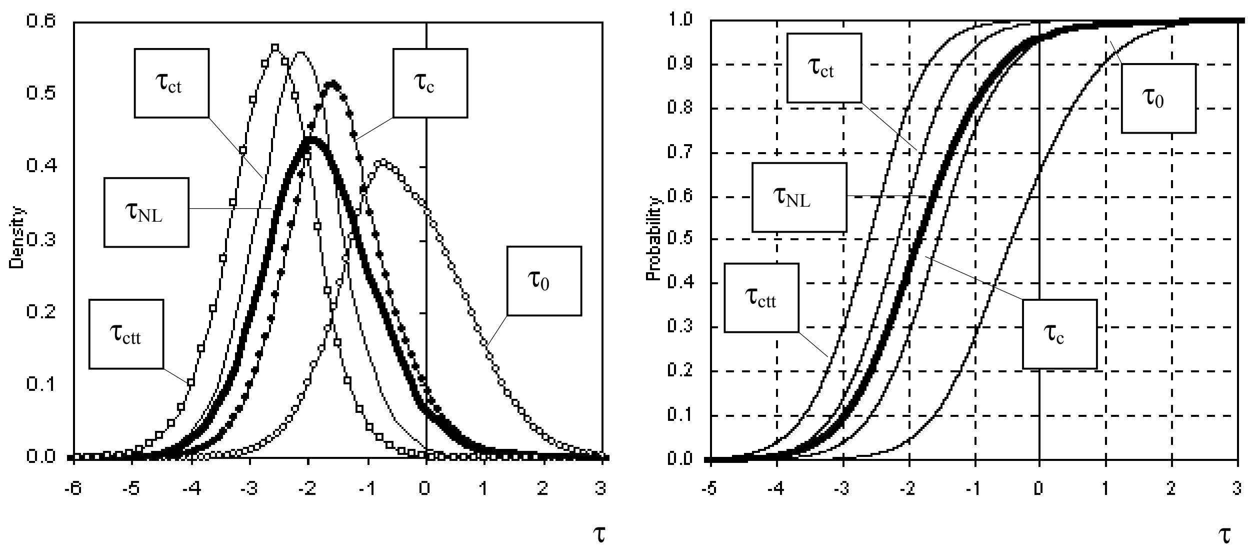
Having obtained t-ratios for (4) and (A1) through (A4) over all trials, their numerical distributions are constructed. Table A1 reports some critical values of these estimated statistics; MacKinnon's (1996) values for the sample size of 83 are in square brackets.

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

Significance level	τ_{NL}	τ_0	τ_c	τ_{ct}	τ_{ctt}
0.1%	-4.8200	-3.3843	-4.2626	-4.8159	-5.2774
		[-3.3633]	[-4.2508]	[-4.8080]	[-5.2576]
1%	-3.9634	-2.6015	-3.5134	-4.0684	-4.5160
		[-2.5931]	[-3.5113]	[-4.0724]	[-4.5164]
5%	-3.3103	-1.9478	-2.8991	-3.4598	-3.9017
		[-1.9448]	[-2.8968]	[-3.4649]	[-3.9059]
10%	-2.9776	-1.6163	-2.5856	-3.1575	-3.5954
		[-1.6142]	[-2.5856]	[-3.1590]	[-3.5983]
20%	-2.5846	-1.2214	-2.2202	-2.8042	-3.2418
		[-1.2276]	[-2.2226]	[-2.8044]	[-3.2422]

The deviations of estimated critical values of τ_0, τ_c, τ_{ct}, and τ_{ctt} statistics in the table from the MacKinnon's values fall into the band of [–0.5%, +0.6%]. This can be deemed as rather good accuracy, providing reason to believe that the estimates for τ_{NL} are sufficiently accurate as well.

Figure A1 demonstrates the probability density of τ_{NL} and its cumulative distribution in comparison with those of conventional τ-statistics, and Figure A2 plots the left-hand tails of the cumulative distributions.



(a) Probability densities (b) Cumulative distributions

Fig. A1. Distributions of τ-statistics

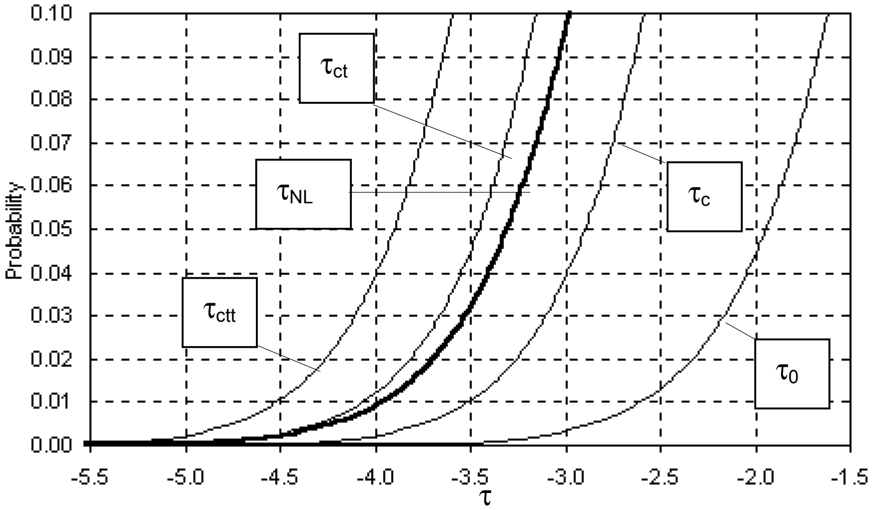


Fig. A2. Left-hand tails of cumulative distributions of τ-statistics

As seen from the table and figures, a τ-test is – for the most part – more powerful in rejecting unit root in the case of nonlinear trend of form (1) than in the case of linear trend (not to mention the quadratic trend). Almost along the whole its length, the cumulative distribution of τ_{NL} lies between τ_c and τ_{ct}. However, at small p-values, lower than 0.002, it is $\tau_{NL} < \tau_{ct}$. Nevertheless, τ_{NL} still remains greater than τ_{ctt}. Though, it is not inconceivable that the former becomes smaller than the latter at very small p-values, lower than 0.00004; however, there are too few observations of τ-statistics in this area for confident judgments. Interestingly, τ_{NL} becomes greater than τ_c at high p-values exceeding 0.96.

Empirical distributions for the case of structural break in time series have been computed in the similar way. The difference in simulated series is that, in each trial, a number of random walks with breaks $\{P_t^{(i)}(t^*)\}_{t=1,\dots,T}$ are generated as $P_t^{(i)}(t^*) = P_{t-1}^{(i)}(t^*) + \gamma_B(B_t(t^*) - B_{t-1}(t^*)) + \varepsilon_t^{(i)}$ ($t = 1,\dots,T$), where $\gamma_B = \bar{P}^{(i)}$, for t^* = 1998:08, …, 1999:02. (Recall that $B_t(t^*) = 1$ if $t < t^*$, and zero otherwise) Over each of these series, Equations (4*) and (6*) have been estimated, yielding a set of the t-ratios of λ for various periods of structural break. Table A2 reports some critical values of these estimated statistics, $\tau_{NL}(t^*)$ and $\tau_0(t^*)$, and Figure A3 demonstrates the left-hand tails of the their cumulative distributions. For comparison, selected τ-statistics from above are included.

As could be expected, the cumulative distributions of τ for the linear model with break lie between those for the linear models without and with the constant term. With this, they are closer to τ_0 than to τ_c. The distributions for the model with nonlinear trend and break lie to the left of that for the relevant model without break. They are rather close to the latter, and lie to the right of the distribution for the model with linear trend, except for low p-values (0.015 and lesser). In both cases, distributions for different break periods are very close to one another, and are hardly distinguishable in the figure.

Table A2. Critical values of the unit root test τ-statistics for models with structural break

Model with nonlinear tend (4*)									
Significance Level	τ_{NL}	$\tau_{NL}(t^*)$ with t^* =							τ_{ct}
		1998:08	1998:09	1998:10	1998:11	1998:12	1999:01	1999:02	
0.1%	-4.8200	-4.8530	-4.8605	-4.8753	-4.8892	-4.8824	-4.8724	-4.8718	-4.8159
1%	-3.9634	-4.0335	-4.0450	-4.0523	-4.0555	-4.0635	-4.0581	-4.0647	-4.0684
5%	-3.3103	-3.3568	-3.3687	-3.3719	-3.3760	-3.3786	-3.3778	-3.3812	-3.4598
10%	-2.9776	-3.0172	-3.0265	-3.0300	-3.0346	-3.0359	-3.0377	-3.0389	-3.1575
20%	-2.5846	-2.6216	-2.6296	-2.6331	-2.6353	-2.6384	-2.6399	-2.6409	-2.8042
Linear model (6*)									
Significance Level	τ_0	$\tau_0(t^*)$ with t^* =							τ_c
		1998:08	1998:09	1998:10	1998:11	1998:12	1999:01	1999:02	
0.1%	-3.3843	-3.8372	-3.8519	-3.8549	-3.8593	-3.8665	-3.8703	-3.8719	-4.2626
1%	-2.6015	-2.9746	-2.9805	-2.9854	-2.9876	-2.9918	-2.9987	-3.0044	-3.5134
5%	-1.9478	-2.2323	-2.2351	-2.2389	-2.2438	-2.2456	-2.2498	-2.2551	-2.8991
10%	-1.6163	-1.8746	-1.8767	-1.8782	-1.8811	-1.8806	-1.8836	-1.8865	-2.5856
20%	-1.2214	-1.4798	-1.4808	-1.4804	-1.4811	-1.4822	-1.4822	-1.4831	-2.2202

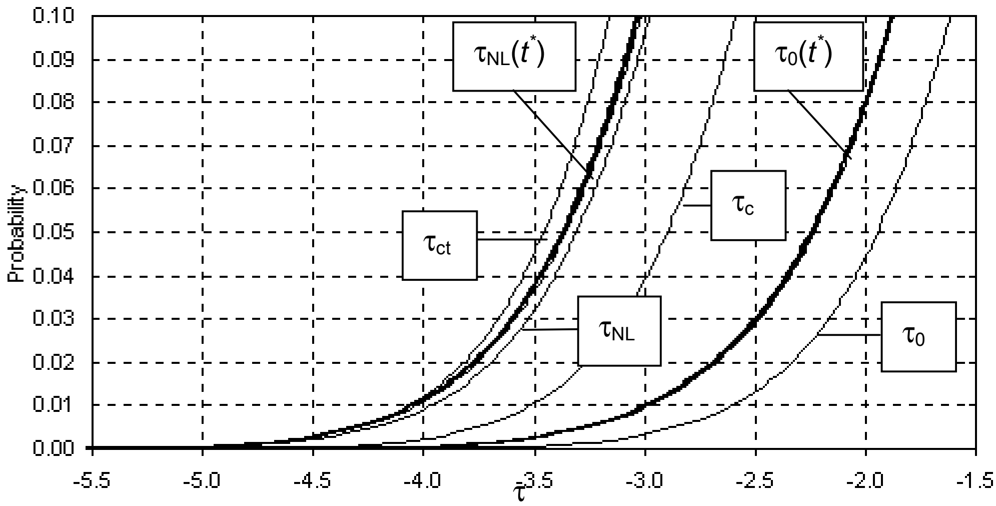


Fig. A3. Left-hand tails of cumulative distributions of τ-statistics for models with break

B. Results of estimations of time-series models

Table B1. Models without structural breaks

Region	Model (4)							Model (6)		
	p(λ=0)	λ		γ		δ		p(λ=0)	λ	
1. Rep. of Karelia	0.003	-0.423	(0.091)	0.186	(0.030)***	-0.0112	(0.0042)***	0.082	-0.069	(0.036)
2. Rep. of Komi	0.007	-0.345	(0.084)	0.281	(0.063)***	-0.0277	(0.0082)***	*0.139*	-0.075	(0.041)
3. Arkhangelsk Obl.	0.011	-0.376	(0.088)	0.343	(0.033)***	-0.0186	(0.0028)***	*0.145*	-0.027	(0.020)
4. Vologda Obl.	0.014	-0.330	(0.086)	-0.057	(0.024)**	-0.0140	(0.0115)	0.014	-0.157	(0.061)
5. Murmansk Obl.	0.041	-0.221	(0.070)	0.426	(0.069)***	-0.0065	(0.0035)*	*0.218*	-0.018	(0.015)
6. Saint Petersburg City	0.006	-0.376	(0.088)	0.002	(0.003)	0.0520	(0.0238)***	0.008	-0.182	(0.066)
7. Novgorod Obl.	0.000	-0.681	(0.107)	-0.044	(0.016)***	-0.0185	(0.0121)	0.000	-0.469	(0.092)
8. Pskov Obl.	0.007	-0.349	(0.084)	-0.113	(0.021)***	-0.0062	(0.0044)	*0.273*	-0.055	(0.037)
9. Kaliningrad Obl.	*0.144*	-0.180	(0.064)	-0.089	(0.071)	-0.0055	(0.0170)	0.038	-0.103	(0.046)
10. Bryansk Obl.	0.011	-0.339	(0.086)	-0.216	(0.021)***	-0.0115	(0.0027)***	*0.105*	-0.032	(0.021)
11. Vladimir Obl.	0.002	-0.406	(0.088)	-0.151	(0.018)***	-0.0122	(0.0034)***	*0.306*	-0.043	(0.032)
12. Ivanovo Obl.	0.016	-0.305	(0.080)	-0.121	(0.025)***	-0.0120	(0.0056)**	*0.122*	-0.059	(0.036)
13. Kaluga Obl.	0.035	-0.239	(0.073)	-0.236	(0.075)***	-0.0417	(0.0166)**	0.040	-0.076	(0.038)
14. Kostroma Obl.	0.041	-0.314	(0.083)	-0.102	(0.020)***	-0.0003	(0.0039)	*0.506*	-0.032	(0.032)
15. Moscow City	0.064	-0.226	(0.070)	0.142	(0.027)***	0.0091	(0.0033)***	*0.707*	-0.003	(0.016)
16. Oryol Obl.	0.015	-0.328	(0.085)	-0.313	(0.029)***	-0.0171	(0.0030)***	0.072	-0.033	(0.021)
17. Ryazan Obl.	*0.120*	-0.152	(0.052)	-0.244	(0.114)**	-0.0317	(0.0151)**	*0.197*	-0.036	(0.030)
18. Smolensk Obl.	0.003	-0.393	(0.089)	-0.253	(0.034)***	-0.0169	(0.0043)***	0.064	-0.064	(0.035)
19. Tver Obl.	0.038	-0.248	(0.072)	-0.116	(0.038)***	-0.0080	(0.0078)	0.041	-0.080	(0.037)

Region	Model (4)							Model (6)		
	p(λ=0)	λ		γ		δ		p(λ=0)	λ	
20. Tula Obl.	0.009	-0.276	(0.068)	-0.246	(0.034)***	-0.0204	(0.0045)***	*0.291*	-0.026	(0.024)
21. Yaroslavl Obl.	0.031	-0.278	(0.075)	-0.122	(0.033)***	-0.0215	(0.0092)**	*0.101*	-0.078	(0.043)
22. Rep. of Mariy El	*0.156*	-0.180	(0.065)	-0.200	(0.034)***	-0.0012	(0.0033)	*0.330*	-0.014	(0.015)
23. Rep. of Mordovia	0.019	-0.299	(0.082)	-0.165	(0.023)***	0.0027	(0.0025)	*0.312*	-0.022	(0.020)
24. Chuvash Rep.	0.013	-0.285	(0.075)	-0.236	(0.019)***	-0.0058	(0.0019)***	*0.447*	-0.010	(0.014)
25. Kirov Obl.	0.049	-0.242	(0.073)	-0.135	(0.027)***	-0.0004	(0.0040)***	*0.340*	-0.027	(0.024)
26. Nizhni Novgorod Obl.	0.011	-0.341	(0.084)	-0.092	(0.019)***	0.0006	(0.0040)***	*0.214*	-0.050	(0.034)
27. Belgorod Obl.	0.000	-0.470	(0.095)	-0.261	(0.027)***	-0.0119	(0.0030)***	*0.218*	-0.054	(0.035)
28. Voronezh Obl.	0.001	-0.449	(0.094)	-0.380	(0.024)***	-0.0250	(0.0027)***	0.037	-0.041	(0.022)
29. Kursk Obl.	0.000	-0.471	(0.097)	-0.245	(0.025)***	-0.0152	(0.0032)***	0.058	-0.066	(0.033)
30. Lipetsk Obl.	0.003	-0.408	(0.091)	-0.233	(0.018)***	-0.0090	(0.0020)***	*0.248*	-0.026	(0.021)
31. Tambov Obl.	0.004	-0.325	(0.077)	-0.264	(0.030)***	-0.0114	(0.0031)***	*0.309*	-0.025	(0.024)
32. Rep. of Kalmykia	0.000	-0.550	(0.099)	-0.188	(0.025)***	-0.0209	(0.0049)***	0.052	-0.118	(0.051)
33. Rep. of Tatarstan	0.000	-0.577	(0.098)	-0.267	(0.017)***	-0.0041	(0.0015)***	0.098	-0.041	(0.025)
34. Astrakhan Obl.	0.000	-0.701	(0.106)	-0.181	(0.020)***	-0.0250	(0.0045)***	0.027	-0.150	(0.057)
35. Volgograd Obl.	0.001	-0.451	(0.093)	-0.112	(0.022)***	-0.0077	(0.0048)	0.024	-0.116	(0.047)
36. Penza Obl.	0.026	-0.279	(0.078)	-0.227	(0.027)***	-0.0099	(0.0031)***	*0.202*	-0.026	(0.020)
37. Samara Obl.	0.001	-0.442	(0.092)	0.000	(0.001)***	0.0746	(0.0705)	0.000	-0.376	(0.087)
38. Saratov Obl.	0.014	-0.316	(0.082)	-0.178	(0.035)***	-0.0105	(0.0052)**	*0.124*	-0.064	(0.036)
39. Ulyanovsk Obl.	0.000	-0.428	(0.084)	-0.416	(0.022)***	-0.0093	(0.0014)***	0.018	-0.035	(0.017)
40. Rep. of Adygeya	0.000	-0.716	(0.107)	-0.233	(0.014)***	-0.0134	(0.0018)***	*0.162*	-0.058	(0.034)
41. Rep. of Dagestan	0.000	-0.574	(0.101)	-0.122	(0.023)***	-0.0124	(0.0052)**	0.006	-0.178	(0.062)

Region	Model (4)							Model (6)		
	p(λ=0)	λ		γ		δ		p(λ=0)	λ	
42. Kabardian-Balkar Rep.	0.000	-0.231	(0.040)	-0.828	(0.079)***	-0.0929	(0.0166)***	0.081	-0.076	(0.043)
43. Karachaev-Cirkassian Rep.	0.011	-0.331	(0.084)	-0.133	(0.034)***	-0.0054	(0.0058)	*0.158*	-0.080	(0.044)
44. Rep. of Northern Ossetia	0.002	-0.445	(0.093)	-0.243	(0.032)***	-0.0252	(0.0053)***	0.073	-0.082	(0.040)
45. Krasnodar Krai	0.001	-0.497	(0.097)	-0.162	(0.026)***	-0.0088	(0.0040)**	0.078	-0.103	(0.047)
46. Stavropol Krai	0.000	-0.554	(0.100)	-0.165	(0.016)***	-0.0091	(0.0025)***	*0.170*	-0.060	(0.036)
47. Rostov Obl.	0.000	-0.679	(0.106)	-0.185	(0.012)***	-0.0066	(0.0016)***	*0.181*	-0.051	(0.032)
48. Rep. of Bashkortostan	0.006	-0.356	(0.085)	-0.134	(0.029)***	-0.0048	(0.0049)	*0.165*	-0.074	(0.042)
49. Udmurt Rep.	0.011	-0.313	(0.081)	-0.129	(0.027)***	-0.0054	(0.0047)	*0.216*	-0.052	(0.035)
50. Kurgan Obl.	0.004	-0.294	(0.066)	-0.055	(0.022)**	0.0109	(0.0066)	0.023	-0.089	(0.039)
51. Orenburg Obl.	0.024	-0.291	(0.078)	-0.062	(0.034)*	0.0088	(0.0092)	0.033	-0.116	(0.052)
52. Perm Obl.	0.003	-0.372	(0.082)	0.160	(0.074)**	-0.0842	(0.0391)**	0.009	-0.204	(0.067)
53. Sverdlovsk Obl.	0.020	-0.292	(0.081)	0.119	(0.044)***	-0.0213	(0.0118)*	0.051	-0.108	(0.052)
54. Chelyabinsk Obl.	0.000	-0.721	(0.108)	-0.007	(0.013)	0.0067	(0.0369)	0.000	-0.698	(0.105)
55. Rep. of Altai	0.003	-0.428	(0.091)	-0.005	(0.015)	0.0199	(0.0428)	0.000	-0.401	(0.088)
56. Altai Krai	0.067	-0.220	(0.069)	-0.099	(0.034)***	0.0028	(0.0063)	*0.274*	-0.042	(0.033)
57. Kemerovo Obl.	0.007	-0.307	(0.076)	0.071	(0.064)	-0.0354	(0.0396)	0.000	-0.237	(0.058)
58. Novosibirsk Obl.	0.002	-0.348	(0.073)	0.022	(0.017)	0.0090	(0.0138)	0.000	-0.234	(0.059)
59. Omsk Obl.	0.012	-0.356	(0.086)	-0.204	(0.031)***	-0.0211	(0.0054)***	0.098	-0.065	(0.035)
60. Tomsk Obl.	0.001	-0.393	(0.086)	-0.001	(0.002)	0.0581	(0.0338)*	0.000	-0.252	(0.071)
61. Tyumen Obl.	*0.104*	-0.185	(0.063)	0.209	(0.138)	-0.0413	(0.0275)	0.061	-0.089	(0.046)
62. Rep. of Buryatia	0.090	-0.208	(0.068)	0.217	(0.094)**	-0.0227	(0.0135)*	0.096	-0.073	(0.040)
63. Rep. of Tuva	0.020	-0.297	(0.079)	0.267	(0.050)***	-0.0074	(0.0042)*	*0.359*	-0.032	(0.027)

Region	Model (4)							Model (6)		
	p(λ=0)	λ		γ		δ		p(λ=0)	λ	
64. Rep. of Khakasia	0.008	-0.337	(0.081)	0.019	(0.014)	0.0170	(0.0114)	0.010	-0.157	(0.058)
65. Krasnoyarsk Krai	*0.189*	-0.173	(0.062)	0.036	(0.068)	-0.0015	(0.0372)	0.014	-0.145	(0.055)
66. Irkutsk Obl.	0.027	-0.288	(0.079)	0.207	(0.087)**	-0.0118	(0.0105)	0.044	-0.113	(0.050)
67. Chita Obl.	0.000	-0.448	(0.089)	0.432	(0.040)***	-0.0152	(0.0025)***	*0.347*	-0.026	(0.023)
68. Rep. of Sakha (Yakutia)	0.093	-0.185	(0.061)	1.297	(0.245)***	-0.0086	(0.0039)**	*0.513*	-0.007	(0.013)
69. Jewish Autonomous Obl.	0.028	-0.271	(0.076)	0.362	(0.051)***	-0.0150	(0.0037)***	0.080	-0.031	(0.019)
70. Primorsky Krai	0.040	-0.282	(0.081)	0.545	(0.060)***	-0.0076	(0.0025)***	*0.384*	-0.012	(0.014)
71. Khabarovsk Krai	0.001	-0.442	(0.094)	0.485	(0.038)***	-0.0121	(0.0019)***	*0.247*	-0.021	(0.018)
72. Amur Obl.	0.044	-0.246	(0.070)	0.282	(0.076)***	-0.0121	(0.0066)*	0.025	-0.061	(0.028)
73. Kamchatka Obl.	0.045	-0.251	(0.071)	1.103	(0.134)***	-0.0059	(0.0025)**	*0.551*	-0.006	(0.011)
74. Magadan Obl.	*0.203*	-0.136	(0.057)	1.403	(0.260)***	-0.0091	(0.0038)**	*0.256*	-0.009	(0.008)
75. Sakhalin Obl.	0.081	-0.187	(0.064)	1.147	(0.181)***	-0.0129	(0.0036)***	*0.337*	-0.010	(0.012)

Table B2. Models with structural breaks

Region	Break period	Model (4*)									Model (6*)				
		p(λ=0)	λ		γ		Break (γ_B)		δ		p(λ=0)	λ		Break (γ_B)	
1. Rep. of Karelia	1998:09	*0.366*	-0.119	(0.053)	6.785	(10.218)	-6.349	(9.947)	-0.0585	(0.0274)**	*0.190*	-0.019	(0.013)	-0.218	(0.036)***
2. Rep. of Komi	1998:12	0.002	-0.439	(0.092)	0.005	(0.058)	0.227	(0.072)***	-0.0168	(0.0063)***	0.001	-0.334	(0.084)	0.129	(0.017)***
3. Arkhangelsk Obl.	1998:12	0.006	-0.428	(0.093)	0.195	(0.049)***	0.119	(0.039)***	-0.0138	(0.0030)***	*0.283*	-0.042	(0.028)	0.064	(0.032)**
4. Vologda Obl.	1998:09	0.013	-0.360	(0.091)	-0.015	(0.017)	-0.032	(0.018)*	-0.0022	(0.0123)	0.001	-0.347	(0.089)	-0.043	(0.010)***
5. Murmansk Obl.	1998:09	*0.194*	-0.162	(0.061)	1.448	(0.440)***	-0.852	(0.348)**	-0.0217	(0.0054)***	*0.233*	-0.013	(0.009)	-0.207	(0.036)***
6. Saint Petersburg City	1998:09	0.010	-0.355	(0.086)	2.701	(3.325)	-2.657	(3.313)	-0.0489	(0.0199)**	*0.420*	-0.028	(0.024)	-0.183	(0.036)***

Region	Break period	Model (4*)									Model (6*)				
		p(λ=0)	λ		γ		Break (γ_B)		δ		p(λ=0)	λ		Break (γ_B)	
7. Novgorod Obl.	1998:09	0.000	-0.674	(0.108)	0.002	(0.010)	-0.036	(0.018)*	-0.0003	(0.0125)	0.000	-0.677	(0.106)	-0.034	(0.007)***
8. Pskov Obl.	1998:09	0.006	-0.384	(0.089)	-0.060	(0.024)**	-0.039	(0.015)**	0.0005	(0.0054)	0.027	-0.181	(0.069)	-0.088	(0.021)***
9. Kaliningrad Obl.	1998:09	0.083	-0.208	(0.067)	-0.005	(0.009)	-0.047	(0.034)	0.0207	(0.0147)	0.017	-0.173	(0.063)	-0.125	(0.030)***
10. Bryansk Obl.	1998:08	0.066	-0.274	(0.083)	-0.385	(0.108)***	0.147	(0.088)*	-0.0176	(0.0045)***	0.093	-0.022	(0.014)	0.098	(0.030)***
11. Vladimir Obl.	1998:09	0.008	-0.380	(0.091)	-0.057	(0.021)***	-0.070	(0.017)***	-0.0029	(0.0043)	0.030	-0.175	(0.067)	-0.122	(0.018)***
12. Ivanovo Obl.	1999:01	0.007	-0.382	(0.090)	-0.045	(0.022)**	-0.060	(0.019)***	-0.0044	(0.0051)	0.002	-0.301	(0.084)	-0.090	(0.012)***
13. Kaluga Obl.	1998:09	*0.453*	-0.069	(0.036)	0.000	(0.000)	0.000	(0.000)	0.2692	(0.2479)	0.053	-0.098	(0.049)	-0.119	(0.028)***
14. Kostroma Obl.	1998:09	0.030	-0.333	(0.086)	-0.045	(0.017)***	-0.035	(0.009)***	0.0094	(0.0051)*	*0.422*	-0.078	(0.053)	-0.090	(0.028)***
15. Moscow City	1998:08	0.030	-0.258	(0.072)	0.249	(0.060)***	-0.084	(0.041)**	0.0020	(0.0037)	*0.788*	-0.003	(0.013)	-0.070	(0.028)**
16. Oryol Obl.	1998:08	0.008	-0.370	(0.089)	-0.505	(0.124)***	0.170	(0.106)	-0.0216	(0.0036)***	0.077	-0.027	(0.017)	0.061	(0.040)
17. Ryazan Obl.	1998:09	0.093	-0.186	(0.061)	-0.037	(0.072)	-0.153	(0.093)	-0.0217	(0.0113)*	0.019	-0.153	(0.060)	-0.083	(0.019)***
18. Smolensk Obl.	1998:09	0.000	-0.534	(0.101)	-0.090	(0.036)**	-0.133	(0.032)***	-0.0091	(0.0037)**	0.000	-0.395	(0.091)	-0.182	(0.018)***
19. Tver Obl.	1998:09	0.000	-0.438	(0.088)	-0.019	(0.010)*	-0.072	(0.014)***	0.0075	(0.0048)	0.000	-0.344	(0.082)	-0.118	(0.013)***
20. Tula Obl.	1998:09	0.009	-0.299	(0.072)	-0.145	(0.053)***	-0.082	(0.044)*	-0.0161	(0.0046)***	*0.308*	-0.042	(0.033)	-0.050	(0.031)
21. Yaroslavl Obl.	1998:09	0.005	-0.396	(0.089)	-0.013	(0.021)	-0.084	(0.026)***	-0.0087	(0.0066)	0.000	-0.388	(0.088)	-0.077	(0.009)***
22. Rep. of Mariy El	1999:02	0.050	-0.267	(0.076)	-0.129	(0.025)***	-0.048	(0.014)***	0.0038	(0.0027)	*0.486*	-0.016	(0.018)	-0.045	(0.031)
23. Rep. of Mordovia	1998:09	0.055	-0.262	(0.079)	-0.303	(0.077)***	0.108	(0.056)*	-0.0049	(0.0039)	*0.282*	-0.015	(0.014)	0.125	(0.039)***
24. Chuvash Rep.	1998:10	0.018	-0.301	(0.081)	-0.163	(0.025)***	-0.052	(0.016)***	-0.0015	(0.0022)	*0.661*	-0.012	(0.018)	-0.070	(0.027)**
25. Kirov Obl.	1998:09	0.036	-0.273	(0.076)	-0.050	(0.016)***	-0.052	(0.010)***	0.0114	(0.0043)**	*0.386*	-0.050	(0.040)	-0.125	(0.030)***
26. Nizhni Novgorod Obl.	1998:11	0.004	-0.441	(0.093)	-0.033	(0.011)***	-0.037	(0.007)***	0.0124	(0.0042)***	0.085	-0.129	(0.057)	-0.099	(0.024)***
27. Belgorod Obl.	1998:09	0.001	-0.463	(0.095)	-0.314	(0.101)***	0.046	(0.081)	-0.0137	(0.0044)***	*0.393*	-0.040	(0.029)	0.056	(0.064)

Region	Break period	Model (4^*)									Model (6^*)				
		p(λ=0)	λ		γ		Break (γ_B)		δ		p(λ=0)	λ		Break (γ_B)	
28. Voronezh Obl.	1998:08	0.000	-0.524	(0.098)	-0.646	(0.142)***	0.249	(0.129)*	-0.0288	(0.0029)***	0.069	-0.036	(0.020)	0.042	(0.045)
29. Kursk Obl.	1998:09	0.001	-0.490	(0.099)	-0.412	(0.130)***	0.148	(0.112)	-0.0202	(0.0045)***	*0.121*	-0.044	(0.025)	0.079	(0.053)
30. Lipetsk Obl.	1998:09	0.002	-0.468	(0.095)	-0.391	(0.071)***	0.134	(0.059)**	-0.0148	(0.0026)***	*0.226*	-0.019	(0.016)	0.084	(0.036)**
31. Tambov Obl.	1998:10	0.004	-0.362	(0.082)	-0.176	(0.046)***	-0.068	(0.033)**	-0.0074	(0.0034)**	*0.362*	-0.038	(0.031)	-0.059	(0.044)
32. Rep. of Kalmykia	1998:10	0.000	-0.548	(0.103)	-0.045	(0.038)	-0.117	(0.037)***	-0.0115	(0.0054)**	0.000	-0.401	(0.091)	-0.127	(0.016)***
33. Rep. of Tatarstan	1998:09	0.000	-0.614	(0.101)	-0.363	(0.058)***	0.077	(0.045)*	-0.0077	(0.0022)***	*0.162*	-0.030	(0.020)	0.100	(0.061)
34. Astrakhan Obl.	1998:12	0.000	-0.699	(0.107)	-0.131	(0.079)	-0.047	(0.072)	-0.0235	(0.0054)***	0.000	-0.390	(0.089)	-0.098	(0.017)***
35. Volgograd Obl.	1998:12	0.001	-0.483	(0.094)	-0.040	(0.020)**	-0.051	(0.015)***	0.0021	(0.0057)	0.000	-0.354	(0.084)	-0.099	(0.015)***
36. Penza Obl.	1998:09	0.060	-0.247	(0.075)	-0.349	(0.100)***	0.101	(0.076)	-0.0146	(0.0046)***	*0.275*	-0.020	(0.015)	0.073	(0.033)**
37. Samara Obl.	1998:12	0.001	-0.469	(0.095)	1.625	(4.531)	-1.661	(4.548)	-0.0475	(0.0422)	0.000	-0.372	(0.088)	-0.022	(0.017)
38. Saratov Obl.	1998:09	0.079	-0.228	(0.071)	-0.774	(0.503)	0.526	(0.451)	-0.0285	(0.0112)**	*0.255*	-0.027	(0.020)	0.144	(0.046)***
39. Ulyanovsk Obl.	1998:09	0.000	-0.577	(0.098)	-0.600	(0.068)***	0.152	(0.057)***	-0.0133	(0.0016)***	0.036	-0.032	(0.016)	0.044	(0.058)
40. Rep. of Adygeya	1998:09	0.000	-0.772	(0.108)	-0.366	(0.068)***	0.118	(0.059)**	-0.0178	(0.0025)***	*0.302*	-0.035	(0.025)	0.084	(0.053)
41. Rep. of Dagestan	1999:02	0.000	-0.582	(0.102)	-0.074	(0.045)	-0.039	(0.035)	-0.0084	(0.0066)	0.000	-0.481	(0.096)	-0.090	(0.014)***
42. Kabardian-Balkar Rep.	1998:08	0.000	-0.232	(0.040)	5.224	(9.665)	-6.051	(9.679)	-0.0932	(0.0166)***	0.066	-0.108	(0.052)	-0.064	(0.044)
43. Karachaev-Cirkassian Rep.	1998:09	0.005	-0.392	(0.090)	-0.399	(0.205)*	0.229	(0.180)	-0.0183	(0.0078)**	*0.428*	-0.043	(0.032)	0.084	(0.053)
44. Rep. of Northern Ossetia	1998:09	0.002	-0.444	(0.094)	-0.391	(0.198)*	0.138	(0.177)	-0.0284	(0.0068)***	*0.229*	-0.064	(0.037)	0.033	(0.051)
45. Krasnodar Krai	1998:09	0.000	-0.619	(0.105)	-0.430	(0.157)***	0.234	(0.140)*	-0.0199	(0.0053)***	*0.251*	-0.092	(0.049)	0.014	(0.058)
46. Stavropol Krai	1998:09	0.000	-0.568	(0.101)	-0.273	(0.076)***	0.091	(0.063)	-0.0146	(0.0039)***	*0.315*	-0.035	(0.027)	0.070	(0.044)
47. Rostov Obl.	1998:09	0.000	-0.692	(0.108)	-0.219	(0.041)***	0.027	(0.032)	-0.0085	(0.0026)***	*0.309*	-0.047	(0.031)	0.014	(0.048)

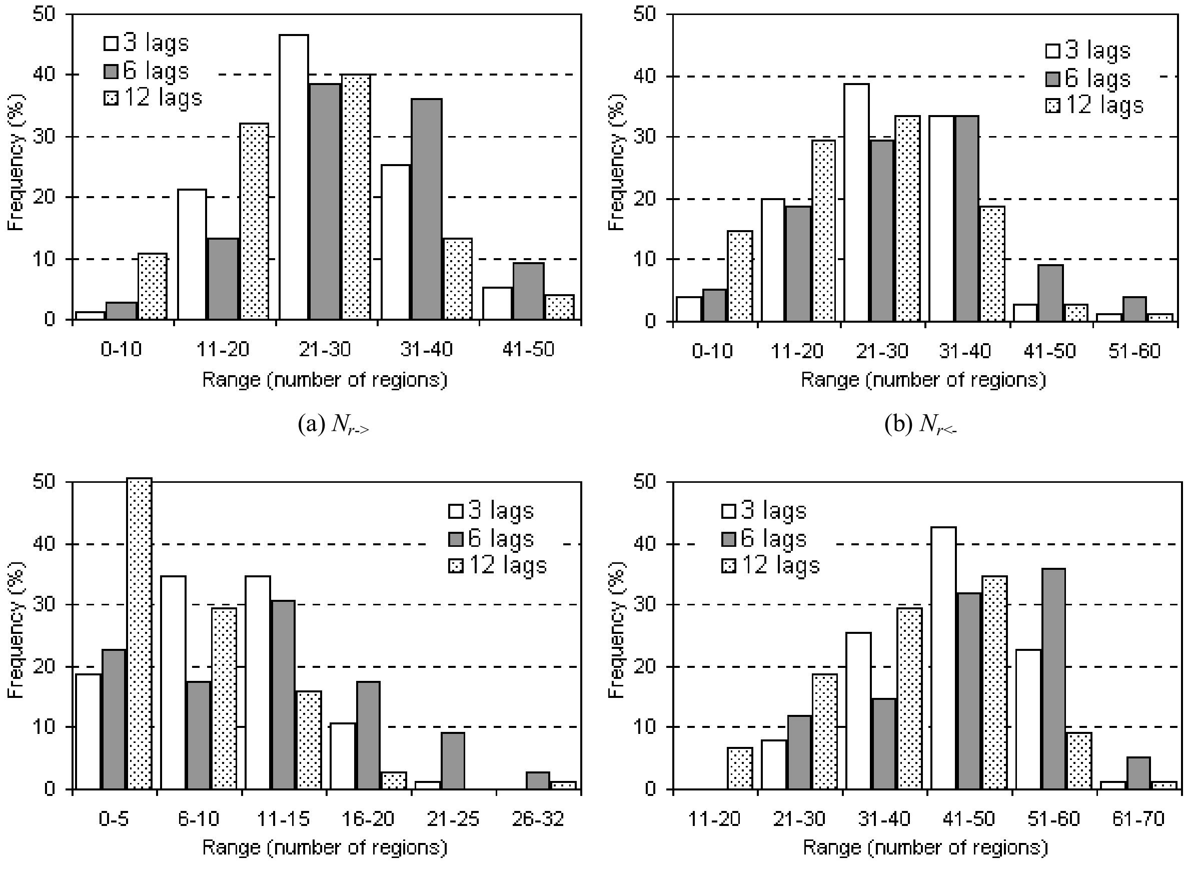
Region	Break period	Model (4*)									Model (6*)				
		p(λ=0)	λ		γ		Break (γ_B)		δ		p(λ=0)	λ		Break (γ_B)	
48. Rep. of Bashkortostan	1998:12	0.005	-0.397	(0.090)	-0.058	(0.026)**	-0.054	(0.018)***	0.0037	(0.0057)	0.006	-0.240	(0.073)	-0.126	(0.024)***
49. Udmurt Rep.	1998:11	0.005	-0.378	(0.089)	-0.034	(0.013)**	-0.058	(0.012)***	0.0086	(0.0047)*	0.017	-0.185	(0.064)	-0.129	(0.022)***
50. Kurgan Obl.	1998:11	0.002	-0.335	(0.071)	-0.017	(0.011)	-0.019	(0.007)***	0.0250	(0.0085)***	0.007	-0.131	(0.042)	-0.099	(0.031)***
51. Orenburg Obl.	1998:10	0.006	-0.390	(0.089)	-0.008	(0.007)	-0.021	(0.010)**	0.0334	(0.0112)***	0.020	-0.167	(0.060)	-0.110	(0.040)***
52. Perm Obl.	1999:02	0.000	-0.515	(0.091)	-1.971	(2.709)	2.086	(2.733)	-0.0625	(0.0202)***	0.005	-0.240	(0.072)	0.019	(0.013)
53. Sverdlovsk Obl.	1999:01	0.017	-0.376	(0.088)	0.937	(0.855)	-0.782	(0.824)	-0.0401	(0.0137)***	*0.265*	-0.060	(0.039)	-0.043	(0.033)
54. Chelyabinsk Obl.	1998:08	0.000	-0.811	(0.109)	0.000	(0.000)	-0.002	(0.004)	0.0602	(0.0411)	0.000	-0.722	(0.105)	-0.014	(0.009)
55. Rep. of Altai	1998:09	0.006	-0.476	(0.095)	-17.318	(59.734)	17.279	(59.717)	-0.0906	(0.0581)	0.000	-0.394	(0.088)	0.008	(0.017)
56. Altai Krai	1998:09	0.019	-0.287	(0.076)	-0.341	(0.152)**	0.200	(0.129)	-0.0132	(0.0070)*	*0.506*	-0.023	(0.024)	0.077	(0.039)*
57. Kemerovo Obl.	1999:01	0.002	-0.397	(0.081)	-0.116	(0.165)	0.179	(0.193)	-0.0160	(0.0191)	0.000	-0.310	(0.069)	0.038	(0.015)**
58. Novosibirsk Obl.	1999:01	0.002	-0.359	(0.073)	0.003	(0.004)	0.007	(0.007)	0.0337	(0.0208)	0.000	-0.306	(0.070)	0.033	(0.013)**
59. Omsk Obl.	1999:01	0.000	-0.578	(0.101)	-0.910	(0.296)***	0.667	(0.282)**	-0.0340	(0.0045)***	*0.171*	-0.036	(0.024)	0.082	(0.040)**
60. Tomsk Obl.	1998:09	0.000	-0.545	(0.096)	-0.011	(0.015)	0.017	(0.020)	0.0269	(0.0194)	0.003	-0.256	(0.072)	0.010	(0.021)
61. Tyumen Obl.	1998:09	*0.255*	-0.149	(0.059)	-0.368	(1.121)	0.628	(1.319)	-0.0452	(0.0370)	0.033	-0.138	(0.056)	0.068	(0.024)***
62. Rep. of Buryatia	1998:09	0.050	-0.249	(0.076)	0.011	(0.047)	0.163	(0.080)**	-0.0093	(0.0110)	0.005	-0.232	(0.073)	0.118	(0.022)***
63. Rep. of Tuva	1998:09	0.007	-0.380	(0.090)	0.113	(0.037)***	0.105	(0.024)***	0.0022	(0.0044)	*0.331*	-0.073	(0.046)	0.118	(0.044)***
64. Rep. of Khakasia	1999:01	0.013	-0.329	(0.081)	0.007	(0.008)	0.007	(0.005)	0.0298	(0.0171)*	0.017	-0.200	(0.068)	0.038	(0.018)**
65. Krasnoyarsk Krai	1998:09	0.063	-0.238	(0.071)	0.000	(0.004)	0.026	(0.032)	0.0279	(0.0252)	0.014	-0.196	(0.066)	0.070	(0.026)***
66. Irkutsk Obl.	1999:02	0.011	-0.347	(0.086)	0.049	(0.052)	0.125	(0.059)**	-0.0020	(0.0099)	0.001	-0.342	(0.085)	0.147	(0.026)***
67. Chita Obl.	1998:09	0.001	-0.450	(0.091)	0.298	(0.076)***	0.106	(0.054)*	-0.0115	(0.0034)***	*0.430*	-0.046	(0.035)	0.111	(0.048)**
68. Rep. of Sakha (Yakutia)	1998:11	0.074	-0.248	(0.073)	0.830	(0.208)***	0.298	(0.116)**	-0.0034	(0.0037)	*0.679*	-0.007	(0.014)	0.080	(0.075)

Region	Break period	Model (4*)									Model (6*)				
		p(λ=0)	λ		γ		Break (γ_B)		δ		p(λ=0)	λ		Break (γ_B)	
69. Jewish Autonomous Obl.	1999:02	0.003	-0.422	(0.091)	0.183	(0.045)***	0.148	(0.035)***	-0.0097	(0.0028)***	*0.134*	-0.035	(0.021)	0.024	(0.035)
70. Primorsky Krai	1998:09	*0.229*	-0.189	(0.072)	0.818	(0.228)***	-0.218	(0.153)	-0.0121	(0.0045)***	*0.363*	-0.011	(0.011)	-0.120	(0.043)***
71. Khabarovsk Krai	1998:12	0.000	-0.571	(0.104)	0.298	(0.048)***	0.143	(0.034)***	-0.0073	(0.0020)***	*0.409*	-0.025	(0.022)	0.068	(0.046)
72. Amur Obl.	1999:01	0.010	-0.305	(0.074)	0.093	(0.046)**	0.144	(0.043)***	-0.0026	(0.0060)	0.006	-0.216	(0.063)	0.170	(0.028)***
73. Kamchatka Obl.	1998:12	0.004	-0.428	(0.092)	0.569	(0.083)***	0.569	(0.083)***	0.0017	(0.0020)	*0.790*	-0.005	(0.014)	0.179	(0.063)***
74. Magadan Obl.	1998:12	*0.326*	-0.113	(0.053)	0.853	(0.243)***	0.333	(0.111)***	-0.0032	(0.0048)	*0.478*	-0.008	(0.010)	0.155	(0.051)***
75. Sakhalin Obl.	1998:12	*0.174*	-0.177	(0.065)	0.725	(0.187)***	0.293	(0.108)***	-0.0079	(0.0042)*	*0.535*	-0.010	(0.014)	0.137	(0.055)**

C. Granger causality test results for different number of lags

Table C1. Summary statistics

Statistic	$N_{r\text{->}}$, number of regions			$N_{r\text{<-}}$, number of regions			$N_{r\text{<->}}$, number of regions			N_r, number of regions		
	3 lags	6 lags	12 lags	3 lags	6 lags	12 lags	3 lags	6 lags	12 lags	3 lags	6 lags	12 lags
Minimum	10	8	7	7	7	5	1	1	0	22	26	12
Maximum	49	47	45	55	58	54	21	32	27	61	65	61
Average	27	29	22	27	29	22	10	12	7	44	46	38
Correlation with 3-lag results	–	0.79	0.48	–	0.71	0.23	–	0.68	0.36	–	0.82	0.52
Correlation with 6-lag results	0.79	–	0.60	0.71	–	0.49	0.68	–	0.61	0.82	–	0.64
Correlation with 12-lag results	0.48	0.60	–	0.23	0.49	–	0.36	0.61	–	0.52	0.64	–

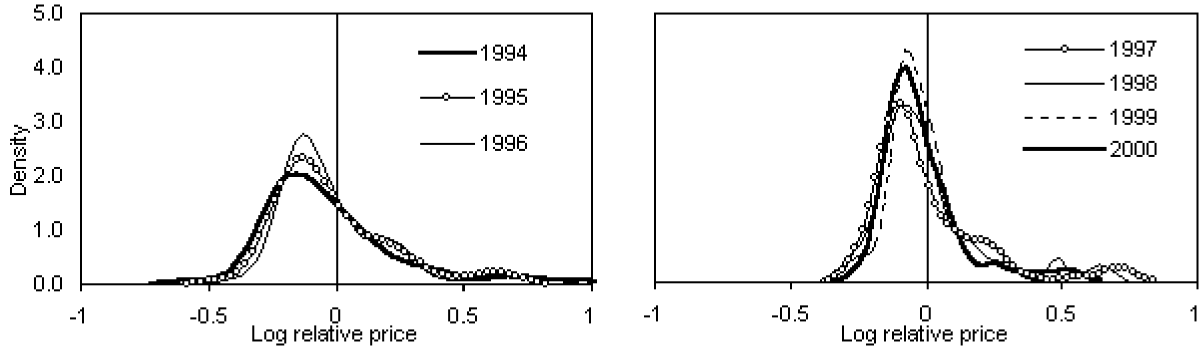


(a) $N_{r\text{->}}$ (b) $N_{r\text{<-}}$

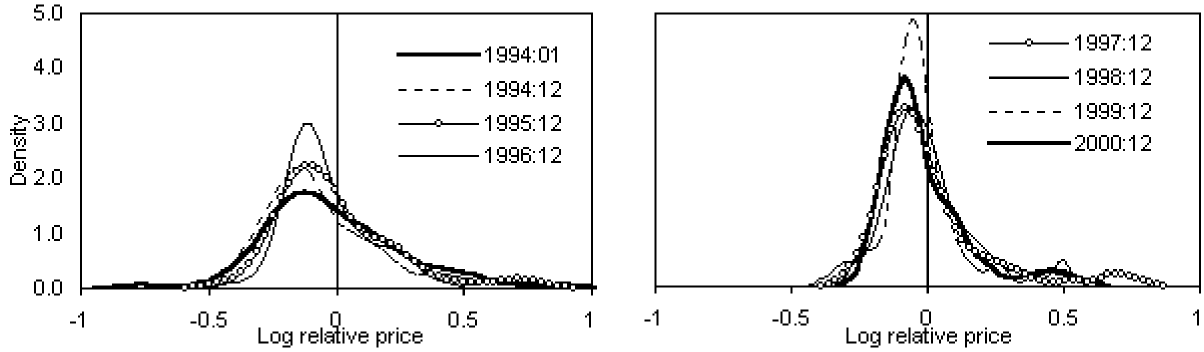
(c) $N_{r\text{<->}}$ (d) N_r

Fig. C1. Histograms of results obtained with different number of lags

D. Non-parametric estimates of price distributions

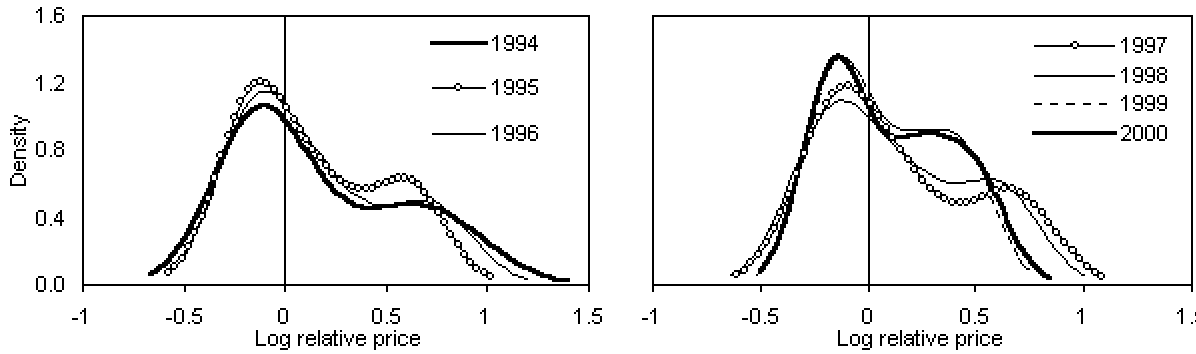


(a) Yearly distributions

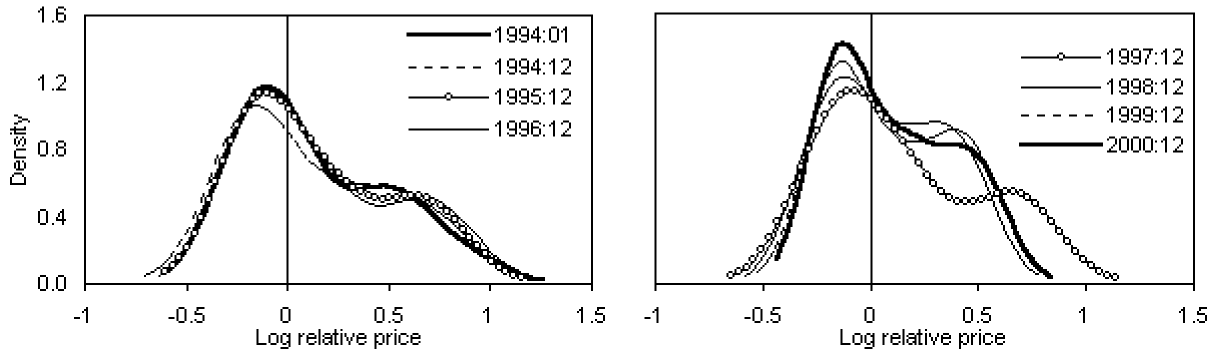


(b) Instantaneous distributions

Fig. D1. All regions

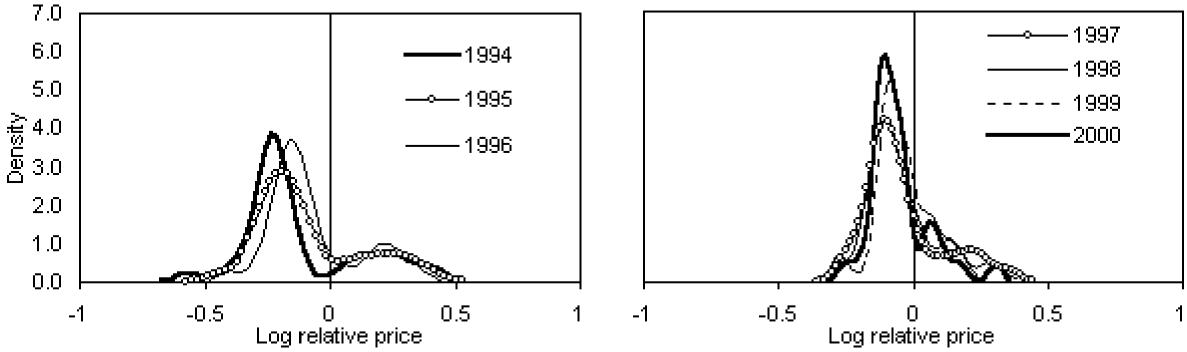


(a) Yearly distributions

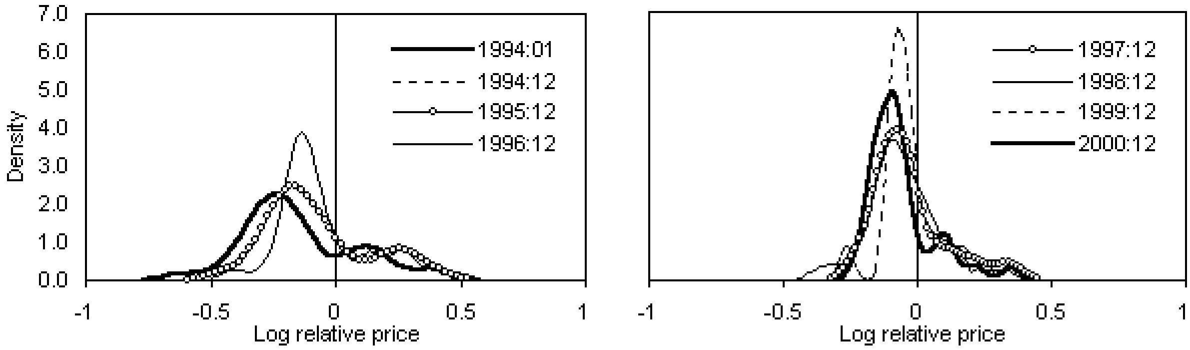


(b) Instantaneous distributions

Fig. D2. Non-integrated regions

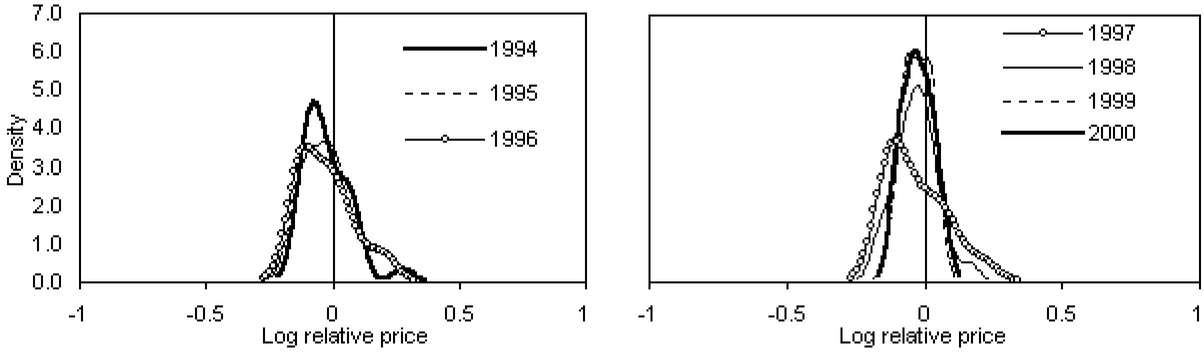


(a) Yearly distributions

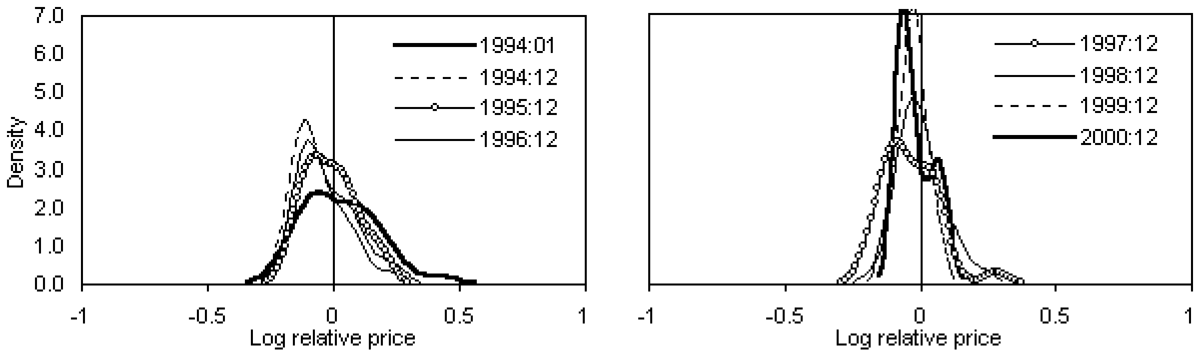


(b) Instantaneous distributions

Fig. D3. Regions tending to integration



(a) Yearly distributions



(b) Instantaneous distributions

Fig. D4. Integrated regions

E. Price inequality and mobility measures

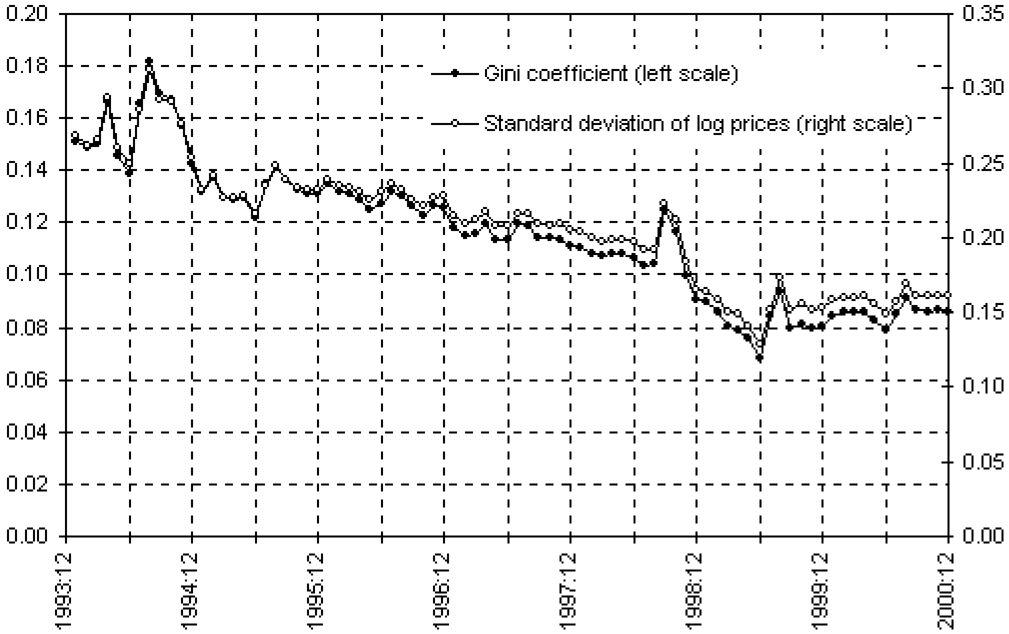


Fig. E1. The Gini coefficient *vs.* the standard deviation of log prices

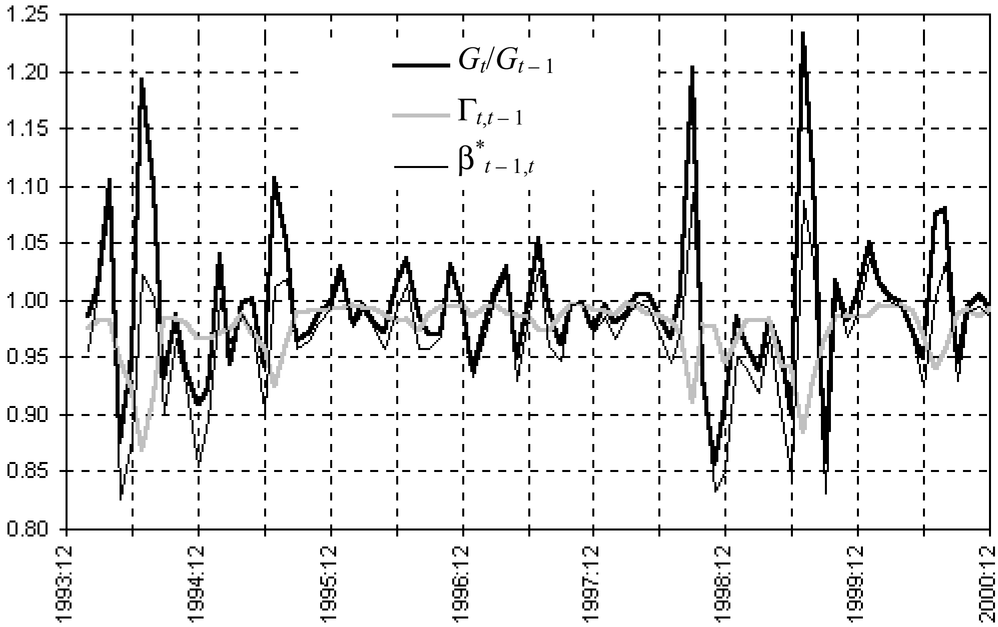


Fig. E2. Relative vs. absolute price mobility

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