Empir Econ (2016) 51:1193–1213
DOI 10.1007/s00181-015-1039-3

Distribution dynamics of Russian regional prices

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Received: 11 May 2015 / Accepted: 20 October 2015 / Published online: 4 January 2016

Abstract The objective of this paper is twofold: first, to show an application of the distribution dynamics approach developed in the literature on economic growth and income inequality to spatial price analysis, and second, to study the behaviour of Russian regional prices for staples during the decade of 2001–2010. The study includes three veins: first, tracing the evolution of price dispersion and changes in the shape of the cross-region price distribution over time; second, analysing changes in price ranking of regions (rank mobility); and third, analysing quantity mobility with the use of stochastic kernel. Results obtained evidence that regional relative prices in Russia remained fairly stable during 2001–2010. No significant changes are found in price dispersion and cross-region price distribution over this time span. Rank mobility was very low with seasonal surges. The pattern of quantity mobility manifests neither convergence nor divergence of regional prices. However, a long-run price distribution has an unpleasant feature, predicting potential emergence of a price convergence club in the Russian Far East. Given that potentialities for price convergence among Russian regions existed by 2001, the pattern obtained can be termed stagnation rather than stability.

Keywords Price convergence · Price dispersion · Price mobility · Market integration · Stochastic kernel · Russian regions

JEL Classification P22 · R10 · R15

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1 Introduction

Integration of international product markets is of great interest to economists. The literature on testing purchasing power parity is quite voluminous. Not less—maybe, even more—interesting issue is that of domestic market integration. Albeit it is not that popular as the former, this issue also has the extensive literature, considering spatial behaviour of prices or price levels. The prevailing empirical methodology in this area of research is the regression analysis (Fackler and Goodwin 2001).

The core of a data set to be analysed in such researches is prices across a number of locations (countries, regions within a country, cities, etc.) in a number of points in time. In fact, this is a time series of cross-location distribution of prices. We can take this entire distribution (rather than a location) as an observation, studying its evolution over time. This leads to a different pertinent methodology, namely nonparametric distribution dynamics analysis. Such an approach finds use in studies of spatial income inequality, in particular in empirics of economic growth (see, e.g. Durlauf and Quah 1999), but almost is not applied to spatial price dynamics (except for so simple and obvious method as tracing the path of cross-location price dispersion, a statistic of the price distribution). Rare examples are Liontakis (2012) and Nath and Tochkov (2013) who use Quah's (1996) method to test for convergence of inflation rates (certainly, there may be a few papers more, but in any case they are not numerous).

Analysing price distribution dynamics, we do not arrive at a direct conclusion regarding market integration; we deal with indirect indications of improvement in integration (price convergence) or its deterioration (price divergence). However, this methodology makes it possible to reveal instead a number of interesting features of price behaviour that are beyond the reach of regression analysis, thus enriching the pattern of price behaviour. For example, the concept of mobility can be introduced into this pattern. The objective of this paper is twofold: first, to show an application of some range of methods developed in the literature on economic growth and income inequality to spatial price analysis, and second, to study the behaviour of Russian regional prices for staples during the decade of 2001–2010. In the latter respect, this paper expands the pattern obtained by Gluschenko (2004, 2010b) to the 2000s.

The analysis includes three veins. First, it traces the evolution of price dispersion and changes in the shape of the cross-region price distribution over time. Having obtained a sequence of the distributions, intra-distribution mobility receives study. The second vein is the analysis of rank mobility (i.e. changes in price ranking of regions). Yitzhaki and Wodon's (2004) methodology serves as a tool for studying rank mobility. Its pattern suggests a tendency of 'cheap' and 'expensive' regions to swap their places. The third vein deals with quantity mobility. To characterize it, a transition probability function (stochastic kernel) is estimated, following Quah (1996). The stochastic kernel provides the law of motion of the price distribution. The estimated stochastic kernel yields also a long-run limit of the price distribution.

The dynamics of geographical price dispersion in Russia in early years of its transition from centrally planned to market economy (i.e. in the 1990s) has attracted a significant attention of economists. Koen and Phillips (1993) consider the very early stage of the transition on the basis of informal analysis. Gardner and Brooks (1994), De Masi and Koen (1996), Berkowitz et al. (1998), and Goodwin et al. (1999) focus on the issue of price convergence, using different product and location samples as well as time spans and exploiting time-series regression analysis. Berkowitz and DeJong (2001) measure the degree of Russia's market integration, tracing its evolution over time through running a sequence of cross-sectional regressions for each point in time within the time span under consideration. Unfortunately, the 2000s has declined in popularity. Akhmedjonov and Lau (2012) analyse price convergence in Russian energy markets in 2003–2010; Lau and Akhmedjonov (2012) deal with the market for textile products in 2002–2009; and Yusupova (2008) consider the wheat market in 1999–2005. All the three papers use time-series regression analysis. This paper contributes to the above literature in two aspects. First, it exploits a different approach to analysis, providing a pattern of the evolution of cross-region price distribution. Second, it studies the Russian food market (more exactly, market for staples) in 2001–2010.

The rest of the paper is organized as follows. In Sect. 2, the data and methodology used for the analysis are described. Section 3 provides a brief overview of price dynamics prior to 2001 in order to make guesses regarding further evolution. Section 4 reports results obtained for 2001–2010. The final section summarizes the findings and contains concluding remarks.

2 Data and methodology

The spatial sample covers 79 regions, i.e. all regions of Russia except for the Chechen Republic (lacking statistical data on prices). This sample is referred to as 'Russia as a whole'.

Russian regions are very heterogeneous from the economic geographical viewpoint. To take this into account, empirical analysis is performed also over subsamples of regions. The first one contains 73 regions and represents Russia excluding difficult-to-access regions. These are the Murmansk Oblast, Republic of Sakha (Yakutia), Sakhalin Oblast, Magadan Oblast, Kamchatka Oblast, and Chukchi Autonomous Okrug. They are remote regions lacking (except the Murmansk Oblast) railway and highway—at least, year-round—communication with other regions. Therefore these regions feature the highest consumer prices in the country. Besides, goods arbitrage can hardly be bilateral there, consumer goods being imported only in these regions. This results in a different pattern of price behaviour than in the rest of Russia. Thus, it is reasonable to consider spatial price dynamics, eliminating difficult-to-access regions.

Another subsample represents the European part of Russia excluding its northern territories (the Arkhangelsk Oblast, Murmansk Oblast, and Republic of Komi); it is hereafter referred to simply as 'European Russia'. This subsample contains 54 regions. As the transport infrastructure is more developed in this part of the country, and regions are closer to one another, one might a priori expect European Russia to be more integrated than the remainder of the country and the price behaviour to differ from that in the rest of Russia.

The cost of a staples basket is used as a price representative for the analysis. This basket was introduced by the Russian statistical agency, Rosstat (formerly Goskomstat), in 2000. It includes 33 foods. Rosstat (2006, p. 161) describes the composition of the staples basket. The monthly data on the cost of the staples basket by region are drawn from the online statistical database, Rosstat (2013). To eliminate inflation, the empirical analysis deals with the relative cost of the staples basket, i.e. the cost normalized to the national one (which is a weighted average over all regions) for the same month. The analysis uses annual prices as well. They are computed as the geometric averages of monthly relative prices in the respective years.

Let p_{rt} denotes the relative cost of the staples basket (for brevity, simply price or relative price hereafter) in region r ($r = 1, \ldots, R$) in period t; P_{rt} stands for its logarithm, $P_{rt} = \log(p_{rt})$. The first issue is whether regional prices converge (or diverge) over time. A simple testable version is widely known as σ-convergence. Regional prices are deemed converging if their cross-sectional dispersion tends to decrease over time from t to some $t + \tau$: $D(p_{t+\tau})/D(p_t) < 1$, where $D(\cdot)$ is a measure of price dispersion (e.g. the standard deviation of log prices, $\sigma(\log(\cdot)) = \sigma(P_\cdot)$, Gini coefficient, $G(\cdot)$, etc.) over $r = 1, \ldots, R$, and τ can be one or more months or years.

Being merely one of characteristics of the price distribution, the evolution of price dispersion provides rather poor information on features of price dynamics. In particular, σ-convergence can be consistent with the case of price convergence within two (and more) region clusters without convergence to the national-market price. Such a fact would imply that there are 'price convergence clubs' among regional markets, an analogue of convergence clubs in economic growth (see, e.g. Barro and Sala-i-Martin 2004).

To reveal more detailed properties of the evolution, the behaviour of the entire distribution of regional prices, $f_t(P_t)$, is analysed. The cross-sectional distributions are nonparametrically estimated in a number of points in time with the use of a kernel density estimator

$$\hat{f}_t(P_t) = \frac{1}{Rh}\sum_r K\left(\frac{P_t - P_{rt}}{h}\right). \tag{1}$$

The Epanechnikov kernel is adopted: $K(x) = 0.75(1 - x^2)$, if $x \in [-1, 1]$, otherwise $K(x) = 0$; $h = 0.9 \cdot 15^{0.2} \cdot (4\pi)^{0.1} \cdot R^{-0.2} \cdot \min(\hat{\sigma}, (Q_{0.75} - Q_{0.25})/1.34)$ is the smoothing bandwidth (Silverman 1986; Marron and Nolan 1988), where $Q_{0.75}$ and $Q_{0.25}$ are quartiles of the distribution. Judging from unimodality or multimodality of the distribution, the question of whether there are price convergence clubs is to be answered.

Having estimated such a sequence of the distributions, the transition process between them, i.e. price mobility of regions (or, equivalently, intra-distribution dynamics), is analysed. In doing so, two concepts of mobility are exploited, rank mobility and quantity mobility. In the literature they sometimes are referred to as relative mobility and absolute mobility, respectively. However, these terms are ambiguous: in some other publications, they relate to measuring mobility with the use of relative or absolute indicators. Rank mobility concerns changes in ranking of regions by price level, i.e. the concern here is only with shifts of regions relative to one another. Quantity mobility concerns changes in regions' price levels themselves. That is, the interest here is with shifts of regions along the price axis irrespective of their relative positions.

Yitzhaki and Wodon (2004) propose to measure rank mobility by the Gini symmetric index of mobility:

$$S_t = \frac{G_t M_{t+\tau,t} + G_{t+\tau} M_{t,t+\tau}}{G_t + G_{t+\tau}}, \tag{2}$$

where $M_{t,t+\tau} = (1 - \Gamma_{t,t+\tau})/2$ and $M_{t+\tau,t} = (1 - \Gamma_{t+\tau,t})/2$ quantify mobility forward and backward in time (for easier interpretation, the original indexes are divided by 2). In turn, Γ is the Gini correlation coefficient:

$$\Gamma_{t,t+\tau} = \frac{\text{cov}(p_t, g(p_{t+\tau}))}{\text{cov}(p_t, g(p_t))}, \quad \Gamma_{t+\tau,t} = \frac{\text{cov}(p_{t+\tau}, g(p_t))}{\text{cov}(p_{t+\tau}, g(p_{t+\tau}))},$$

where $g(p_t)$ represents ranks of regions in ascending prices, i.e. $g(p_{rt}) = g_{rt}$ is region's number in the sequence of regions sorted by ascending p_{rt}.

It is readily seen that $\Gamma \in [-1, 1]$ and $S_t \in [0, 1]$. The greater the S_t, the higher the rank mobility, while the smaller (in the algebraic sense) the Γ, the higher the mobility. No mobility occurs if $S_t = 0 (\Gamma_{t,t+\tau} = \Gamma_{t+\tau,t} = 1)$. With $S_t = 1 (\Gamma_{t,t+\tau} = \Gamma_{t+\tau,t} = -1)$, mobility is 'perfect', i.e. there is a total reversal in the ranks. When p_t and $p_{t+\tau}$ are statistically independent, there is no Gini correlation: $\Gamma_{t,t+\tau} = \Gamma_{t+\tau,t} = 0$; in that case, $S_t = 0.5$, implying random mobility.

Indexes Γ, hence, S_t, are not sensitive to monotonic transformations of distribution at t and $t+\tau$. Such a transformation can be some decreases or increases in inter-regional price gaps, suggesting price convergence or divergence. The absence of rank mobility indicates only the fact that the order of regions along the price axis has remained unchanged. But given this, the absolute positions of regions on this axis could have changed, e.g. 'price distances' between regions have decreased. Such changes are characterized by quantity mobility.

To analyse quantity mobility of regions, a methodology put forward by Quah (1996) is exploited. It considers the evolution of, in our case, prices as a homogeneous Markov process with discrete time and continuous state space; price classes being the states. Let $M(P_t^{(i)}, P_{t+\tau}^{(j)})dP$ be the fraction of regions being in (infinitesimal) price class i with prices from $P^{(i)}$ to $P^{(i)} + dP$ at t, and in price class j with prices from $P^{(j)}$ to $P^{(j)} + dP$ at $t + \tau$. Covering all classes, $P \in (-\infty, \infty)$, $\mathbf{M}$ is an operator mapping the price distribution from period t to period $t + \tau$:

$$f_{t+\tau}(P_{t+\tau}) = \mathbf{M} \cdot f_t(P_t). \tag{3}$$

This operator is a stochastic kernel or a transition probability function which is a generalization of the transition probability matrix. ($\mathbf{M}$ may be viewed as such a matrix with continuous, hence infinite, number of rows and columns.) It is readily seen that the transition function is a probability density of prices at $t+\tau$ conditional on prices at t : $\mathbf{M} = f(P_{t+\tau}|P_t)$. Then we can rewrite (3) as $f_{t+\tau}(P_{t+\tau}) = \int_{-\infty}^{\infty} f(P_{t+\tau}|P_t) f_t(P_t) dP_t$.

The stochastic kernel is estimated in a way similar to that used for the univariate distributions; see (1):

$$\hat{f}(P_{t+\tau}|P_t) = \frac{\frac{1}{Rh^2} \sum_r K\left(\frac{P_{t+\tau} - P_{r,t+\tau}}{h}\right) K\left(\frac{P_t - P_{rt}}{h}\right)}{\hat{f}_t(P_t)}. \tag{4}$$

The numerator in (4) is the estimate of the joint distribution of P_{t+t} and P_τ, and the denominator is the estimate—by Formula (1)—of the marginal distribution; $h = \max(h_t, h_{t+\tau})$.

Under the assumption of time invariance of the transition function, i.e. of the underlying transition mechanism, the application of transformation (3) n times yields a distribution for $t + n\tau$, that is, $f_{t+n\tau}(P_{t+n\tau}) = \mathbf{M}^n \cdot f_t(P_t)$. Taking $n \to \infty$ yields the ergodic distribution, $f_\infty(P)$, i.e. such that $f_\infty(P) = \mathbf{M}^\infty \cdot f_\infty(P)$, where $\mathbf{M}^\infty = f(P_{t+\infty}|P_t)$ is the limit of $\mathbf{M}^n = f(P_{t+n\tau}|P_t)$ with $n \to \infty$. The ergodic distribution is the long-run limit of the price distribution. 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.

With sufficiently great n, $\mathbf{M}^n$ approximates $\mathbf{M}^\infty$. Numerically integrating (a 101 × 101 grid is used in this study) in relationship

$$f(P_{t+n\tau}\big|P_t) = \int\limits_{-\infty}^{\infty} \ldots \int\limits_{-\infty}^{\infty} f(P_{t+n\tau}\big|P_{t+(n-1)\tau}) \ldots f(P_{t+2\tau}\big|P_{t+\tau}) f(P_{t+\tau}\big|P_t) dP_{t+(n-1)\tau} \ldots dP_{t+\tau} dP_t$$

yields an estimate of $\mathbf{M}^n$. Since $\mathbf{M}^\infty$ degenerates into $f(P_{t+\infty}\big|P_t^{(i)}) = f(P_{t+\infty}\big|P_t^{(j)})$ for each pair $P_t^{(i)}$ and $P_t^{(j)}$, the fulfilment of this condition accurate to 10^{-3} is used as a criterion of convergence of $\mathbf{M}^n$ to $\mathbf{M}^\infty$.

3 Prehistory: consumer prices in Russia in the 1990s

Prior to considering the decade of 2001–2010, it is instructive to take a brief look at what was going on before. In the Soviet times, the overwhelming part of consumer prices was centrally fixed so that they were uniform across all regions of the country or so-called price belts (for certain goods). In January 1992, prices in Russia were liberalized (decontrolled). Therefore significant attention of economists to spatial price dynamics following the price liberalization is no surprise, since it was a kind of natural experiment on transition from planned to market pricing.

By 1992, huge excess demand accumulated, which resulted in dramatic rise in prices; inflation was equal to 245 % in January 1992 (Goskomstat 1995). Albeit rising prices rapidly eliminated this excess demand, wages were rising under the pressure of employees, thus sustaining the wage-price spiral; annual inflation in 1992 reached 2509 % (Goskomstat 1995). As both the initial excess demand and the wage-price spiral varied greatly across regions of the country, the rise in prices was highly geographically heterogeneous. Koen and Phillips (1993) document huge and rising over time spatial prices dispersion in Russia in that time. Although price divergence continued further during the early 1990s, economists believed that this trend should have turned to the opposite direction and sought for signs of such a turn. Gardner and Brooks (1994), De Masi and Koen (1996), Berkowitz et al. (1998), and Goodwin et al. (1999) found the Russian market to be poorly integrated, albeit they revealed week evidences of price convergence among some goods and location groups.

Their belief was based on that as pricing had become market one, then the law of one price should have come into play. It states that if there are no barriers to trade between locations, then the prices for (tradable) goods should be uniform across all locations. A weaker and more realistic version of the law allows for ‘natural’ barriers, namely physical distances. Then prices may differ across locations by (at most) transportation costs. An economic mechanism behind the law of one price is goods arbitrage. However, the law contains an implicit prerequisite: market institutions that are able to maintain arbitrage should exist. No such institutions were in Russia in the beginning of the 1990s; the wholesale trade and the most part of retail trade were state-owned; besides, available (to potential arbitrageurs) information on prices in different parts of Russia was scrappy, if any.

As market institutions were emerging due to mass privatization and market self-organization, the situation, indeed, changed. Results due to Berkowitz and DeJong (2001) cover 1995–1998; they suggest a prevailing trend to improvement in market integration, although with substantial fluctuations of the degree of market integration during that period. Gluschenko (2004), benefiting from Quah (1996), estimates the stochastic kernel describing transition of cross-region price distribution in 1994 to that in 2000; the results obtained unambiguously evidence price convergence.

However, significant ‘artificial’ barriers to inter-regional trade did exist in the second half of the 1990s. Berkowitz and DeJong (1999) find a group of regions denoted as the Red Belt that has impeded market integration in the country because of anti-reform attitude of their governments. This gave rise to an internal border that separated the Red Belt from the rest of Russia, its impact on price dispersion being comparable to the impact of the US–Canadian border. Gluschenko (2010a) estimates the role of various trade barriers in segmentation of the Russian market during 1992–2000. ‘Natural’ barriers (spatial disconnectedness of regions) are found to be responsible for about 70 % of the average cross-region price differential, while the rest is caused by ‘artificial’ barriers such as regional protectionism, organized crime, and intra-region shipping conditions (as well as unidentified barriers). The role of ‘artificial’ barriers diminished in the last years of the period under consideration; nonetheless, it remained significant, providing more than 20 % of the price differential in 2000.

Therefore the further evolution in the 2000s is a priory unclear. Three options can be equally well expected. First, ‘artificial’ barriers to inter-regional trade are vanishing or, at least, lowering, which manifests itself in price convergence. Second, no changes occur in the Russian consumer market; then, the cross-region price distribution remains approximately the same as that observed by 2001. Third, transportation tariffs rising faster than consumer prices may cause price divergence; the same effect is possible if some ‘artificial’ barriers—especially among those remained unidentified in Gluschenko’s (2010a) study—increase. Certainly, the pattern may be mixed, different trends predominating in one or other duration within 2001–2010.

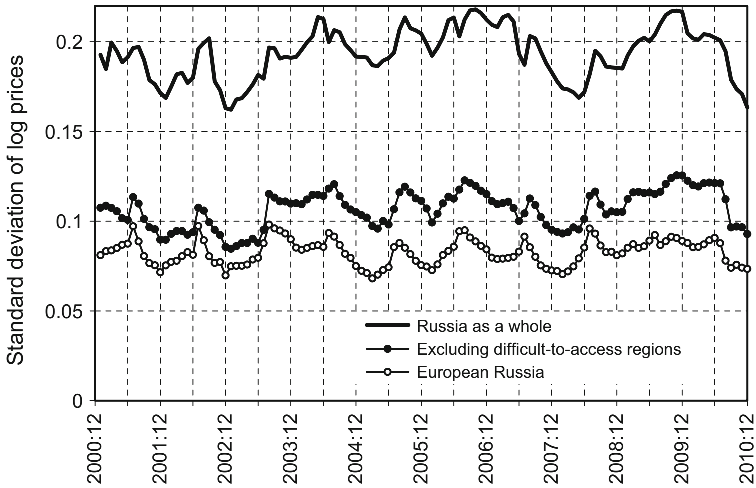

Fig. 1 The evolution of inter-regional price dispersion

4 Results

4.1 Price dispersion and the shape of price distribution

Turning to the 2000s, let us first take a look at price dispersion. Figure 1 plots the dynamics of price dispersion measured as $\sigma_t = \sigma(P_t)$, the cross-sectional standard deviation of log relative prices. As expected, the maximum price dispersion takes place over all regions (with the time average of 0.19). The 95 % confidence interval is $[0.87\sigma_t, 1.19\sigma_t]$, not overlapping with the confidence intervals of σ_t in two other subsamples. The exclusion of difficult-to-access regions crudely halves price dispersion, reducing the average to 0.11. At last, European Russia yields the minimum price dispersion, with the average of 0.08. The 95 % confidence interval of price dispersion is $[0.87\sigma_t, 1.20\sigma_t]$ for Russia excluding difficult-to-access regions and $[0.85\sigma_t, 1.25\sigma_t]$ for European Russia. Since the paths of σ_t in these subsamples are close to each other, the respective confidence intervals overlap, not rejecting the hypothesis of equality of price dispersion between these two subsamples.

Figure 1 suggests that the dispersion paths are fairly stable, fluctuating around some constant levels (in particular, no pronounced effects of the global crisis are seen on the paths). As the augmented Dickey–Fuller test suggests, all the three series σ_t are stationary (p-value of the test equals 0.041 for Russia as a whole, 0.025 for Russia excluding difficult-to-access regions, and 0.001 for European Russia). Estimates of price dispersion on the annual basis corroborate its approximate time invariance. They are depicted in Fig. 2.

To gain further insight into the behaviour of regional prices in Russia, let us consider changes in the shape of the cross-region price distribution over time. To assess these changes, probability densities have been nonparametrically estimated using Formula (1) for each year from 2001 to 2010. Figure 3 depicts the distributions for the

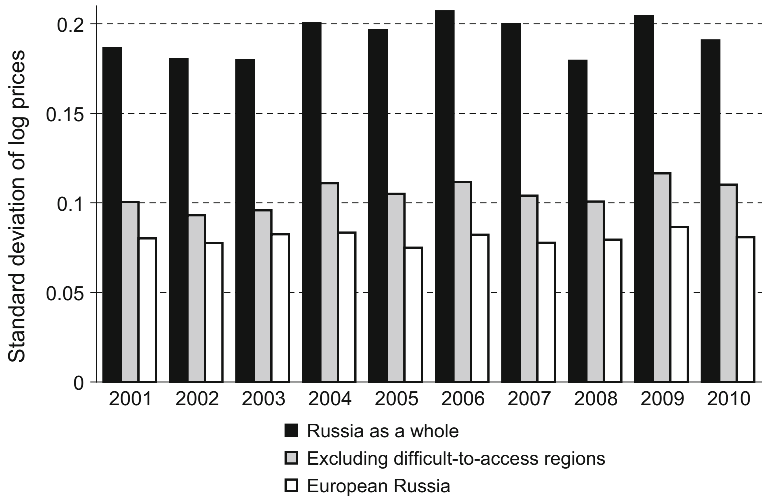

Fig. 2 Inter-regional price dispersion by year

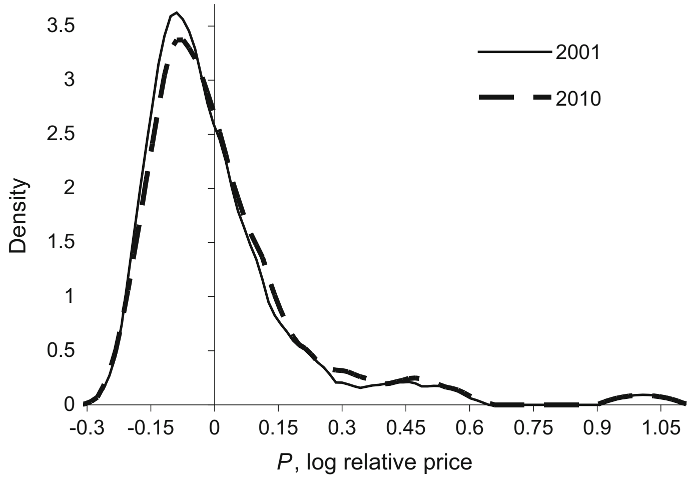

Fig. 3 Estimates of (log) price distributions over Russia as a whole

initial and final years. The distributions in intermediate years are very close to them and are not therefore reported.

Some features of the cross-region distribution of prices in Russia are seen in this figure. The rightmost small mode is due to the only region, the Chukchi Autonomous Okrug, the most expensive region of the country. The cost of the staples basket fluctuated here in the band of 264–327 % of the national average in 2001–2010. The heavy right-hand tail of the distribution, circa from $P = 0.3$ to $P = 0.6$ (or 135–180 % of the national average), comprises of Far-Eastern difficult-to-access regions with prices from 147 to 174 % of the national average: the Republic of Sakha (Yakutia), Sakhalin Oblast, Magadan Oblast, and Kamchatka Oblast. A gap between the left end of this group and the adjacent region was 20 percentage points in 2001. In 2010, two more

Table 1 Spurious-mode check

Year	h	l	The height of the rightmost mode
2001	0.103	0.139	0.092
2002	0.101	0.141	0.094
2003	0.106	0.134	0.089
2004	0.121	0.117	0.078
2005	0.111	0.129	0.086
2006	0.121	0.118	0.079
2007	0.113	0.126	0.084
2008	0.109	0.131	0.087
2009	0.119	0.120	0.080
2010	0.107	0.133	0.089

Far-Eastern regions entered into this group, the Khabarovsk Krai and Primorsky Krai. The left end of the group became at 134 % of the national average, the gap shrinking to 5 percentage points.

To be rigorous, the role of the small mode in the area of the highest prices is to be checked. Cheng and Hall (1998) suggest to count only those modes of height greater than $l = 1.5K(0)/Rh$, considering lower modes as spurious. Table 1 reports results of applying this suggestion to each yearly distribution ($K(0) = 0.75$ for the Epanechnikov kernel). For all years, the height of the mode under consideration is less than l. Thus, the rightmost small peak in the distributions is in fact an outlier rather than a mode. Hence, the cross-region distribution of prices is unimodal, suggesting the absence of price convergence clubs. Nevertheless, there is an anxious tendency of Far-Eastern regions to concentrate in the right-hand tail of the distribution. Over 2001–2010, relative prices in the Russian Far East rose, while they fell in neighbouring Eastern Siberia. This potentially can lead to that the Russian Far East will become a price convergence club, so fragmenting the Russian goods market.

Since the changes in the shape of the price distribution over time prove to be minor, their statistical significance is to be tested. To test the hypothesis of stability of the cross-region price distribution over time, the two-sample Kolmogorov–Smirnov test is implemented, applying it to each pair of the annual distributions. Table 2 tabulates the results of testing, reporting p-values of the null hypothesis that the samples are drawn from the same distribution (i.e. that two given price distributions are identical).

As Table 2 suggests, the null hypothesis is highly significant in all pairwise comparisons (the minimum significance level across the table equals 32 %). Thus, it may be concluded that the cross-region price distribution in Russia remained very stable during 2001–2010 (moreover, the hypothesis cannot be rejected that the distribution remained the same over years).

4.2 Rank mobility of regions

Let us turn to the analysis of intra-distribution mobility, starting with rank mobility. To blend prices in with the context of the methodology applied, price differences between

Table 2 Comparisons of annual (log) price distributions: the Kolmogorov–Smirnov test p-values

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
2001	0.813	0.977	0.997	0.997	0.977	0.916	0.428	0.813	0.813
2002		0.997	0.551	0.916	0.322	0.813	0.551	0.684	0.813
2003			0.916	1.000	0.684	0.997	0.813	0.813	0.977
2004				0.916	0.997	0.916	0.684	0.977	0.916
2005					0.916	0.977	0.551	0.916	0.977
2006						0.916	0.684	1.000	0.813
2007							0.813	0.977	1.000
2008								0.813	0.551
2009									0.997

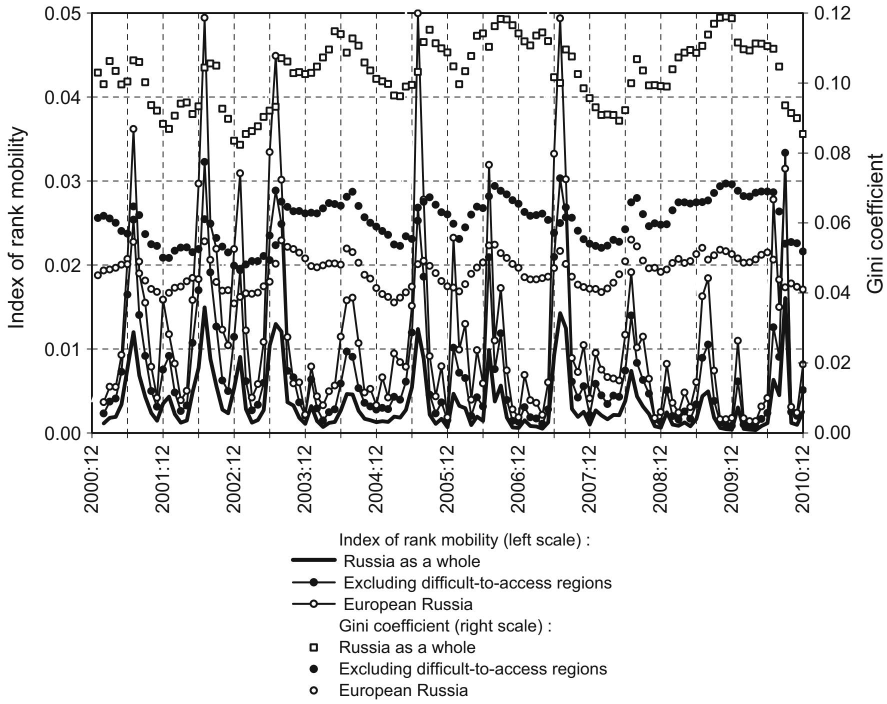

Fig. 4 Rank price mobility of Russian regions and their 'price inequality'

regions are interpreted as their 'price inequality'. It is measured by the Gini coefficient, G_t. In fact, G_t is an alternative measure of price dispersion. Figure 4 plots monthly (i.e. with t measured in months and $\tau = 1$ month) Gini symmetric index of mobility, S_t, computed by Formula (2) versus 'price inequality' (price dispersion). It is worth noting that the behaviour of G_t in Fig. 4 and σ_t in Fig. 1 is similar; being rescaled, the paths of G_t and σ_t almost coincide.

Rank mobility proves to be very low. Its time average equals 0.0035 in Russia as a whole, 0.0074 in Russia excluding difficult-to-access regions, and 0.0117 in European Russia (recall that the range of S_t is [0, 1]). In contrast to price dispersion, relative mobility rises when we pass to more narrow subsamples. This implies that the price ranks of difficult-to-access regions are fairly stable, as might be expected, and that changes in ranks of Siberian and Far-Eastern regions are less than in regions of the European part of the country. Figure 4 suggests that there is a connection between changes in price dispersion and relative price mobility of regions. Indeed, the correlation coefficient between $|(G_{t+\tau} - G_t)/G_t|$ and S_t is equal to 0.49 in Russia as a whole, 0.64 in Russia excluding difficult-to-access regions, and 0.67 in European Russia. The correlation is greater with the increase in price dispersion (positive $(G_{t+\tau} - G_t)/G_t$), equalling to 0.54, 0.72, and 0.78 across the respective spatial samples, while it equals to −0.40, −0.47, and −0.40 in the case of the decrease in price dispersion.

Qualitatively, the behaviour of S_t (as well as G_t) across spatial samples is very similar. Upsurges of mobility occur at regular intervals, having peaks, as a rule, about July of each year. Lesser peaks occur, for the most part, about Januaries. They thus seem to be a seasonal phenomenon. In summer, the rate of rise in prices for many items covered by the staples basket decreases dramatically, not infrequently to negative values. This process is asynchronous across regions, depending on natural conditions in a given region and its agricultural specialization. As a consequence, sufficient changes in the region ranks happen; then, the ranking returns to its original (or close to original) state within a few months. During 2001–2010, inflation was higher in Januaries than in other months, inflation rates significantly differing across regions. This also resulted in changes in the price ranking of regions.

A possible reason for low rank mobility might be the fact that transitions for very short run are considered. Usually, the distribution of prices changes more or less gradually, and so, monthly changes could be rather small. It might be expected that mobility over longer transitions can turn out to be considerable. To verify this, the index of relative mobility is computed for longer time spans, one to nine years. Table 3 (where both t and τ are measured in years) presents the results.

Indeed, the rank mobility tends to be the higher, the longer the transition. For annual transitions, S_t has averages of 0.0063, 0.0132, and 0.0191 for respective spatial samples, being 1.6–1.8 times as high as the averages of monthly transitions. Nonetheless, mobility remains rather low even in the transition over the whole time span, 2001–2010. Interestingly, the nine-year mobility index is approximately twice as high in Russia excluding difficult-to-access regions and three times as high in European Russia as compared to Russia as a whole. Over 2001–2010, about a half of regions changed their ranks by no more than 8 with the maximum (10.1 %) at 4; 6.3 % of regions did not change their ranks. In general, the majority of regions that had been 'cheap' (with prices below the Russian average) in 2001 remained such in 2010; for the most part, the situation did not change for 'expensive' regions as well.

Rank mobility in 1994–2000 reported in Gluschenko (2010b) for Russia as a whole was significantly higher. The average over annual transitions equalled to 0.0165; the 1994–2000 transition yielded 0.047 (as compared to the average over six-year transitions in Table 3 being equal to 0.027). It should be noted that these results and the above-presented ones are not fully comparable, since Gluschenko (2010b) uses a dif-

Table 3 Rank price mobility of Russian regions over different time horizons

τ (years)	t	$t+\tau$	Russia as a whole		Excluding difficult-to-access regions		European Russia	
			$G_{t+\tau}/G_t$	S_t	$G_{t+\tau}/G_t$	S_t	$G_{t+\tau}/G_t$	S_t
1	2001	2002	0.945	0.009	0.916	0.020	0.942	0.024
	2002	2003	1.009	0.007	1.044	0.015	1.081	0.021
	2003	2004	1.143	0.009	1.163	0.018	1.043	0.019
	2004	2005	0.965	0.004	0.932	0.009	0.891	0.017
	2005	2006	1.068	0.006	1.077	0.013	1.112	0.014
	2006	2007	0.955	0.004	0.931	0.008	0.943	0.012
	2007	2008	0.905	0.007	0.976	0.016	1.042	0.028
	2008	2009	1.158	0.005	1.147	0.011	1.089	0.019
	2009	2010	0.925	0.005	0.940	0.010	0.926	0.019
2	2001	2003	0.954	0.015	0.956	0.033	1.018	0.054
	2002	2004	1.153	0.015	1.214	0.031	1.127	0.038
	2003	2005	1.103	0.011	1.085	0.023	0.929	0.028
	2004	2006	1.031	0.009	1.004	0.020	0.991	0.031
	2005	2007	1.020	0.006	1.003	0.012	1.049	0.020
	2006	2008	0.864	0.010	0.908	0.020	0.983	0.033
	2007	2009	1.048	0.006	1.120	0.013	1.135	0.021
	2008	2010	1.071	0.012	1.079	0.024	1.008	0.041
3	2001	2004	1.090	0.018	1.112	0.038	1.062	0.064
	2002	2005	1.113	0.016	1.132	0.034	1.004	0.047
	2003	2006	1.178	0.017	1.169	0.035	1.034	0.040
	2004	2007	0.984	0.012	0.935	0.024	0.935	0.045
	2005	2008	0.923	0.013	0.979	0.027	1.093	0.042
	2006	2009	1.001	0.010	1.042	0.021	1.070	0.033
	2007	2010	0.969	0.012	1.053	0.023	1.050	0.038
4	2001	2005	1.052	0.025	1.037	0.052	0.946	0.093
	2002	2006	1.189	0.021	1.220	0.046	1.117	0.050
	2003	2007	1.125	0.020	1.087	0.042	0.975	0.059
	2004	2008	0.891	0.015	0.912	0.030	0.974	0.044
	2005	2009	1.069	0.011	1.123	0.022	1.190	0.034
	2006	2010	0.926	0.017	0.980	0.035	0.990	0.050
5	2001	2006	1.124	0.023	1.117	0.049	1.053	0.079
	2002	2007	1.135	0.024	1.135	0.051	1.053	0.073
	2003	2008	1.018	0.026	1.061	0.053	1.016	0.067
	2004	2009	1.032	0.017	1.047	0.034	1.060	0.055
	2005	2010	0.989	0.014	1.056	0.028	1.101	0.046
6	2001	2007	1.073	0.029	1.040	0.062	0.993	0.107
	2002	2008	1.027	0.030	1.108	0.062	1.097	0.077

Table 3 continued

t (years)	t	$t+t$	Russia as a whole		Excluding difficult-to-access regions		European Russia	
			G_{t+t}/G_t	S_t	G_{t+t}/G_t	S_t	G_{t+t}/G_t	S_t
	2003	2009	1.179	0.026	1.218	0.053	1.106	0.078
	2004	2010	0.954	0.022	0.984	0.044	0.981	0.073
7	2001	2008	0.971	0.031	1.015	0.064	1.034	0.097
	2002	2009	1.190	0.031	1.271	0.065	1.195	0.096
	2003	2010	1.091	0.031	1.145	0.062	1.024	0.093
8	2001	2009	1.124	0.037	1.164	0.078	1.126	0.134
	2002	2010	1.100	0.037	1.195	0.076	1.106	0.114
9	2001	2010	1.040	0.045	1.095	0.094	1.042	0.160

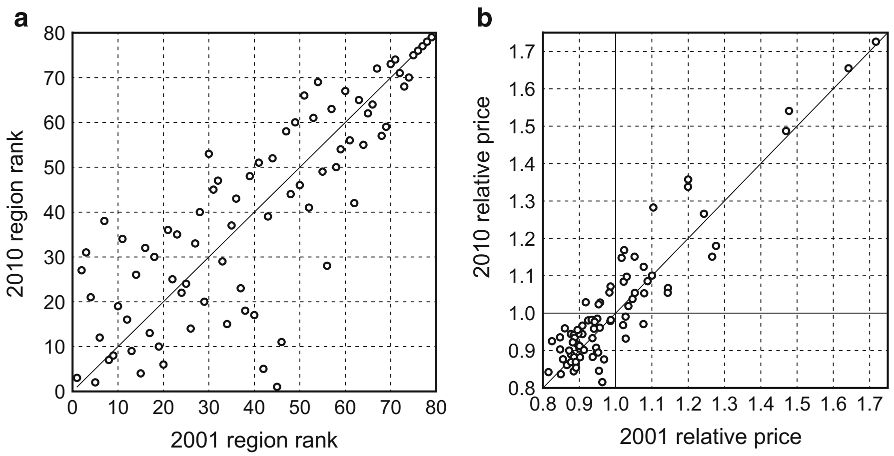

Fig. 5 **a** Scatter plot of ranks. **b** Scatter plot of prices

ferent staples basket (containing 25 foods) and a bit narrower region sample. In regard to the general pattern of rank mobility in 1994–2000, it is qualitatively similar to that in 2001–2010, suggesting that 'cheap' and 'expensive' regions for the most part remain such over time.

Figure 5 provides a better insight into the pattern of rank price mobility of regions and compares it with quantity mobility. All regions are present in this figure, except for the outlier of the Chukchi Autonomous Okrug (with the relative price about 2.7) which is omitted in Figure 5b. The diagonals in Figure 5 are immobility lines. The scatter plot of ranks, Figure 5a, suggests a mixed pattern of rank mobility. In the quadrant with ranks from 1 to 40, mobility is similar to random mobility. In the quadrant of 41–80, the ranks are concentrated in a band around the immobility line; the band borders can be crudely deemed to be parallel to this line. The last five regions here (all difficult-to-access regions, excluding the Murmansk Oblast, with ranks 75–79) lie on the immobility line.

The prices themselves—Fig. 5b—behave in quite different manner, concentrating around the immobility line. This implies neither convergence nor divergence of prices among Russian regions. A difference in ranks by 1 was equivalent to a difference in the relative cost of the staples basket by, on average, 0.012 both in 2001 and 2010 (the outlier excluded); that is, the average distance between regions on the price axis remained stable. The average change in ranks over 2001 to 2010 is 10.3, while the average absolute change in prices, $|p_{r,2010} - p_{r,2001}|$, is 0.052. However, the regions are not distributed on the price axis evenly. Many regions are close to one another on this scale, so that less than a 1 % change in region's price can cause a change in its rank by up to 10. This sheds light on the pattern of rank mobility. For the most part, it is due to regions with close prices (which concentrate in Fig. 5b in the area with relative prices below 1). A change in rank by a few units implies a small change in the relative price, so that clusters of 'cheap' and 'expensive' regions remain generally the same.

4.3 Quantity mobility of regions

This part of the analysis is performed only for Russia as a whole. To analyse quantity mobility, the stochastic kernel approach is used. A usual way of estimating stochastic kernel is to take the transition from the initial period to the final one. In our case, it is $\mathbf{M}_a = f(P_{t+\tau}|P_t) = f(P_{2010}|P_{2001})$. However, such a way possesses two shortcomings. First, there may be accidental differences in the shape of the distributions, which potentially could bias the law of motion as compared to the 'true' one and distort the ergodic distribution (long-run forecast of the price distribution). Second, we lose information on the evolution of the distribution within the time span under consideration.

To benefit from this information and to smooth random deviations, one more stochastic kernel is estimated with the use of all annual transitions. In this estimate, the more distant is a transition from the final period, the lesser importance is attached to it. Namely, the estimate of the stochastic kernel is a weighted average of year-to-year estimates:

$$\mathbf{M}_b = f(P_{2002}|P_{2001}) \cdot 1/45 + f(P_{2003}|P_{2002}) \cdot 2/45 + \cdots + f(P_{2010}|P_{2009}) \cdot 9/45.$$

Both estimates of $\mathbf{M}$ omit the outlier of the Chukchi Autonomous Okrug to make the stochastic kernels well defined. The point is that, as Fig. 3 suggests, the event $0.65 < P < 0.90$ (in 2001; it is somewhat different in other years) is of zero probability; hence, $f(P_{t+\tau}|P_t)$ is indeterminate on this interval of the conditioning variable.

Figure 6 shows three-dimensional plots of estimates of $\mathbf{M}_a$ and $\mathbf{M}_b$. A line projected from a fixed P_t, parallel to the $P_{t+\tau}$ axis, characterizes probability to transit to particular values of prices at $t + \tau$, given the value of the price at t. That is, a respective plane, orthogonal to the price plane, cuts the surface of the stochastic kernel; this cross section is a probability density of the price having had a given value at the initial period. Thus we can see the movement of different parts of the price distribution over time.

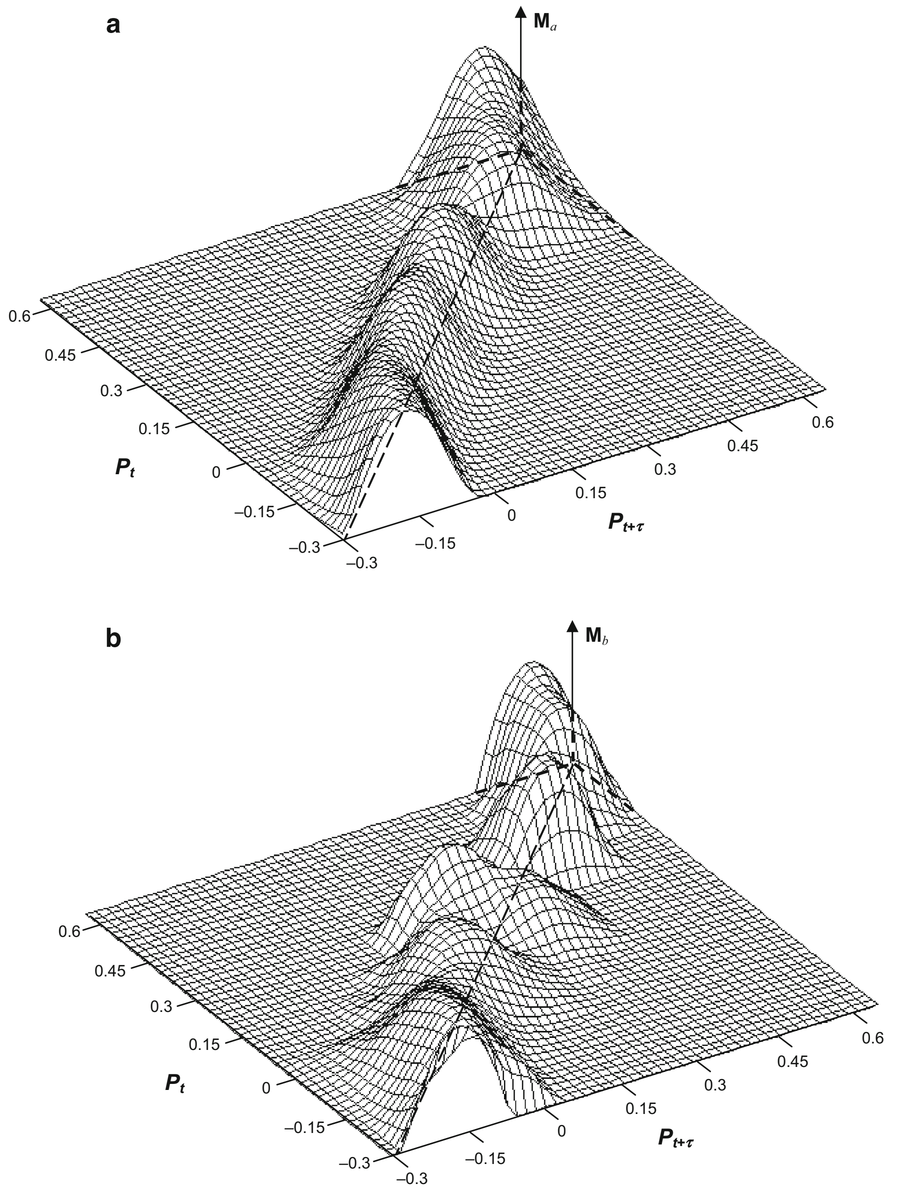

Fig. 6 Stochastic kernels. **a** Estimated with the use of the nine-year transition from 2001 to 2010. **b** Estimated with the use of nine yearly transitions

The dashed line in the figures marks the diagonal which is an immobility line (the line of equal prices at t and $t + \tau$). If most of the probability mass concentrates along this line, this evidences low quantity mobility, indicating a tendency of prices to remain unchangeable. A stochastic kernel with a ridge parallel to the $P_{t+\tau}$ axis indicates random mobility: a future position of a region on the price axis does not depend on its initial position. Perfect price convergence would take place if the stochastic kernel had a ridge parallel to the P_t axis with $P_{t+\tau} = P^*$ and degenerated into the delta function, $\delta(P_{t+\tau} - P^*)$, in each P_t cross section.

Comparing two stochastic kernels in Fig. 6, $\mathbf{M}_a$ looks more 'bumpy' than $\mathbf{M}_b$. This comes as no surprise, since averaging in the latter smoothes accidental distinctions between the yearly price distributions, while such distinctions between distributions for 2001 and 2010 remain as they are in estimating the former. In general, however, both stochastic kernels suggest qualitatively the same pattern. First, we observe rather low quantity mobility in the price distribution, since probability mass concentrates around the diagonal $P_t = P_{t+\tau}$. Second, a peak is observed in the area of high prices; it is more pronounced in $\mathbf{M}_a$. Such a feature of the stochastic kernels is suspicious from the viewpoint of emergence of a convergence club over time.

To discern more details of the price-transition dynamics, it is helpful to view the stochastic kernels 'from above'. Figure 7 provides this top view, demonstrating contour plots, i.e. projections of cross sections of the stochastic kernel by horizontal planes corresponding to densities $\mathbf{M} = 0.5$ and 1 to 7 (to 6 in the case of $\mathbf{M}_b$) on the price plane ($\mathbf{M} = 0$). Differences between the two estimates of the stochastic kernel are much more pronounced than in the three-dimensional plots. Although price distributions for 2001 and 2010 are very similar to each other, as Fig. 3 suggests, and to distributions for the rest years, $\mathbf{M}_a$ and $\mathbf{M}_b$ demonstrate fairly distinct patterns. The former almost breaks up into two parts at point (0.3, 0.3), while $\mathbf{M}_b$ only narrows slightly about point (0.35, 0.35). One may suppose that the area of high prices is a potential location of convergence club, a high one according to $\mathbf{M}_a$, and a small one according to $\mathbf{M}_b$. Except for this, both kernels suggest neither convergence nor divergence of prices, being concentrated along the immobility line.

This fundamentally differs from what is observed in stochastic kernels for 1994–2000 reported in Gluschenko (2004). Their ridges are turned counterclockwise, crossing the immobility line 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. In other words, this means price converge in the country.

An ergodic distribution, $f_\infty(P)$, reveals eventual results of price dynamics, being an estimate of long-run limit of the price distribution. Figure 8 presents ergodic distributions generated by the two estimates of the stochastic kernel and compares it with the actual distribution for 2010. Quah (1996) considers a peak that sits on (or almost on) the 45-degree diagonal as an indication of 'convergence club behaviour'. However, this seems to be not the case. There are five such peaks in $\mathbf{M}_a$ and four peaks in $\mathbf{M}_b$, as Fig. 7 shows. Then one would expect engendering four to five convergence clubs in the long run. But we see only two convergence clubs in the limiting price distributions. Probably, Quah's (1996) statement is due to features of empirical data he deals with. Indeed, his distributions both at t and $t + \tau$ are bimodal, which produces a stochastic kernel with two relevant local maxima. It seems probable that this 'twin-peakedness' will still hold in the long run, but it is impossible to assert for sure, as Quah (1996) does not report the ergodic distribution generated by his stochastic kernel.

The two estimates of the ergodic distribution are quite different. That generated by the stochastic kernel based on averaged yearly transitions is fairly close to the

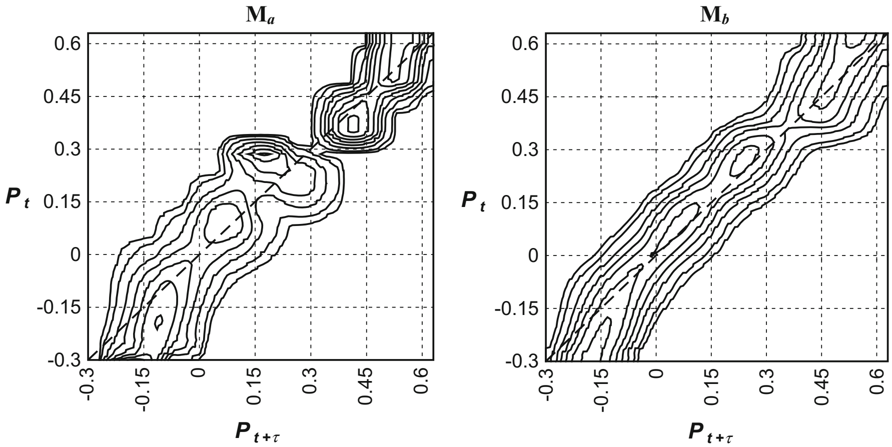

Fig. 7 Stochastic kernels, contour plots at levels 0.5, 1, 2, ..., 7

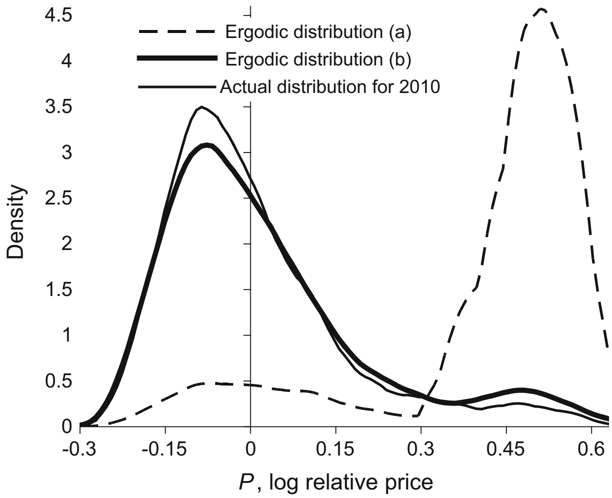

Fig. 8 Long-run limit of the distribution of regional prices. *Note* Ergodic distribution (*a*) is generated by $\mathbf{M}_a$, and ergodic distribution (*b*) is generated by $\mathbf{M}_b$

actual cross-region price distribution for 2010, which implies stability of relative prices across Russian regions. However, a small but important distinction does exist. In the long run, a convergence club in the area of high prices can emerge. Regions in the right-hand tail of the distribution are those from the Russian Far East. This suggests that, under unchangeable price dynamics, the Russian goods market would become fragmented. That is, the market would split up into two internally integrated parts: the Far-Eastern regions and the rest of Russia. The ergodic distribution generated by the stochastic kernel estimated from a single nine-year transition from 2001 to 2010 predicts much more pronounced splitting up into two convergence clubs, the most distribution mass being concentrated in the area of high prices. However, the first pattern seems more probable. First, according to the Kolmogorov–Smirnov test (see Table 2), the differences between price distributions for 2001 and 2010 can be merely random shocks. Second, the applied procedure of estimating ergodic distributions assumes operator **M** to be time invariant. It is inconceivable that this assumption is overly strong. Stochastic kernel $\mathbf{M}_b$ smoothes gradual changes in the law of motion, while $\mathbf{M}_a$ could accumulate them, so distorting the long-run dynamics.

The emergence of the convergence clubs is due to the process noted in Sect. 4.1: the shift of some Far-Eastern regions along the price axis towards the difficult-to-access regions. The stochastic kernels capture such a process; the ergodic distributions reflect its eventual consequences. A possible economic reason may be the rise in transportation costs. The above-mentioned Far-Eastern regions are located along the Trans-Siberian railway, the most part of goods being delivered there by rail. Over 2001–2010, tariffs for goods transportation by rail became higher by a factor of 4.49, while food prices increased by a factor of 'only' 3.09 (calculated from Rosstat 2004, 2008, 2012). Transportation costs make a significant contribution to retail prices in these regions because of their remoteness. Therefore, the fast growth of transportation tariffs might cause prices for staples to rise faster than on average in the country. The first channel of this rise is the increase in the transportation cost component of prices. The second channel is the substitution of domestics by goods imported from abroad (which might get cheaper than domestic goods delivered from far away). Indeed, import of foods from neighbouring counties (mostly from China and Korea) to the Far-Eastern regions of Russia grew during 2001–2010. For example, the import of mutton from Australia proved to be cheaper than from regions westward of the Russian Far East, albeit the price for mutton increased in this case, too.

Unlike the pattern in Fig. 8, ergodic distributions generated by the 1994–2000 stochastic kernels (Gluschenko 2004) suggest no convergence club. Moreover, they predict the heavy right-hand tail of the distribution to shorten.

5 Conclusion

In this paper, the distribution dynamics approach from the fields of income inequality and economic growth has been applied to cross-sectional price dynamics. Such an analysis has revealed interesting features of the behaviour of Russian regional prices over the decade of 2001–2010 that regression analysis can hardly capture.

Results obtained suggest no sizeable changes in the nature of spatial price dynamics in Russia during 2001–2010. Price dispersion proves to be more or less stable during the decade; the shape of the annual cross-region distribution of prices is also similar across years. Rank mobility is found to be very low and stable with seasonal deviations from a more or less constant level. Thus, 'expensive' and 'cheap' regions generally remain such. The pattern of quantity mobility (characterized by stochastic kernels) manifests neither convergence nor divergence of regional prices. However, a long-run price distribution has an unpleasant feature, predicting potential emergence of a price convergence club in the Russian Far East. This implies fragmentation of the Russian market. This process is at a very early stage, though; so this result is not to be overstated.

The pattern obtained dramatically differs from that for 1992–2000. As Gluschenko (2004) finds, prices for staples diverged across Russian regions in the early 1990s and then started to converge. Stochastic kernels estimated over the 1994–2000 data evidence price convergence.

Regarding the evolution of relative prices across regions of Russia, 2001–2010 could be called ‘the decade of stability’. However, given that possibilities for further price convergence have remained by 2001 (‘artificial’ barriers to inter-regional trade noted in Sect. 3), ‘stagnancy’ seems to be a more proper term. Stable price dynamics evidence that no efforts were made to lower these barriers. (Moreover, the evolution of transportation tariffs tended to raise the ‘natural’ barrier.) A striking feature is that the global crisis (which affected the Russian economy circa between the second half of 2008 and the second half of 2010) has not changed the general pattern. The crisis caused devaluation of the Russian national currency, rouble, by about 25 %. Therefore, Russian producers of consumer goods had favourable possibilities for strengthening price competition with producers from other countries, ousting the latter from the Russian market. This would have widened inter-regional trade in the country, which, in turn, decreased cross-region price dispersion. As it is seen from the results obtained, Russian producers did not benefit from these possibilities.

Acknowledgments I am grateful to participants at the 71st International Atlantic Economic Conference (Athens, 2011)—especially to Vasil Zhuk, Second Russian Economic Congress (Suzdal, 2013), and Seminar ‘Market Studies and Spatial Economics’ (Moscow, 2013) for helpful comments and discussions. Special thanks are due to Glenn Sueyoshi from IHS Inc. for his advices on some subtle features of EViews.

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