Regional Cost-of-Living Adjustments Without Price Data: A Non-parametric Approach

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Abstract

Price indexes play a crucial role in the economy of countries. However, price indexes either suffer from potential bias as in the case of consumer price index or they do not exist at all as in the case of cost-of-living index. Therefore, we propose an approach to price indices measurement without prices data. The approach is based on the idea that subjective well-being depends on income, prices and material needs. Given a change in prices, price index is defined as index that eliminates income differences conditional on unchanged well-being and satisfaction of material needs. Empirically, we suggest to apply a matching technique that allows individuals to be matched according to subjective well-being level. Using this approach we construct price indices for Russian regions. A comparison of our price indices and price indices from Statistical Office of Russia proves the feasibility of the approach.

Keywords — Prices; Income Satisfaction; Matching Approach

JEL classification

1 Introduction

It is of particular importance for policy makers as well as researchers to adjust for differences in prices. Ignoring differences might lead to bias in international and interregional analysis and, consequently, to misleading conclusions and policy implications (see Almås (2012)).

However, price indices suffer from potential bias. The traditional way to measure changes in prices is to employ the concept of unchanged basket of goods and services. This concept does not reflect the constantly changing nature of consumption behavior, does not account for introduction of new products and outlets and disappearance of old items in systemic way, and does not account for technological change leads to changes in the quality of goods (for further discussion on bias in price indices see Diewert (1998)).

Furthermore, price indices for cross-regional comparison, that is cost-of-living indices, are frequently not available. Therefore, we propose a method, namely matching method, for estimating price indices without data on prices. Our method is based on the idea that individual subjective satisfaction is a function of income, prices and material needs. Given that, price index is a measure that equalizes income differences, occurred from changes in prices, by keeping subjective well-being unchanged given satisfaction of material needs. Empirically, we apply a matching technique that pairs individuals based on the well-being which is approximated by the satisfaction level. The price index is defined so that it eliminates income differences between paired individuals.

The contribution of our paper is twofold. First, we introduce an innovative approach to estimating price indices without information on prices. Our approach is based on the simple idea of equalizing an individual's utility assigned to income. Price indices are constructed by exploiting information on individual's income, subjective well-being and socio-demographic characteristics that captures material needs. The required data is collected for most of the countries and regions. Furthermore, the matching approach is direct, flexible and non-parametric. It allows price indices to be constructed across time, across space and for individuals of different demographic types including age, educational attainment, employment type, number of children, etc.

Second, by illustrating our approach on data from Russian regions and comparing price indices with the official price indices, we prove feasibility of our method: price indices from the matching approach are very similar to the official indices. We also estimate inequality and poverty and provide evidence for bias in inequality and poverty trends caused by not accounting for differences in the prices. We find that Russia experienced even larger decrease in inequality driven by a decrease in

between-region inequality.

The matching method is related to the Leyden school and the literature on the measurement of equivalence scale, in particular, to the so-called subjective approach (Biewen & Juhasz (2017); Van Praag (1968); Melenberg & van Soest (1995); Bellemare et al. (2002)). We utilize the Leyden's concept of welfare that is derived from income utility in mind, and apply it to the framework of equivalence scale measurement. The subjective approach to equivalence scale and the matching approach construct an estimator that allows incomes of heterogeneous individuals to be compared. However, they differ on conceptual point of view. The subjective approach to equivalence scale aims to account for heterogeneity in household characteristics, such as number of children and adults. While the matching approach aims to account for heterogeneity in prices faced by households. Therefore, the matching approach can be applied to over time and space adjustments. Second, according to the subjective approach to equivalence scale is dependent of reference income. The matching approach compares individuals from different regions without assuming that one region is a reference region. Naturally, there is a reference region, but the price estimates are not sensitive to changes in the reference.

The reminder of the paper is organized as follows. In section 2, we discuss related literature. Section 3 introduces our approach and describes the econometric set-up. Section 4 presents the data, price indices and application to inequality and poverty analysis. Section 5 concludes.

2 Related Literature

We put special emphasis on contributions of the Leyden school and literature on subjective equivalence scale, because they build the theoretical framework of our approach.

The Leyden approach was developed by Van Praag (1968) with the idea that cardinal utility can be measured by utilizing individuals' responses on level of income they consider to be (i) very bad, (ii) bad, (iii) insufficient, (iv) sufficient, (v) good, and (vi) very good. Assuming a lognormal distribution of welfare function, every respondent is assigned to an individual welfare function that takes values from zero to one (for a detailed discussion of this assumption, see Van Praag (1968)). This allows household equivalence scale to be constructed (see Kapteyn & Van Praag (1978); Van Praag & Warnaar (1997)), to measure poverty (see Goedhart et al. (1977); Van Praag et al. (1982); Hagenaars (2014)), to measure inequality (see Van Praag (1977)), and to estimate climate equivalence scale (see Van Praag (1988); Frijters & Van Praag (1998)). It can also be applied to

various economic issue including constructing cost-of-living indices as we do in this paper.

The Leyden approach is based on theoretical assumptions. We discuss the most relevant assumptions for our paper. First, every individual is able to evaluate his own situation and any hypothetical situation if required in relative terms. This implies that the Leyden's welfare concept is derived from the income utility in mind. Additionally, the Leyden approach equalizes concepts of income utility, income satisfaction, and economic welfare. Second, individual's verbal evaluations can be transformed into a meaningful numerical evaluation. And finally, the same verbal response corresponds to the same feeling to every person. We address potential criticism of these assumptions in the following section. For further discussion on the Leyden approach and its validity see Van Praag & Kapteyn (1994); Van Praag & Frijters (1999).

Despite the common theoretical background, our approach is somewhat different in that it employs a direct question on subjective well-being, that is "*How satisfied are you with **your** economic conditions at the present?*". In this way, it is related to studies on subjective equivalence scale (Melenberg & van Soest 1995; Bellemare et al. 2002; van den Bosch 1996). The subjective approach to equivalence scale is an approach that constructs a numeric ratio to equalize the utility assigned to income across heterogeneous households. It is defined as *subjective* because it is based on the concept of subjective welfare. In contrast to the Leyden approach, the literature on the subjective equivalence scale assumes that measuring economic well-being of respondents by asking about their satisfaction with income is sufficient for learning on respondent's welfare function. Equalizing incomes across heterogeneous households leads to equivalence scale estimates, while equalizing incomes across spaces to cost-of-living indices. For a detailed discussion on the validity of the subjective approach to equivalence scale see Biewen & Juhasz (2017).

This paper also contributes to the strand of studies on alternative approaches to price estimations (see Costa (2001); Hamilton (2001); Almås (2012); Coondoo et al. (2011)).The key concept of these studies, the so-called Engel Curve approach, is that any differences in household expenditures of homogeneous households in two different countries are attributed to changes in prices. This approach requires information on quantities and prices of consumed goods. The Engel curve method and the proposed matching approach are similar in their intention to account for bias in official price indies. However, the data on prices and quantities of consumer goods is often not available and, thus the method cannot be applied universally. We propose a method that is flexible and does not require data on prices.

3 Econometric Model

Let the S_i denote subjective satisfaction of individual $i = 1, ..., N$. We assume that subjective satisfaction is a function of income, prices, and material needs, and it takes the following form

$$S_i = U(Y_i; P\_r(i); Z_i) \tag{1}$$

where Y_i is income of individual i, $P\_r(i)$ are prices in region where individual i resides, and Z_i are material needs of individual i that are captured in observable characteristics. This function shows the level of subjective satisfaction that an individual i can achieve at given prices and income conditional on satisfaction of his material needs. Material needs include all aspects that affect cost of living (for example, age, gender, family composition, working status, type of residence and place of residence).

Let us now consider a change in prices from $P\_r(i)$ to $\widehat{P\_r(i)}$. Given this change, we need to define the amount of income necessary to preserve the welfare of individual i. This is addressed by using a deflator. Given this, the subjective satisfaction of individual i after a price change is given by

$$S_i = U(Y_i \times COL; \widehat{P\_r(i)}; Z_i) \tag{2}$$

where COL is a measure of price change in region $r(i)$. COL defines the amount of additional income necessary to maintain an individual's welfare given his material needs Z_i under the new price regime $\widehat{P\_r(i)}$. It represents a relative price change with respect to a reference region. The reference region can either be the same region at a different point of time or another benchmark region.

Empirically, it can be derived by asking an individual about the amount of income needed to obtain the same welfare level under the new price regime. The idea of our approach is to adopt a matching technique that does not involve asking individuals about the amount of income, nor requires constructing the utility function. We argue that the knowledge of two points on the same indifference curve is sufficient to measure price change.

The matching approach runs as follows. Let the S_j denote subjective satisfaction of individual $j = 1, ..., K$ from region $r(j)$. It also takes a function of income and prices given material needs. Individual i from region $r(i)$ is matched with individual j from region $r(j)$ under the following

conditions:

$$\begin{cases} S_i = S_j \\ Z_i \approx Z_j \end{cases} \tag{3}$$

This implies that individuals are matched if they experience the same level of welfare, and posses approximately the same material needs. This matching is performed for all possible pairs of regions. Having done so, an individual is assigned to his actual income and price level as well as to a set of incomes that correspond to different price levels. Following our framework, the price deflator is defined as the estimator such that it eliminates price differences:

$$COL(r(i); r(j)) = \exp\left(\frac{1}{N}\sum(\ln Y_i - \ln Y_j)\right) \tag{4}$$

, where $COL(r(i); r(j))$ is a price index between region $r(i)$ and region $r(j)$. It can be constructed for any pair of regions to correct incomes of individuals from different regions experiencing differences in cost-of-living. In the Appendix A we show how to derive the deflator in details.

This matching technique is flexible in its application. It allows the price deflator to be estimated for geographical units (for example, cities, regions, countries), for heterogeneous individuals and families (for example, for families with and without children, for individual with different educational attainment) and between different time periods without knowledge of the utility function and without data on prices.

Yet, our approach makes a series of important assumptions. First, we assume that every respondent is able to evaluate his situation on a scale from one to five. Second, we assume that verbal responses to subjective question across respondents are comparable, implying that verbal labels convey the same feeling to every respondent. Third, information on observable characteristics of respondents allows noise in satisfaction measure to be controlled. We explore the sensitivity of our approach with respect to the choice of subjective measures and the unit of response in the following section.

Last, we address the question of precisely what prices changes we measure. By looking at the amount of income individuals need to achieve the same subjective welfare, we measure prices changes in traded and non-traded goods. Changes in prices of traded goods are those changes in prices of goods, that can be bought on the market. These prices changes are aimed to be captured by the official statistics with the constant basket of goods and services approach. However, this approach does not capture changes in prices of new goods that are already consumed by individuals,

changes in prices due to introduction of new store types such as on-line stores or discounters, changes in prices due to changes in quality such as improved technical characteristics of cellphones. The matching approach, however, takes into account these changes. Furthermore, it also accounts for price changes in non-traded goods such as possibility of home production, quality of infrastructure, quality of air and water, proximity to larger cities, that have a direct impact on individual welfare. What the matching approach cannot make is to separate changes in price of traded and non-traded goods as well as to separate bias in price of traded goods.

4 Application to Regions in Russia

We illustrate the proposed framework on the real-world data on regions in Russia. We estimate price indices for Russian regions by using the household survey data. We also compare these indices to the office price indices from the Russian Statistical Office.

4.1 Household Survey Data

The RLMS-HSE is an annual survey that collects information on socio-demographic characteristics, employment, satisfaction measures, and income sources. The survey is conducted in 32 out of 85 regions, covering 96% of the whole Russian population (see Kozyreva et al. (2016)). Our dataset includes 16 waves covering 2000-2015 years. RLMS-HSE is the only household survey that collects information subjective well-being and, therefore, we choose it as the source of evidence.

In order to estimate price indices with the matching approach, we need information on income, material needs and welfare level. All of this information is provided by the survey. Income is defined as nominal household income, which is a sum of all private sources of income of every household member, state transfers minus taxes. We adjust it by the OECD equivalence scale. Material needs are captured by household and individual characteristics. These include age and gender of respondents, household size, household composition, number of children, number of pensioners, number of employed household members, type of residence (owned, rented, or dormitory) and place of residence (urban or rural). Welfare is captured by satisfaction with income. We use answers to the question "*How satisfied are you with* ***your*** *economic conditions at the present?*" , on a scale from one to five. The phrasing of this question in Russian aims at capturing a respondent's satisfaction with his living conditions, material well-being and purchasing power, which is not reflected in translation to English. As our approach is based on equalizing the utility assigned to

economic well-being, this subjective measure captures well the satisfaction with the respondent's material needs and is the best fit for our approach. Table 1 in the Appendix provides summary statistics of the pooled sample.

Given the fact that satisfaction with economic conditions is a subjective measure, we address potential obstacles related to its use (for a detailed discussion, see Bertrand & Mullainathan (2001)). Answers to subjective questions might be shaped by various factors including question ordering, question phrasing, scale design, and survey framing. Furthermore, they might be subject to measurement error which might be correlated to observable characteristics of respondents. We claim that the RLMS-HSE survey is a nationally representative household survey and, therefore, we exclude any bias resulted from surveying particular demographic groups. Second, despite the fact that this question includes a five and not commonly used ten-point Likert scale, we stress that this scale is appropriate for our approach as the five-point scale is used in educational system and, thus, it is a very common scale of evaluation for Russians. Third, the well-being question does not involve negative wording. Fourth, a question about satisfaction with financial well-being comes after a satisfaction with life question, which is preceded by a general section on employment. Thus, reported answers are not affected by non-related matters (for example, no questions on health or political attitudes are asked before financial satisfaction question). Finally, Krueger & Schkade (2008) shows evidence for reliability of subjective measures, especially if the question is part of a repeated sample, sufficiently specific, or if comparison between socio-demographic groups is the purpose of the study. Summing up, we are confident about using the subjective question on satisfaction for the purpose of the study.

4.2 Federal State Statistics Data

Since 2009 the Russian Federal Statistical Office (Rosstat) has published cost-of-living indices across cities in Russia (Federal State Statistical Agency of Russia (2020)). This index shows how much more or less expensive the same basket of goods and services is. The basket consists of 275 items which are consumed by a majority of the local population. Every item is weighted according to its share in total consumer expenditures from the yearly household budget survey conducted by Rosstat. We convert this index from city-level to region-level by re-weighting according to the share of population in the region. We set the price level in Moscow as the reference level and, thus, normalize price indices to price levels in Moscow.

4.3 Price Indices Estimates

Using the household survey data, we estimate price indices for 38 regions in Russia over the years 2000-2015. We compare price indices with the official indices from the Rosstat over the period 2009-2015. Price indices are normalized to price level in Moscow. Price estimates are shown on the Figure B in the Appendix and correlation is shown on Table 2 in the Appendix .

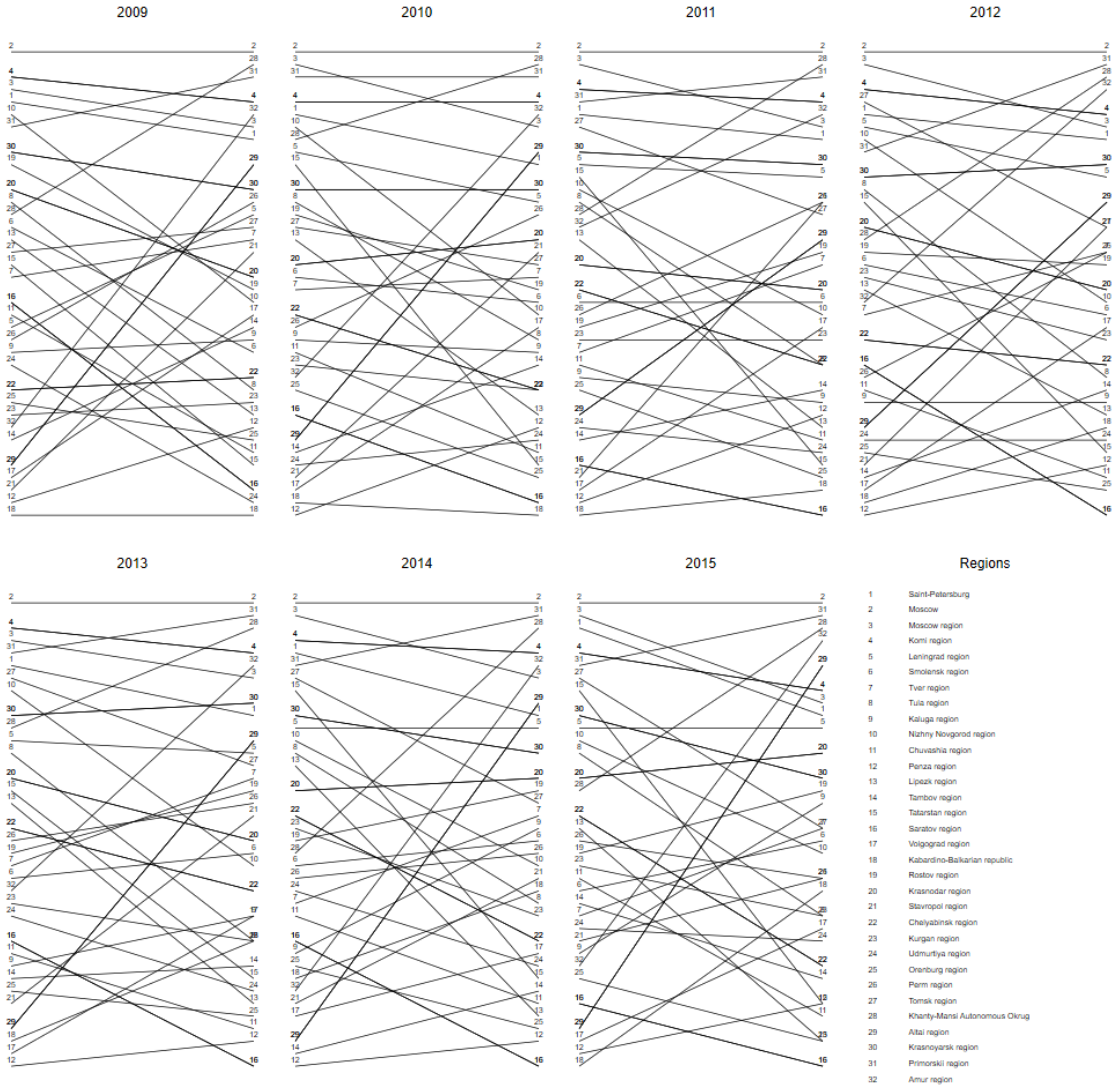
We find that for some regions the price indices are very identical (see, for example, Chuvashia region, Saratov region, Chelyabinsk region, Krasnoyarsk region), some regions are more expensive according to the matching approach (see, fore example, Komi region, Leningrad region, Saint-Petersburg), while some regions are cheaper (see, for example, Tver region, Penza region, Rostov region). Importantly, even when the two indices differ, we find that they follow similar trends. This indicates that the conceptual gap between the two approaches is constant. Thus, we conclude that price indices from the Rosstat and the matching approach are very alike: they follow similar trends at the different levels. Correlation estimates confirm the results that the two price indices are very similar.

We also analyze price indices in relative terms by ranking the regions from the most expensive to the cheapest over the years 2009-2015. Figure 1 shows the results. The regions on the left-hand side are ranked according to the matching approach, and on the right-hand side according to the Rosstat. The most expensive and the cheapest regions are depicted at the top and the bottom. Over the years 2009-2015 Moscow is the most expensive region according to the two approaches. The majority of the regions remain in their relative positions according to the two approaches. For some regions we document a tendency to a reversed relationship: the more expensive regions from Rosstat data tend to be cheaper in the matching approach, and the more cheaper regions from Rosstat data tend to be more expensive in the matching approach. In particular, all regions from the Far-East Federal district move from the average-expensive to very expensive according to the matching approach, while some regions from the Central, Southern and Volga Federal districts move from average-expensive to cheaper regions.

4.4 Implications for Inequality and Poverty

As prices play an important role in inequality and poverty analysis, we investigate the impact of price adjustments on inequality and poverty. Therefore, we compute the Gini index, average income and poverty rate with and without price adjustments. Figure 2 shows the estimates under three

Figure 1: Ranking of the Russian regions according to the cost-of-living



Source: RLMS-HSE (2020); Federal State Statistical Agency of Russia (2020), own calculations.

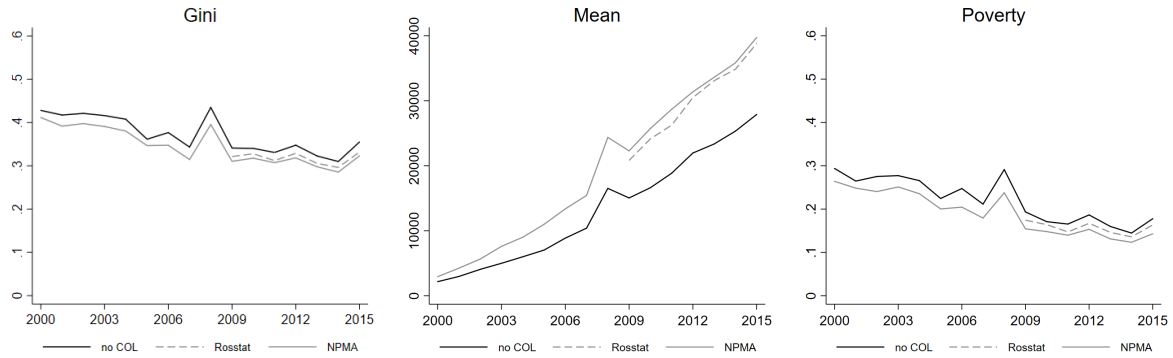
Note: the Rosstat ranking is shown on the left-hand side; the matching ranking on the right-hand side.

scenarios: without price adjustments (black line), with price adjustments from the Rosstat (dashed gray line), and with price adjustments from the matching approach (solid gray line).

Overall, there was a decrease in income inequality and poverty over the years 2000-2015, but the decrease is even larger once accounted for price changes. Accounted for price changes inequality follows similar trends but different levels as non-accounted for price changes inequality. Income levels differ substantially once accounted for price changes: an increase from 28,000 Rubles in 2000 to 41,000 Rubles in 2015 compare to an increase from 20,000 Rubles in 2000 to 28,000 Rubles in 2015. We also document that incomes adjusted by the Rosstat and the matching approaches yield

very similar trends in inequality, poverty and average levels. Therefore, we conclude that, first, inequality and poverty estimates differ when adjusted for price changes, and, more importantly, price indices from the matching approach show very similar results as price indices from the Rosstat.

Figure 2: Inequality and Poverty Trends in Russia



Source: RLMS-HSE (2020); Federal State Statistical Agency of Russia (2020), own calculations.

Note: Poverty line is defined as 50% of the average income.

Additionally, we address the question of what are the drivers of a decrease in inequality and poverty by decomposing inequality into within-region and between-region inequality. The results are given on Figure 2 in the Appendix. We find that accounting for price changes decrease the between-region inequality. Furthermore, between-region inequality accounted for price changes from the matching approach is very close to zero, which means that the price indices from the matching approach equalize regions in term of cost-of-living, which allows for better income comparison across regions. The larger decrease in inequality is driven by a reduction in between-region inequality.

5 Conclusion

In this paper, we introduce a new approach for estimating price indices. This approach makes price indices available if they do not exist and it offers alternative estimates if they exist. Price index is defined as a measure that equalizes incomes of individuals with the same level of welfare, with similar material needs but experiencing different price levels. The welfare is approximated with the subjective satisfaction following the Leyden school. Empirically, we employ the matching technique: first, individuals from different regions are matched under condition of the same welfare and material needs; second, individuals are assigned to matched income; then price index is estimated such that it eliminates income differences among matched pairs.

The matching approach makes price indices easily available because it does not require data on prices and quantities. It allows price indexes to be estimated for countries and regions as well as over time period. It also allows heterogeneity of countries, families and individuals to be accounted for: for example, it makes it possible to construct a price index for highly educated individuals or an price index that takes into account weather conditions.

Using the matching approach we estimate price indices for Russian regions over the years 2000-2015. Russia is a perfect case for study because prices vary greatly across regions. We also compare the matching indexes with the official price indexes from the Russian Statistical Office. We find that the two price indices are very similar: they are almost the same for some regions, they differ in levels but not in trends for other regions. In the case of different levels, the gap between the two indices remain unchanged. This indicates that the conceptual difference between the two approaches is constant. Thus, we conclude that the matching approach is the feasible approach to estimate price indices.

We also assess the impact of price changes on inequality and poverty. We find that when accounted for price changes Russia experienced a larger decrease in inequality, poverty and a larger increase in income levels. Income levels adjusted by price indices differ substantially from non-adjusted levels, however, income levels adjusted by price indices are very similar. Adjustment for price changes is important, but even more important for absolute income levels. We decompose inequality into between- and within-region inequality and find that application of the matching price indices lead to equalizing across regions: the between-region inequality is zero. This indicates that the matching approach is efficient in making income comparable.

Application to the real work data stresses the importance of acknowledging the existing spatial

differences in prices and its impact on inequality and poverty estimates, which, consequently, have an impact on governmental policies. It also proves the feasibility of our approach. The matching approach is an alternative approach that make prices available without data on prices.

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A Appendix

Here we show how we derive the price deflator with the proposed matching approach. Let the S_i denote subjective satisfaction of individual $i = 1, ..., N$ in region $r(i)$. Subjective satisfaction is defined as function of individual income Y_i, material needs Z_i and level of prices $P\_r(i)$, that is $S_i = U(Y_i; P\_r(i); Z_i)$. We also consider individual $j = 1, ..., K$ with subjective satisfaction $S_j = U(Y_j; P\_r(j); Z_j)$ residing in region $r(j)$ with different price levels. Price deflator is defined such that it eliminates differences in income arised from price changes given unchanged welfare level and satisfaction of material needs:

$$\frac{Y_i}{COL(r(i); r(j))} - Y_j = 0 \tag{1}$$

$$\ln COL(r(i); r(j)) = \ln Y_i - \ln Y_j \tag{2}$$

$$COL(r(i); r(j)) = \exp(\ln Y_i - \ln Y_j) \tag{3}$$

Averaging indices across all matches between regions gives:

$$COL(r(i); r(j)) = \exp\left(\frac{1}{N}\sum(\ln Y_i - \ln Y_j)\right) \tag{4}$$

, where $COL(r(i); r(j))$ is a price index between regions i and j.

B Appendix

Table 1: Descriptive Statistics of the pooled sample, 2000-2015 years

	Mean	SD
Age	43.61	18.68
Female	0.57	0.50
Urban	0.73	0.44
Children	0.73	0.91
Employed	0.55	0.50
Retired	0.62	0.78
Family size	3.33	1.64
Family type 1	0.07	0.25
Family type 2	0.08	0.28
Family type 3	0.03	0.16
Family type 4	0.33	0.47
Family type 5	0.03	0.16
Family type 6	0.46	0.50
Home ownership	0.91	0.29
Renting	0.06	0.24
Living in dormitory	0.03	0.16
Income	15282.92	32982.03
Fully satisfied	0.03	0.17
Fully unsatisfied	0.26	0.44

Source: RLMS-HSE (2020), own calculations.

Note: Income is defined as nominal household disposable income adjusted by the OECD equivalence scale. We consider individuals to be employed if (a) they are currently working; or (b) they are on paid leave; or (c) they are on unpaid leave; or (d) they are self-employed; or (e) they are farmers. Household composition: type 1 - single pensioner, type 2 - multiple pensioners, type 3 - single adult without children, type 4 - multiple adults without children, type 5 - single adult with children, type 6 - multiple adults with children.

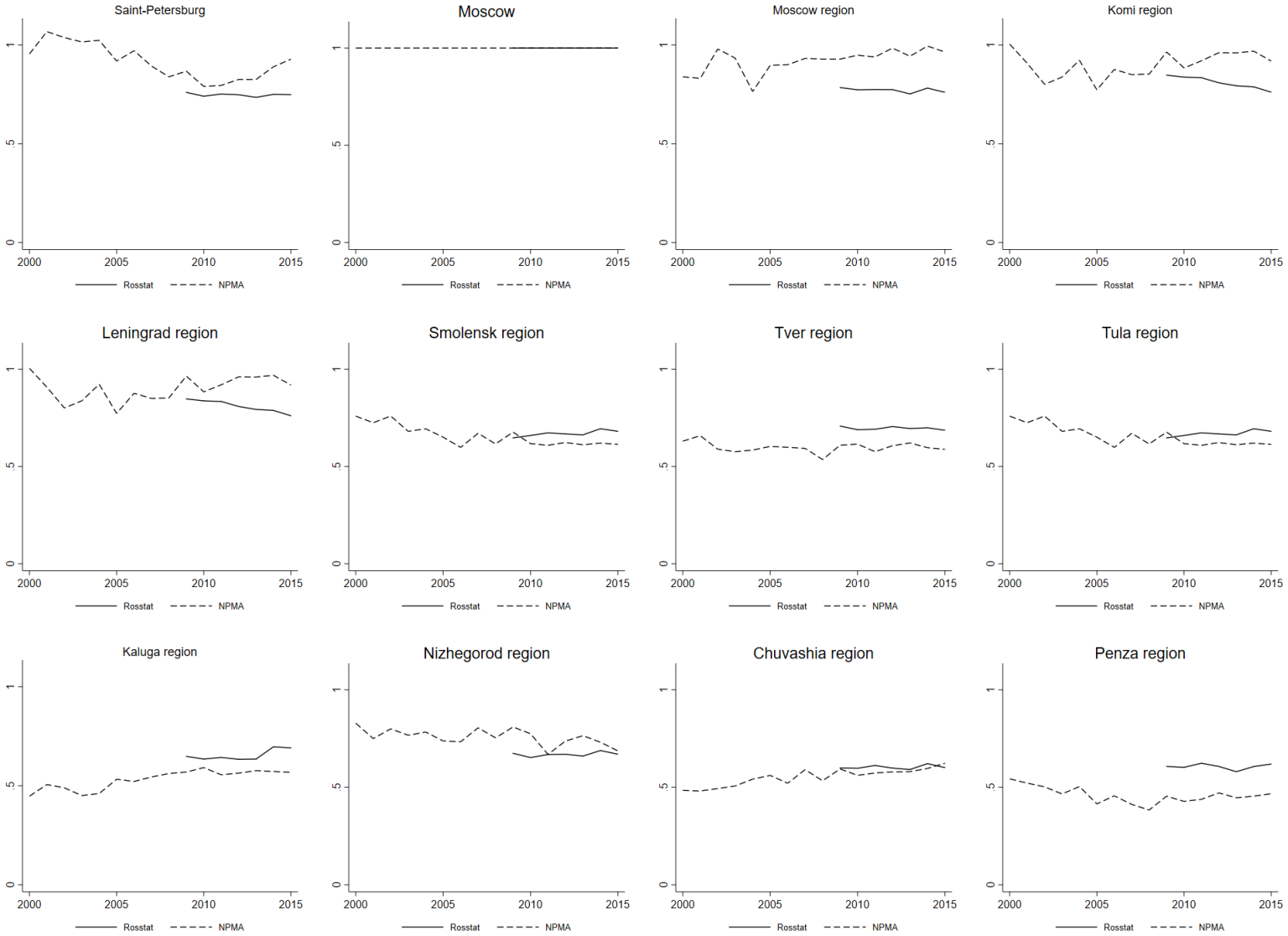
Table 2: Correlation between Rosstat and survey-based cost-of-living indices

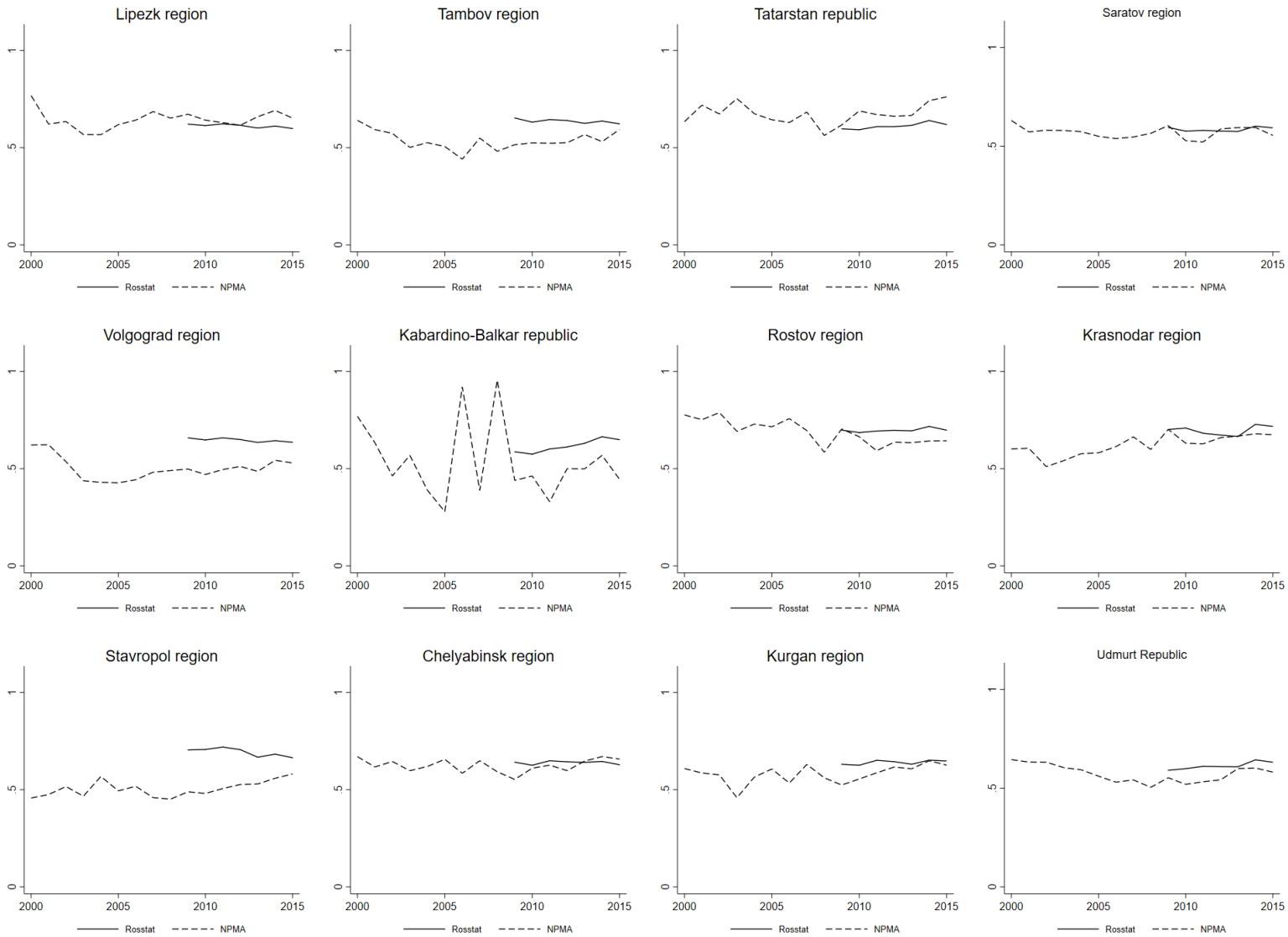
	2009	2010	2011	2012	2013	2014	2015
Spearman correlation	0.580^{***}	0.584^{***}	0.758^{***}	0.727^{***}	0.668^{***}	0.553^{***}	0.564^{***}

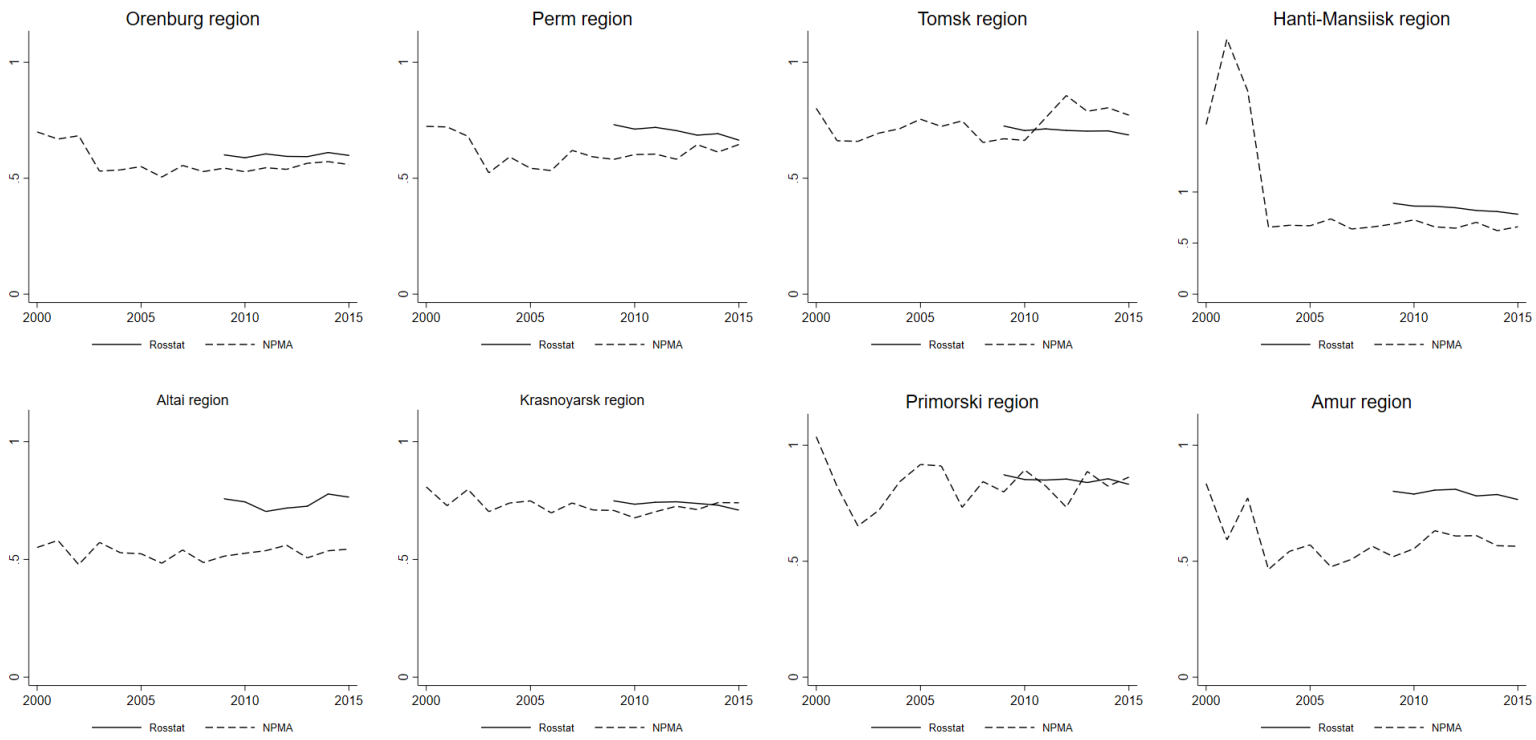
Source: RLMS-HSE (2020); Federal State Statistical Agency of Russia (2020), own calculations.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1: Price indices for Russian regions, 2000-2015

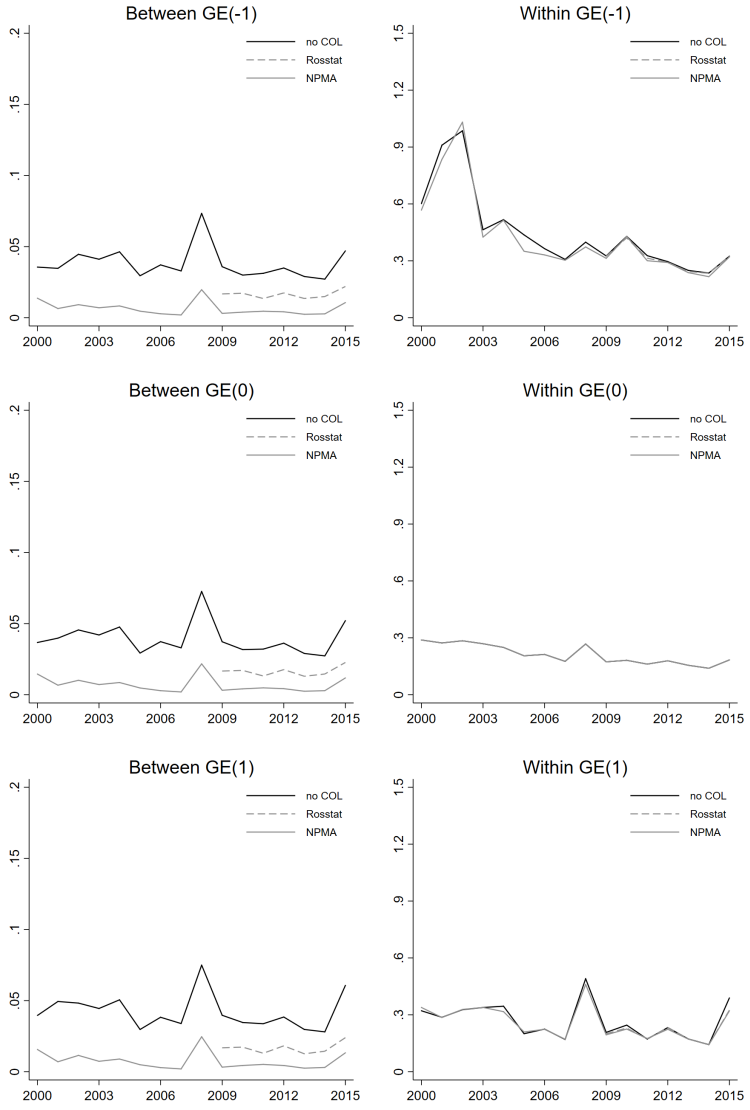



Lipezk region
Tambov region
Tatarstan republic
Saratov region
Volgograd region
Kabardino-Balkar republic
Rostov region
Krasnodar region
Stavropol region
Chelyabinsk region
Kurgan region
Udmurt Republic
0
.5
1
2000
2005
2010
2015
Rosstat
NPMA



Source: RLMS-HSE (2020); Federal State Statistical Agency of Russia (2020), own calculations.

Figure 2: Between- and within-regions decomposition of inequality



Source: RLMS-HSE (2020); Federal State Statistical Agency of Russia (2020), own calculations.

Note: GE(α) is a General Entropy Family measure. The larger the α is, the more sensitive GE(α) to changes in incomes at the top.