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Diffusion of Environmental Awareness*

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Abstract: A high level of "environmental awareness" in the participating countries will likely raise the success of the Kyoto Protocol negotiated in Paris in 2015. In this context it is of interest to investigate the diffusion of environmental awareness, and also the (economic) factors, on which this diffusion depends. This paper addresses these questions for the regions of the Russian Federation, which are sufficiently diverse regarding cultural and economic issues. From a formal point of view, a "Multiple-Indicator-Multiple-Causes" (MIMIC) approach, based on a variety of "indicators" for environmental awareness, derived from search entries in ©Yandex, and a variety of "causes", economic and socio-economic factors, is applied. The empirical results point first to a strong dependence of environmental awareness on the level of GRP per capita. Moreover, the diffusion seems to spread from the eastern part of Russia towards the western regions.

Keywords: Regional economics, environmental awareness, Kyoto Protocol, diffusion processes, Multiple Indicators-Multiple Causes (MIMIC) model

JEL Classification Numbers: C10, C13, Q50, R10.

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1 Introduction

In December 2015, the parties to the Kyoto Protocol reached an agreement for reducing anthropogenic greenhouse gas emissions. The success of this agreement depends substantially on the willingness of the participating countries, the level of "environmental awareness" in the population. The necessity arises, to investigate the spreading of environmental awareness, and also the (economic) factors, on which this spreading depends. This paper addresses these questions for the Russian regions over several periods of time.

Taking the research from Khakimova et al. (2017) into account, a first question refers to the abstract concept of "environmental awareness": How to define it? How to measure it? The "Multiple-Indicator-Multiple-Causes" (MIMIC) approach, based on indicators of environmental awareness and on causes, potentially influencing this awareness, is applied in the paper. The indicators are queries of environmental phrases from the Russian Internet search engine ©Yandex. Observable causes variables, such as the Gross Regional Product (GRP) per capita, help to explain the latent variable "environmental awareness". Khakimova et al. (2017) focus the interest in environmental topics of the Russian population during the time of the enormous RUB depreciation in the second half year of 2014 and the first month in 2015.
In contrast, the current paper investigates diffusion of environmental awareness in the Russian regions with respect to the following issues:

- the dependence of environmental awareness on GRP per capita with consequences for diffusion;
- the diffusion of environmental awareness across the regions over a sequence of time periods including rankings;
- geographical aspects of the diffusion of environmental awareness.

The results allow some insight into this diffusion of the awareness. In particular, the empirical investigation shows that the level of GRP per capita has a strong influence on environmental awareness, exhibiting some dependence of environmental awareness on GDP per capita – in the flavor of the "Environmental Kuznets Curve" (EKC).

The paper is structured as follows: the next section contains the literature survey and addresses the methodology including relevant aspects of the MIMIC model. Thereafter, the empirical results of the model will be discussed, some final remarks conclude the paper.

2 Literature Survey, Research Methodology, and Data

2.1 Environmental Awareness in the Literature

Environmental awareness is usually understood to induce environment-friendly behavior. However, it is not so straightforward to conceptualize it in order to make stringent use of it in academic research.

In the 1960s researchers in marketing and social psychology focused on personal characteristics of environmentally conscious people (cf. Soyez et al., 2009). In the 1970s and 1980s environment-friendly behavior was more explained in terms of attitudes measurable by means of multi-item scales (cf. Ajzen, 1991). Personal value orientation as precursor of sustainable behavior was considered in a further stream of research followed by a focus on cultural values (cf. Soyez et al., 2009; Soyez, 2012).

As environmental commodities are likely characterized by a higher income elasticity, at least in industrialized countries, the link between the economic situation and environment-friendly behavior is established. Consequently, the resulting functional relationship between GDP per capita and the level of pollution could be seen as the downward sloping part of an EKC. This view is, among others, supported by investigations of Grossman and Krueger (1995).

The EKC is, of course, a hypothesized relationship between various indicators of environmental pollution and GDP per capita. Stern (2004) provides an interesting survey on the rise and the fall of the EKC, characterizing the EKC as an essentially empirical phenomenon, with not much support from econometrics (cf. also Huang et al., 2008). On the other hand, Fosten et al. (2012) analyze the EKC and provide an useful literature survey on the econometric methods used in this context (cf. also Brajer et al., 2011; He and Richard, 2010; Wang, 2013; Yang et al., 2015), thus giving some support for the EKC hypothesis. A comprehensive survey of the EKC hypothesis till the year 2004 is provided by Dinda (2004).

Moreover, Diederich and Goeschl (2014) uncover causes of voluntary climate action, among them education. Karytsas and Theodoropoulou (2004) examine the demographic and socioeconomic factors that determine someone's knowledge on different forms of renewable energy.

What is still missing, is a systematic approach to indicators and causes of environmental awareness, and a careful investigation of the diffusion of environment-friendly behavior. Observe that environmental policies of various countries, such as the renewable energy policy in Germany, are to some extent justified to promote diffusion to other countries.

2.2 Research Methodology: The MIMIC Model

The above literature survey shows that the spreading of environment-friendly behavior is of relevance for various issues, ranging from marketing to climate change. Moreover, although some concepts of "environmental awareness" are introduced, a clear definition is, however, still missing. In addition, there seem to links between economic variables (GRP per capita), other socio-economic variables (education, demographics, ...), and environmental awareness.

The index of environmental awareness introduced in this paper is derived as a latent variable from various categories of search entries in ©Yandex, the prominent Russian search engine, from January 2014 through April 2016. As already mentioned in the literature survey, this indicator is presumably dependent on certain causes, which then also have to be integrated into the model. The resulting Multiple Indicators-Multiple Causes (MIMIC) model allows to estimate the proposed index. It is, thus, based on the assumption that environmental awareness can hardly be described by means of a single indicator, and that framework conditions, causes, can affect this awareness.

The MIMIC model was developed originally by Jöreskog and Goldberger (1975), and is a special case of the general structural equation model. It uses well defined indicators to measure a latent construct with associated properties and regresses them against theoretically discovered causes. Buehn and Farzanegan (2013) use the MIMIC approach to construct an index of air pollution for 122 countries for the period between 1985 and 2005.

Measuring environmental consciousness, Khakimova et al. (2017) introduce an environmental awareness index, which is estimated by a MIMIC model. That index permits to compare different regions in terms of the insight into the environment of the local population. Following the notation from Khakimova et al. (2017) the two parts of the basic MIMIC model can be explained as a measurement model for the latent construct and a structural part, which describes the causal structure of the model. The measurement part is given as follows:

$$y = \lambda \eta + \varepsilon, \tag{1}$$

where $y = (y_1, y_2, \dots, y_p)^\top$ is a set of observable endogenous indicators, which are affected by environmental awareness, which is the latent variable η, and $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p)^\top \sim \mathrm{N}(0, \Theta^2)$ with $\Theta = \operatorname{diag}(\theta_1, \theta_2, \dots, \theta_p)$ being a vector of p random errors. The factor loadings are summarized in the p-vector λ. The structural part follows our theoretical assumptions and can be written as:

$$\eta = \beta^\top x + \zeta, \tag{2}$$

where $x = (x_1, x_2 \dots, x_k)^\top$ are exogenous causes, $\beta = (\beta_1, \beta_2, \dots, \beta_k)^\top$ is a set of model parameters, and $\zeta \sim \mathrm{N}(0, \sigma^2)$ being independent from the other random factor ε. The

parameters λ and β, as well as the variances Θ^2 and σ^2 of the error terms ε and ζ, are estimated using a ML approach (cf. Jöreskog and Goldberger, 1975). As there is indeterminacy in the structural parameters one of the parameters is fixed (cf. Goldberger and Hauser, 1971). We further use the method from Satorra and Bentler (1994) to correct the estimated variances (cf. Trujillo-Ortiz and Hernandez-Wall, 2003).
In the model, the indicators y include the relative number of queries from the Internet search engine ©Yandex. These queries, collected monthly from January 2014 through April 2016, are based on approximately 200 environmental phrases, in Russian or English, and clustered in advanced into the following categories:

Y1: Climate Change Queries,

Y2: Endangered Environment Queries,

Y3: Political Queries,

Y4: Science Queries,

Y5: Renewable Energies and Technologies Queries.

Following the data collection, the sums of compatible requests in each region and in each category are summarized and divided by the sum of all search requests from ©Yandex in these regions. The indicator variables y are then computed as follows:

$$y_{in} = \frac{\text{number of queries of category } i \text{ in region } n}{\text{number of all queries in region } n}, \tag{3}$$

where $i = 1, \ldots, p$ with $p = 5$ is the index of category and $n = 1, \ldots, N$ the index of Russian region with $N = 81$.

In addition, observable causes are needed to explain the index variable η. The GRP per capita in purchasing power parity in first, second and third order is considered, also in order to allow for the EKC. Furthermore, we control for the structure of the industry, the emissions of greenhouse gases per capita and some controls for agglomeration, social status and education. Figure 1 shows the model with all specifications. Arrows mark the direct effects of the exogenous variables on environmental awareness, and the mediation effect of the index on the indicators. The associated default MIMIC model looks as follows:

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{pmatrix} \underbrace{\left[\begin{pmatrix} \beta_1 \\ \vdots \\ \beta_k \end{pmatrix}^{\top} \begin{pmatrix} \text{GRP per capita} \\ \text{GRP per capita}^2 \\ \text{GRP per capita}^3 \\ \text{set of control variables} \end{pmatrix} + \zeta \right]}_{\eta = \text{Index of Environmental Awareness}} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{pmatrix}. \tag{4}$$

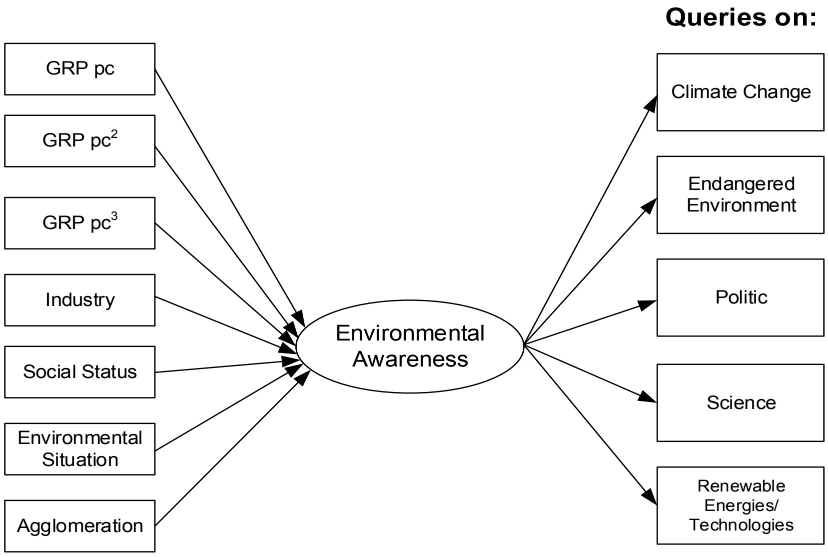

Figure 1: Path Diagram of the MIMIC Model

2.3 The Empirical Model with Season and Trend Components

Since the relative number of Internet queries are subject to seasonal deviations, the primary structural part of the MIMIC model is extended through a time component, which captures quarterly and yearly fixed effects.

The structural model part, which explains the latent variable $\tilde{\eta}$, is described now in the following way:

$$\tilde{\eta} = \beta^\top x + \gamma^\top z + \zeta. \tag{5}$$

Thereby, x is a matrix of cause variables. The matrix z includes three binary variables for the quarters (reference is the 4th quarter) and two binary variables for the years (reference is the year 2016). Moreover, β and γ are coefficient vectors and ζ is the normally distributed random error. The extended MIMIC model is

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \end{pmatrix} \underbrace{\left[\begin{pmatrix} \beta_1 \\ \vdots \\ \beta_k \end{pmatrix}^\top \begin{pmatrix} \text{GRP per capita} \\ \text{GRP per capita}^2 \\ \text{GRP per capita}^3 \\ \text{set of control variables} \end{pmatrix} + \begin{pmatrix} \gamma_1 \\ \vdots \\ \gamma_5 \end{pmatrix}^\top \begin{pmatrix} 1^{st} \text{ quarter} \\ 2^{nd} \text{ quarter} \\ 3^{rd} \text{ quarter} \\ 1^{st} \text{ year} \\ 2^{nd} \text{ year} \end{pmatrix} + \zeta \right]}_{\tilde{\eta}=\text{Index of Environmental Awareness}} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \end{pmatrix}. \tag{6}$$

The whole model is again estimated in one step, all the theory holds from the used ML estimation.

2.4 Identification and Data Considerations

As mentioned above, the number of Internet queries of environmental phrases and the total number of all queries in each region were provided by ©Yandex. Compared with Khakimova et al. (2017), in the current paper more data are available. The previous paper uses Internet queries from July, September, November 2014 and January, March and May 2015. Instead of the queries for 6 month, currently, we have access to Internet queries for 28 month: from January 2014 to April 2016. This enable us to investigate the temporal and spatial development of the EA index. The data for the regional cause variables are on year level available and provided by the RFSSS (2016). They include the GRP per capita in purchasing power parity, unemployment rate (for 2014 and 2015), proportion of young people (<18 years) and elderly people (>65 years) on total population, population density as average year population/square meter of a region, share of labor force in mining and manufacturing sector, as well as fishery, on total labor force. In addition information about the share of households with Internet broadband access, number of vehicles for 1000 population and the share of employees in education are available for 2014. Furthermore there is information about nitrogen oxides and carbon dioxide. Considering the pollutants, as well as air pollutants, which are released into the atmosphere during the year from fuel combustion (for generating electricity and heat) and from stationary sources (as index values).

The MIMIC model (6) is estimated with various selections of specifications for the period from January 2014 to April 2016.

The Internet data for each of the 81 Russian regions at month level are used as indicators. Since the regional data are not available at month level, the cause variables are included at year level in the model. Then, the data are stacked, which leads to a sample size of $N = 81$ regions $\times$ 28 month $= 2268$ observations. All variables are standardized over all years (all 2268 observations), not removing the time component. The standardization of the variables compensates for different scaling and helps to avoid problems in the convergence process applying the iterative ML approach.

3 Results of the MIMIC Model

Investigating the development of environmental awareness in the Russian regions, the index $\tilde{\eta}$ is estimated through the MIMIC model (6) with time components. The estimated coefficients are shown in Table 1. All of the models m_1 to m_6 include the five indicators y and the GRP per capita-cause variables x, as well as binary variables z for the time components: quarters (z_1, z_2 and z_3) and years (z_4, z_5). In addition, model m_2 to m_6 are extended by extra cause variables.

The reduced model m_1 has the lowest Akaike information criterion (AIC) value and thus shows the best model fit. The values for the robust Root Mean Square Error of Approximation (r.RMSEA) hardly differ from model to model. Small values for RMSEA indicates a good model fit, too. More information about the used model fit measurements are in Table 2 in the appendix.

As in Khakimova et al. (2017) most coefficients of the awareness indicators λ_i are either positive or not significant. Thus, as expected, there is a positive relationship between the index and environmental queries. The index can be interpreted as high interest in the environment, what supports the aim of the study.

To sum up, model m_1 fits the data well enough. The other cause variables, besides the GRP per capita and the time components, seem to have a weak impact of the EA index. The most of them have significant coefficients, but hardly affect the model fit.

Nonetheless, it is worthwhile looking at the signs of the coefficients. All λs are positive as expected. The most interesting Internet queries seem to be the *Climate Change* topics, because λ_1 shows the highest coefficient values in each model. The coefficient of the GRP per capita is positive in the first and third order, β_1 and β_3, but negative in the second order β_2. This suggests a curvilinear relationship between wealth of a region and the awareness index.

The coefficient values and signs are similar to the results from Khakimova et al. (2017). It indicates that the relation between the awareness index and per capita income of the regions is curvilinear. Consequently, promising efforts to stimulating environmental awareness are fundamentally related to the economic system. This is in the flavor of the concept of an EKC, without necessarily exhibiting all aspects of a EKC.

4 Diffusion of the Environmental Awareness

The estimation of model (6) with time components yields the following results regarding awareness in the eight richest regions in comparison to all others:

As Figure 2 shows, the richest regions (based on GRP) reveal the highest awareness index. That confirms the above mentioned relationship between wealth and environmental awareness. As already suspected, a relation between the geographical area and environmental consciousness is also found and illustrated in Figure 3.

The highest interest in environmental topics is in the East Asian part of Russia (gray line). The average awareness index continuously decreases from East to West. The smallest values are measured in the European part of Russia, although there are some of the richest regions (red and green). However, there are no measurable differences between the North and the South in Europe.

Moreover, comparing the maps in the Appendix (Figures 4 - 6), it seems that there is a kind of diffusion of environmental awareness from East to West between January 2014 to April 2016, which is just interrupted by seasonal deviations. However, there is

Table 1: Results for Six Different Variations of the Extended MIMIC Model.

	m_1	m_2	m_3	m_4	m_5	m_6
λ_1 Climate Change	0,487	0,475	0,393	0,448	0,380	0,381
λ_2 Endangered Environment	0,092 ***	0,093 ***	0,104 ***	0,100 ***	0,107 ***	0,107 ***
	(0,026)	(0,027)	(0,032)	(0,027)	(0,033)	(0,033)
λ_3 Politic Queries	0,109 ***	0,113 ***	0,111 ***	0,116 ***	0,113 ***	0,115 ***
	(0,032)	(0,034)	(0,043)	(0,036)	(0,043)	(0,043)
λ_4 Renewable Energy	0,173 ***	0,178 ***	0,225 ***	0,185 ***	0,232 ***	0,230 ***
	(0,036)	(0,039)	(0,049)	(0,040)	(0,049)	(0,049)
λ_5 Science Queries	0,138 ***	0,141 ***	0,167 ***	0,151 ***	0,167 ***	0,167 ***
	(0,027)	(0,028)	(0,040)	(0,029)	(0,041)	(0,041)
β_1 GRP per capita	1,999 ***	2,227 ***	1,241 ***	2,334 ***	1,048 ***	1,102 ***
	(0,191)	(0,215)	(0,182)	(0,225)	(0,215)	(0,208)
β_2 (GRP per capita)^2	-4,311 ***	-4,667 ***	-3,824 ***	-4,959 ***	-3,490 ***	-3,597 ***
	(0,472)	(0,506)	(0,478)	(0,526)	(0,513)	(0,522)
β_3 (GRP per capita)^3	2,588 ***	2,737 ***	2,528 ***	2,916 ***	2,364 ***	2,427 ***
	(0,309)	(0,322)	(0,312)	(0,330)	(0,323)	(0,341)
β_4 Manufacturing			-0,211 ***		-0,222 ***	-0,214 ***
			(0,027)		(0,033)	(0,034)
β_5 Mining			0,161 **		0,117 *	0,108
			(0,068)		(0,068)	(0,068)
β_6 Fishery					-0,068 **	-0,074 **
					(0,029)	(0,029)
β_7 Air pollution		-0,135 ***	-0,144 ***	-0,154 ***	-0,231 ***	-0,198 ***
		(0,022)	(0,026)	(0,029)	(0,030)	(0,033)
β_8 Carbon dioxide				0,193 ***	0,114 ***	0,127 ***
				(0,027)	(0,029)	(0,031)
β_9 Nitrogen dioxide				-0,160 ***		-0,056 **
				(0,029)		(0,025)
β_{10} Unemployment			-0,269 ***		-0,283 ***	-0,282 ***
			(0,043)		(0,042)	(0,046)
β_{11} Share of old people			-0,243 ***		-0,278 ***	-0,288 ***
			(0,053)		(0,052)	(0,096)
β_{12} Share of young people						-0,015
						(0,095)
β_{13} Education						0,009
						(0,056)
Controlling time-fixed effects						
γ_1 January - March	-0,248 ***	-0,114 ***	-0,204 ***	-0,236 ***	-0,095 **	-0,098 **
	(0,038)	(0,039)	(0,039)	(0,039)	(0,038)	(0,038)
γ_2 April - June	-0,023	-0,034	-0,028	-0,028	-0,035	-0,035
	(0,051)	(0,048)	(0,051)	(0,052)	(0,047)	(0,048)
γ_3 July - September	-0,130 ***	-1,178 ***	-1,277 ***	-1,294 ***	-1,144 ***	-1,148 ***
	(0,061)	(0,063)	(0,063)	(0,062)	(0,063)	(0,063)
γ_4 Year 2014	0,343 ***	0,320 ***	0,345 ***	0,349 ***	0,314 ***	0,314 ***
	(0,045)	(0,043)	(0,045)	(0,045)	(0,042)	(0,042)
γ_5 Year 2015	0,382 ***	0,282 ***	0,358 ***	0,381 ***	0,265 ***	0,267 ***
	(0,042)	(0,041)	(0,043)	(0,043)	(0,040)	(0,040)
N	2268	2268	2269	2269	2268	2268
AIC	43947	65801	57455	48981	74835	81811
r.RMSEA	0,093	0,100	0,089	0,091	0,096	0,094

Standard errors in parentheses; significance level: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

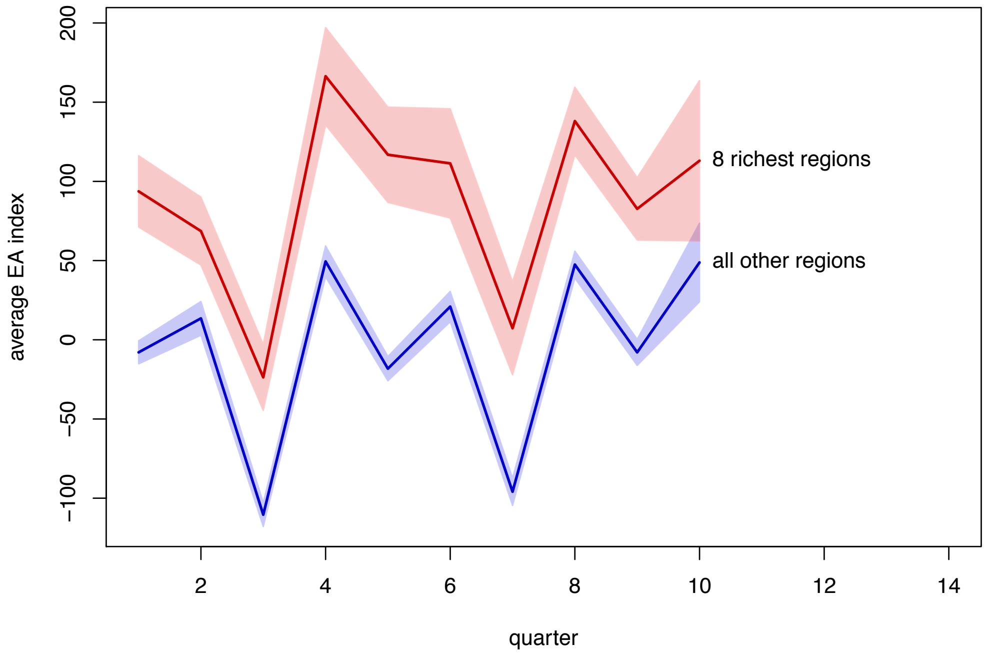

Figure 2: Estimated average EA index for 10 quarters with 95% CI, separately for the eight richest regions (red line) and all of the others (blue line).

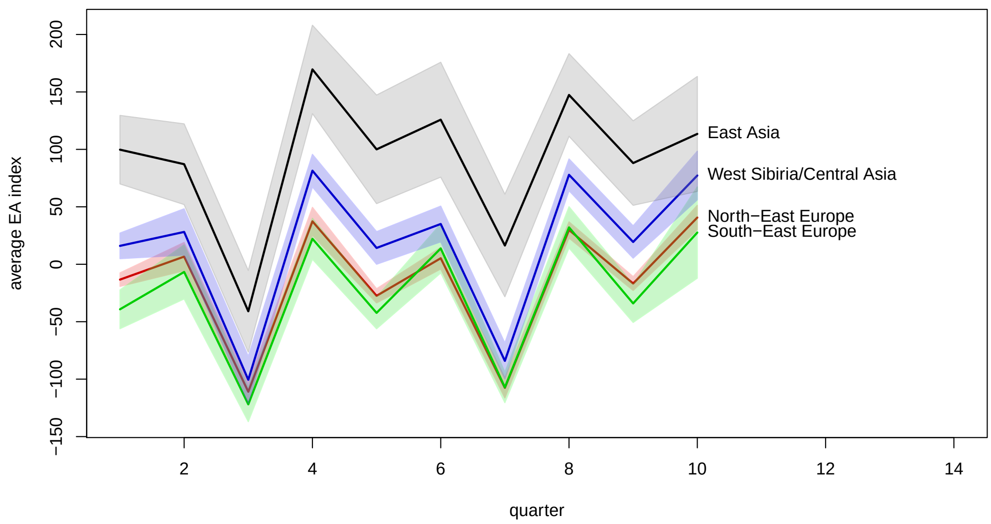

Figure 3: Estimated average EA index for 10 quarters with 95% CI, separately for four geographical areas in Russia: North-East Europe (red), South-East Europe (green), West Sibiria/Central Asia (purple) and East Asia (gray).

no significant trend measurable. A reason is the relative short observable duration of two years. With a larger time span it might be possible to measure a statistical significant time trend.

5 Concluding Remarks

The current paper extends and evaluates investigations of Khakimova et al. (2017) measuring environmental awareness and its temporal and spatial development of 81 Russian region through the MIMIC approach. The MIMIC model belongs to the general structural equation models. The main idea is to estimate environmental awareness, which is not directly observable, through endogenous indicator and exogenous cause variables. The MIMIC approach is a cost-effective and time-saving procedure to estimate this latent variable.

As endogenous indicators the relative numbers of Internet queries of environmental relevant topics are used. These queries are available for 28 months: from January 2014 to April 2016, and are provided by the Russian search engine ©Yandex. Regional attributes like gross regional product (GRP) per capita, industry, unemployment rate, age structure, carbon dioxide, nitrogen dioxide emissions, air pollution, etc. for 2014, and partly 2015, are used as cause variables. The data set allows an insight in the spread or diffusion of environmental awareness in the regions of the Russian Federation.

Looking at the results, the quarterly levels of environmental awareness are significantly higher for the eight richest regions in comparison to all the others. In addition, the geographical position of the regions plays a role regarding interest in climate change. Especially, the regions in East Siberia are characterized by high awareness indices. It seems that there is a diffusion of awareness from the Eastern to the Western part of Russia.

For further research, a longer observation period should allow solid time and spatial trend estimations of the awareness index. Clearly, the methodology applied in this paper could be used to estimate comparable parameters for other environmental issues and for other countries and regions.

Appendix

Table 2: Goodness-of-Fit Measures

Measure	Formula
Akaike Information Criterion	$AIC = \chi^2_{model} + g(g+1) - 2\,df_{model}$ $\chi^2_{model} \ldots$ χ^2-value of the full model $g \ldots$ number of variables in the full model $df_{model} \ldots$ degrees of freedom of the full model Source: Tanaka (1993)
Robust Root Mean Square Error of Approximation	$r.RMSEA = \sqrt{\max\left(0, \frac{\hat{c}(\chi^2_{SB,n} - df_{model})}{(n-1)df_{model}}\right)}$ $\chi^2_{SB,n} \ldots$ *Satorra-Bentler* χ^2-value of the full model $\hat{c} \ldots$ scaling constant Source: Brosseau-Liard et al. (2012)

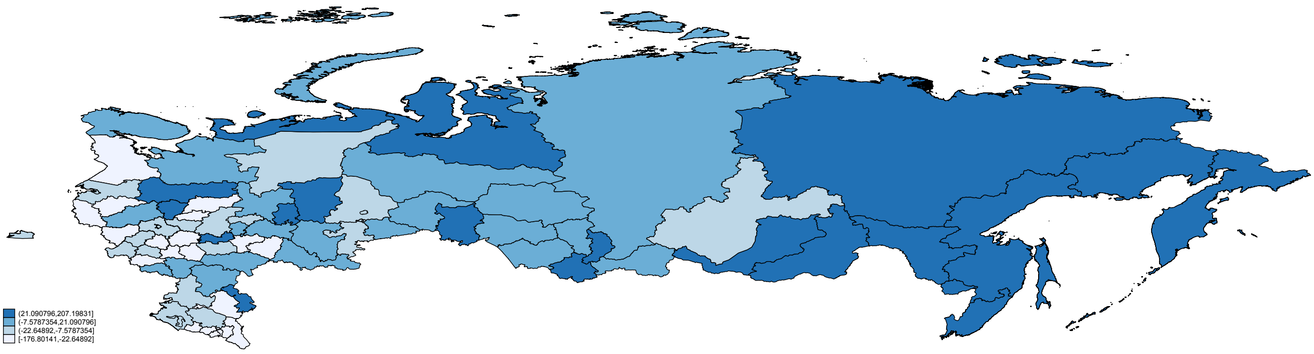

Figure 4: Map of 80 Russian regions illustrating the Environmental Awareness Index for January 2014 until March 2014 (without Autonomous Okrug Chukotka). High ranked regions are dark blue (rank: 1-22) and low ranked regions light blue (rank: 62-81).

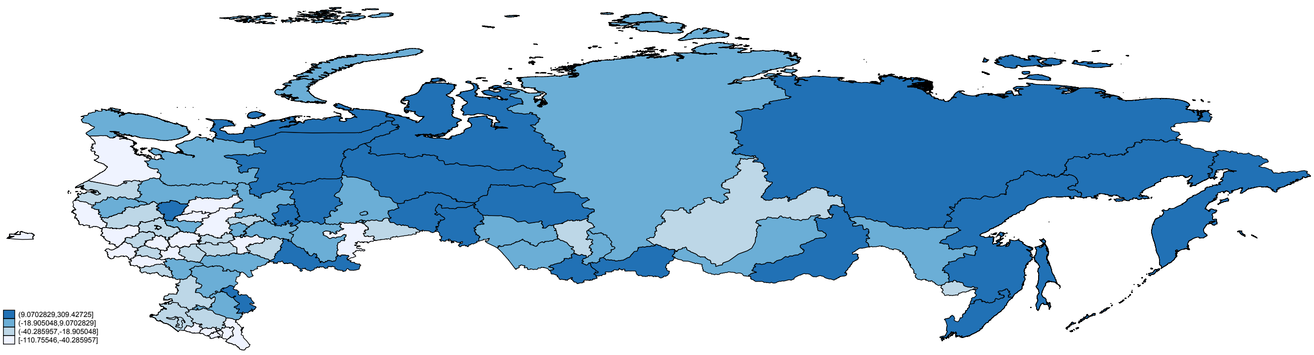

Figure 5: Map of 80 Russian regions illustrating the Environmental Awareness Index for January 2015 until March 2015 (without Autonomous Okrug Chukotka). High ranked regions are dark blue (rank: 1-22) and low ranked regions light blue (rank: 62-81).

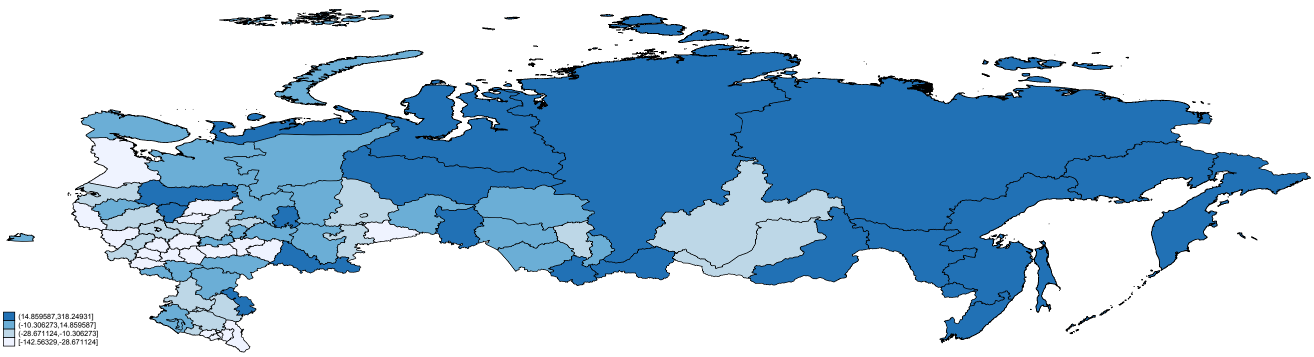

Figure 6: Map of 80 Russian regions illustrating the Environmental Awareness Index for January 2016 until March 2016 (without Autonomous Okrug Chukotka). High ranked regions are dark blue (rank: 1-22) and low ranked regions light blue (rank: 62-81).

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