TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät der Verkehrswissenschaften „Friedrich List“

Awareness of Global Warming
A MIMIC Approach

D. Khakimova [1] D. Wende [2] H. Wiesmeth [3,4] S. Lösch [3] O. Okhrin [3]

1 New Economic School in Moscow/Russia
2 WIG^2 GmbH in Leipzig/Germany
3 Technische Universität in Dresden/Germany
4 UrFU - Ural Federal University in Ekaterinburg/Russia

MOVING THE WORLD.

TECHNISCHE UNIVERSITÄT DRESDEN

Introduction

Figure 1: Source: © shutterstock.com

TECHNISCHE UNIVERSITÄT DRESDEN

Introduction

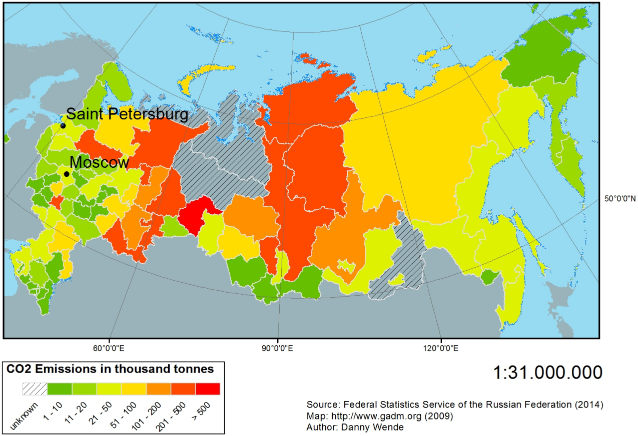


Figure 2: Russia: Carbon Dioxid Emissions (2012), Source: RFSSS

TECHNISCHE UNIVERSITÄT DRESDEN

Literature

- *Environmental awareness* originated by ecological movements in 1960s
- Social psychology and marketing focused socio-demographic attributes of environmentally conscious people (Soyez et al. 2009)
- In 1970s and 80s environmentally friendly behaviour was explained by environmentally friendly *attitudes* measurable by means of multi-item scales (Ajzen, 1991)
- *Personal value orientation* and *cultural values* were investigated over the last ten years (Soyez et al. 2009, 2012)

Primary Goal

Introduce an *Index of Global Warming* or *Index of Environmental Awareness* for 81 Russian Regions using a structural equation model.

TECHNISCHE UNIVERSITÄT DRESDEN

Index of Environmental Awareness

- Comparing regions or countries using quality indices: *Environmental Performance Index* (EPI) and the *Environmental Sustainability Index* (ESI) (see Emerson et. al., 2012)
- Das and DiRienzo (2010) found a negative relation between environmental quality and ethnic diversity in countries using EPI
- Grafton and Knowles (2004) found no strong evidence for effects of social capital on environmental performance using ESI
- Park et. al (2007) investigated the relationship between cultural and environmental sustainability measures using ESI and found some evidence
- Also discussed in the literature: the *Environmental Kuznets Curve* (EKC), for example by Dinda (2004), He and Richard (2010), Brajer et. al. (2011), Fosten et. al. (2012), Wang (2013), Yang et. al. (2015)

TECHNISCHE UNIVERSITÄT DRESDEN

Environmental Kuznets Curve (EKC)

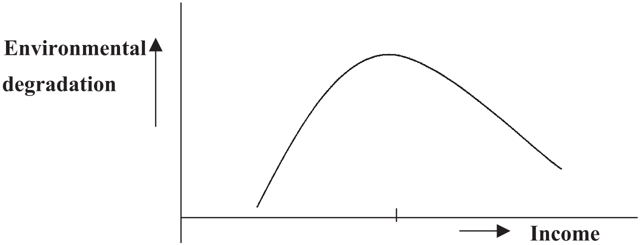


Figure 3: Environmental Kuznets Curve (Dinda, 2004)

Secondary Goal

Search evidence for the *Environmental Kuznets Curve* in Russia.

TECHNISCHE UNIVERSITÄT DRESDEN

Multiple Indicators-Multiple Causes Model (MIMIC)

Buehn and Farzanegan (2013) introduced a *Multiple Indicators-Multiple Causes Model* to investigate the relation between air pollution and emissions using more than one indicator variable (CO_2).

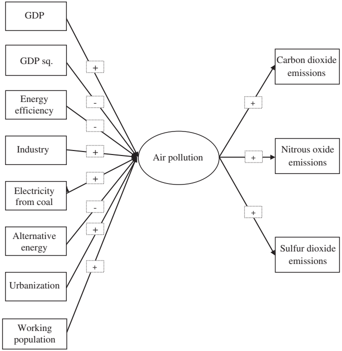


Figure 4: Path diagram of the Air Pollution Index (Buehn and Farzanegan)

TECHNISCHE UNIVERSITÄT DRESDEN

MIMIC Approach

MIMIC-Model from Jörekog and Goldberger, 1975

$$Y = \lambda \eta + \varepsilon, \quad (1)$$

where $Y = (Y_1, Y_2, \dots Y_p)^\top$ is a set of *observable* endogenous indicators, which are affected by a latent variable η.

$\Rightarrow$ Here, η is the *Index of Global Warming* and is defined as

$$\eta = \beta^\top X + \zeta \quad (2)$$

with $X = (X_1, X_2 \dots, X_k)^\top$ is a set of *observable* exogenous causes of η.

$\lambda = (\lambda_1, \lambda_2, \dots, \lambda_p)^\top$ and $\beta = (\beta_1, \beta_2, \dots, \beta_k)^\top$ are model parameters, and $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p)^\top$ and ζ are random errors.

TECHNISCHE UNIVERSITÄT DRESDEN

MIMIC - Assumptions

Equation (2) into (1)

$$Y = \lambda \left(\beta^\top X + \zeta\right) + \varepsilon = \Pi^\top X + v,$$

with $\Pi = \beta \lambda^\top$ and $v = \lambda \varepsilon + \zeta$

Assumption: Random errors ε and ζ are assumed to be mutually independent and normally distributed

$$\varepsilon \sim \mathrm{N}(0, \Theta^2) \quad \text{and} \quad \zeta \sim \mathrm{N}(0, \sigma^2),$$

where

$$\Theta = \mathrm{diag}(\theta_1, \theta_2, \ldots, \theta_p).$$

Independence assumption implies

$$E(\zeta\varepsilon^\top) = 0^\top \quad \text{and} \quad E(\varepsilon\varepsilon^\top) = \Theta^2.$$

TECHNISCHE UNIVERSITÄT DRESDEN

Restrictions of the MIMIC Model

Assumption: X and Y are jointly normally distributed, with $X \sim \mathrm{N}(0, \Phi^2)$

- Identifiability (Hauser and Goldberger, 1971)

$$k \cdot p + 1/2p(p+1) \geq k + 2 \cdot p$$

  In general, the model is identified if $p \geq 3$.
- Otherwise some parameters may be set fixed, e.g. $\sigma_\zeta = 1$ or $\lambda_1 = 1$. (See Jörekog and Goldberger, 1975)
- If the Model is identifiable and restricted, the parameter values of

$$\lambda,\ \beta,\ \theta^2\ \left(\text{and } \sigma_\zeta^2\right)$$

  can be estimated using a ML-Approach.

TECHNISCHE UNIVERSITÄT DRESDEN

Maximum Likelihood Estimation

Following Jörekog and Goldberger (1975): N is the sample size. The log-likelihood can be computed through

$$\mathcal{L} = -N \cdot 1/2\{\log|\Omega| + \mathrm{tr}(\Omega^{-1}W)\} + C \to \text{ max!}$$

C is some constant, Ω implies the covariance matrix $\Omega = E\left(vv^\top\right) = \sigma^2\lambda\lambda^\top + \Theta^2$ and $W = (Y - X\Pi)^\top(Y - X\Pi)$.

TECHNISCHE UNIVERSITÄT DRESDEN

Maximum Likelihood Estimation

- Step 1: Set initial $\hat{\lambda}_0$, $\hat{\Omega}_0$
- Step 2: Compute

$$\hat{\beta} = \left(\frac{1}{\hat{\lambda}^\top \hat{\Omega}^{-1} \hat{\lambda}} \right) (X^\top X)^{-1} X^\top Y \hat{\Omega}^{-1} \hat{\lambda}$$

- Step 3:

$$\hat{\lambda} = \left(1 + \hat{\beta}^\top X^\top X \hat{\beta} \right) \hat{\lambda}$$

- Step 4:

$$\hat{\theta}_i^2 = r_{ii} - \left(1 + \hat{\beta}^\top X^\top X \hat{\beta} \right) \hat{\lambda}_i^2 \qquad \text{for } (i = 1, \dots, p)$$

  r_{ii} is the ith diagonal element of $R = Y^\top Y$.
- Step 5: Go to step 2 and repeat until convergence.

TECHNISCHE UNIVERSITÄT DRESDEN

Data

Figure 5: Russian Federation: Regions, Source: www.mapsofworld.com

TECHNISCHE UNIVERSITÄT DRESDEN

Data

Indicator Variables Y

More than 300 relevant phrases about environmental topics came from Yandex ("Google" for Russia) in Russian and English and the number of queries of these phrases for 81 Russian regions (for Sept./Oct. 2014 and Dec./Jan. 2014/15).

Zwischenablage | Schriftart | Ausrichtung | Zahl

G116

	A	B	C	D
1	RegionID	PollutionQuery	UserCount	QueryCount
104	1	экотерроризм	7	9
105	1	экотуризм	304	1210
106	1	энергетическая автономия	1	1
107	1	энергетический бюджет	0	0
108	1	энергосохранение	0	0
109	1	энтеральная ферментация	0	0
110	1	ядерная зима	153	217
111	1	ядерные отходы	18	23
112	1	acid rain	11	38
113	1	air pollution	22	30
114	1	alternative energy sources	4	6
115	1	amur tiger	7	13
116	1	arctic climate impact assessment	0	0
117	1	berkeley earth	0	0

Figure 6: Example of Dataset: Some environmental phrases for 81 Russian regions from Yandex (Dec./Jan. 2014/15)

TECHNISCHE UNIVERSITÄT DRESDEN

Indicator Variables Y

Classification of the phrases in 6 categories

Y_1 : Climate Change Queries

Y_2 : Endangered Environmental Queries

Y_3 : Political Queries

Y_4 : Climate Model Queries

Y_5 : Renewable Energies Queries

Y_6 : Genetically modified organism Queries

$$Y_{in} = \frac{\text{number of queries of category } i \text{ in region } n}{\text{number of all queries in region } n}$$

Thereby are the category $i = 1, \ldots, p$ with $p = 6$ and the region $n = 1, \ldots, N$ with $N = 81$.

TECHNISCHE UNIVERSITÄT DRESDEN

Causes Variables X

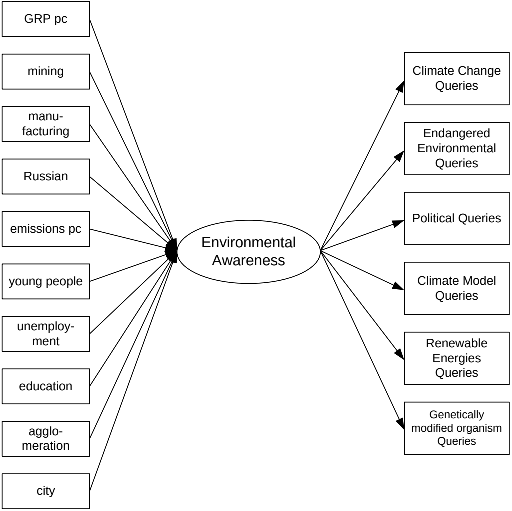
Causes Variables X from Federal Statistics Service of Russia (RFSSS) and National Human Development Report 2013

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
GRP pc ppp	3494	10941	12860	14818	15987	57175
mining/GRP	0.001	0.009	0.041	0.206	0.277	1.180
manufacturing/GRP	0.006	0.330	0.579	0.608	0.853	1.930
Russian	0.010	0.650	0.860	0.753	0.930	0.970
emissions pc	0.000	0.036	0.075	0.284	0.163	4.997
agglomeration	0.071	3.827	22.206	31.612	42.227	400.255
young people < 18 y.	0.130	0.150	0.170	0.181	0.190	0.350
unemployment	0.032	0.069	0.081	0.092	0.092	0.500
education	0.804	0.890	0.899	0.900	0.912	0.955

Table 1: Statistics of the Causes Variables

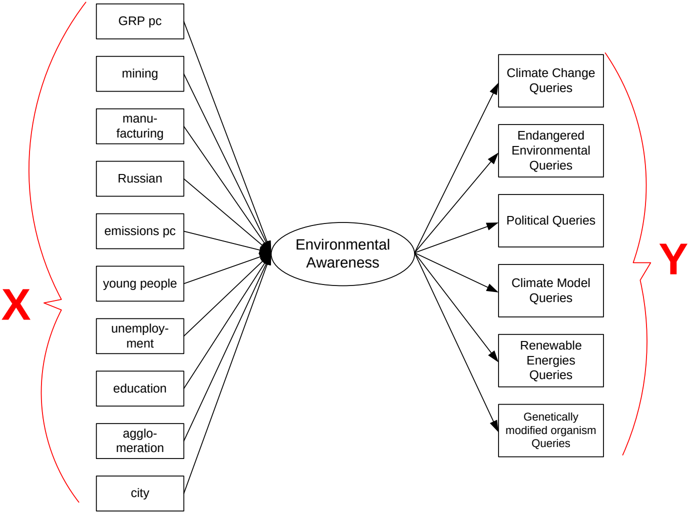
TECHNISCHE UNIVERSITÄT DRESDEN

MIMIC - Model



TECHNISCHE UNIVERSITÄT DRESDEN

MIMIC - Model



TECHNISCHE UNIVERSITÄT DRESDEN

MIMIC - Model

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \\ y_6 \end{pmatrix} = \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \end{pmatrix} \underbrace{\left[\begin{pmatrix} \beta_1 \\ \vdots \\ \beta_k \end{pmatrix}^\top \begin{pmatrix} \text{GRP per capita} \\ \text{GRP per capita}^2 \\ \text{GRP per capita}^3 \\ \text{mining} \\ \text{manufactoring} \\ \text{emission} \\ \text{set of control variables} \end{pmatrix} + \zeta^\top \right]}_{\eta = \text{Index of Global Warming}} + \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \\ \varepsilon_5 \\ \varepsilon_6 \end{pmatrix}$$

- Model is over-identified with $p = 6$ indicators and $k = 12$ causes
- Estimating the parameter values, $\lambda_1 = 1$ is fixed
- Using a robust ML-approach, because normality assumption cannot be hold:
  - MLM: standard errors are weighted by asymptotic covariance matrix (Satorra and Bentler, 1994)
  - MLR: standard errors are estimated using *Sandwich* estimator (Yuan and Bentler, 2000)

TECHNISCHE UNIVERSITÄT DRESDEN

Results - Parameter Values

	Sept/Oct Est. (1)	Dec/Jan Est. (1)	Sept/Oct Est. (2)	Dec/Jan Est. (2)	Sept/Oct Est. (3)	Dec/Jan Est. (3)
GRP per capita	4.719 ***	3.441 ***	5.148 ***	3.938 **	2.450 **	2.748 **
	(1.481)	(1.481)	(1.453)	(1.681)	(1.194)	(1.229)
GRP per capita^2	-11.304 ***	-8.488 ***	-11.189 ***	-8.492 **	-5.581 *	-5.874 ***
	(3.345)	(3.345)	(3.585)	(3.868)	(3.190)	(2.091)
GRP per capita^3	6.814 ***	5.272 ***	6.404 ***	4.923 **	3.192	3.290 **
	(1.968)	(1.968)	(2.177)	(2.477)	(2.007)	(1.203)
mining/GRP	0.400	0.420				
	(0.281)	(0.281)				
manufacturing/GRP	-0.101	-0.093	-0.256 *	-0.239 **		
	(0.242)	(0.242)	(0.154)	(0.110)		
Russian	-0.379 *	-0.018	-0.374 *	-0.001		
	(0.223)	(0.223)	(0.211)	(0.101)		
emissions per capita	-0.333	-0.369	-0.160	-0.186		
	(0.208)	(0.208)	(0.196)	(0.304)		
agglomeration	-0.219	-0.290 ***	-0.194	-0.258 ***		
	(0.156)	(0.156)	(0.163)	(0.091)		
young people	-0.667 **	-0.346 **	-0.636 **	-0.289 **		
	(0.312)	(0.312)	(0.290)	(0.142)		
unemployment	0.529 **	0.586 ***	0.517 **	0.577 ***		
	(0.214)	(0.214)	(0.215)	(0.140)		
education	-0.110	0.179	-0.100	0.183		
	(0.135)	(0.135)	(0.138)	(0.142)		
city	0.683 ***	0.589 ***	0.561 **	0.452 ***	0.142	0.106
	(0.229)	(0.229)	(0.245)	(0.123)	(0.105)	(0.071)

Standard errors in parentheses (MLR); significance level: $***p < 0.01$, $**p < 0.05$, $*p < 0.1$

Table 2: Estimated β-Parameters Using MIMIC Approach

TECHNISCHE UNIVERSITÄT DRESDEN

Results - Parameter Values

	Sept/Oct Est. (1)	Dec/Jan Est. (1)	Sept/Oct Est. (2)	Dec/Jan Est. (2)	Sept/Oct Est. (3)	Dec/Jan Est. (3)
λ_1 fixed	1.000	1.000	1.000	1.000	1.000	1.000
λ_2	0.469 ***	-0.331	0.502 ***	-0.311	0.461 **	-0.193
	(0.137)	(0.376)	(0.139)	(0.368)	(0.148)	(0.324)
	(0.250)	(0.250)	(0.216)	(0.448)	(0.215)	(0.551)
λ_3	0.371	1.233 ***	0.394	1.252 ***	0.366	0.896
	(0.294)	(0.269)	(0.313)	(0.275)	(0.306)	(0.438)
	(0.384)	(0.384)	(0.376)	(0.424)	(0.372)	(0.682)
λ_4	0.767 ***	0.181	0.794 ***	0.171	0.766 **	0.170
	(0.263)	(0.219)	(0.274)	(0.219)	(0.290)	(0.199)
	(0.334)	(0.334)	(0.323)	(0.318)	(0.338)	(0.245)
λ_5	0.397 ***	-0.144	0.407 ***	-0.153	0.395 ***	-0.137
	(0.142)	(0.409)	(0.151)	(0.413)	(0.127)	(0.309)
	(0.121)	(0.121)	(0.148)	(0.468)	(0.120)	(0.367)
λ_6	0.410 ***	0.397	0.433 ***	0.412	0.400 ***	0.282
	(0.101)	(0.410)	(0.104)	(0.415)	(0.101)	(0.350)
	(0.140)	(0.140)	(0.119)	(0.557)	(0.113)	(0.568)
df	87	87	81	81	39	39
CFI	0.380	0.463	0.436	0.446	0.743	0.573
RMSE	0.085	0.051	0.077	0.052	0.053	0.054
SRMR	0.076	0.092	0.077	0.088	0.072	0.110

Standard errors in parentheses (MLM above, MLR among); significance level: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table 3: Estimated λ-Parameters Using MIMIC Approach

TECHNISCHE UNIVERSITÄT DRESDEN

Index of Global Warming

Region	Sept./Oct. 2014	Ranking	Dec./Jan. 2014/15	Ranking
Kamchatka	475.4	1	-57.5	73
Adygea	171.5	2	-110.2	78
Arkhangelsk	156.1	3	89.6	3
Khanty-Mansi AO	154.7	4	58.8	9
Penza	135.6	5	42.1	13
⋮	⋮	⋮	⋮	⋮
Moscow	82.4	12	27.1	20
⋮	⋮	⋮	⋮	⋮
St.Petersburg	20	29	24.2	26
⋮	⋮	⋮	⋮	⋮
Magadan	-50.4	65	253	1
⋮	⋮	⋮	⋮	⋮
Karachay-Cherkessia	-179.4	77	-137.6	79
Altai	-191.1	78	-33.7	61
Jewish	-219.4	79	-56.8	72
Nenets AO	-278.7	80	-209.6	81
Chukotka AO	-363.5	81	-175.6	80

TECHNISCHE UNIVERSITÄT DRESDEN

Results and Prospective Research

Results

- Structure of the indicators did not change from period to period
- Indicator variables are positive, but the most are not significant for Dec./Jan. 2014/15
- GRP per capita in the first order is significantly positive and in the second order significantly negative → Environmental Kuznets Curve can be identified
- Unemployment rate and the city dummy have positive impact on environmental awareness
- Share of Russian and share of young people are significantly negative

Prospective Research

- Avoiding normality
- Using non-linear models

TECHNISCHE UNIVERSITÄT DRESDEN

References

Ajzen, I. (1991): The theory of planned behavior. Organizational Behavior and Human Decision Processes 50:179-211.
http://dx.doi.org/10.1016/0749-5978(91)90020-T

Brajer, V., Mead, R. W., Xiao, F. (2011) Searching for an Environmental Kuznets Curve in China's air pollution. China Economic Review 22: 383-397.
http://dx.doi.org/10.1016/j.chieco.2011.05.001

Buehn, A., Farzanegan, M. R. (2013): Hold your breath: a new index of air pollution. Energy Economics 37:104-113.
http://dx.doi.org/10.1016/j.eneco.2013.01.011

Dinda, S. (2004) Environmental Kuznets Curve Hypothesis: A Survey. Ecological Economics 49: 431-455.
http://dx.doi.org/10.1016/j.ecolecon.2004.02.011

Das, J., DiRienzo, C.E. (2010): Is ethnic diversity good for the environment? A cross-country analysis. The Journal of Environment & Development XX: 91?113.
http://jed.sagepub.com/content/early/2009/12/29/1070496509355274

Emerson, J., Hsu, A., Levy, M.A., deSherbinin, A., Mara, V., Esty, D.C., Jaiteh, M. (2012): Environmental Performance Index and Pilot Trend Environmental Performance Index. Yale Center for Environmental Law and Policy, New Haven.

Fosten, J., Morley, B., Taylor, T. (2012) Dynamic misspecification in the environmental Kuznets curve: Evidence from CO_2 and SO_2 emissions in the United Kingdom. Ecological Economics 76: 25-33.
http://dx.doi.org/10.1016/j.ecolecon.2012.01.023

Grafton, R.Q., Knowles, S. (2004): Social capital and national environmental performance: a cross-sectional analysis. The Journal of Environment & Development 13(4): 336-370.

TECHNISCHE UNIVERSITÄT DRESDEN

References

He, J., Richard, P. (2010): Environmental Kuznets curve for CO2 in Canada. Ecological Economics 69: 1083-1093.
http://dx.doi.org/10.1016/j.ecolecon.2009.11.030

Joreskog, K. G., Goldberger, A. S. (1975): Estimation of a Model with Multiple Indicators and Multiple Causes of a Single Latent Variable. Journal of the American Statistical Association 70:631-639.
http://www.jstor.org/stable/2285946

Park, H., Russell, C., & Lee, J. (2007). National culture and environmental sustainability: A cross-national analysis. Journal of Economics and Finance, 31(1), 104-121.

Satorra, A., Bentler, P.M. (1994): Corrections to test statistics and standard errors in covariance structure analysis, in: A. von Eye, C.C. Clogg (Eds.), Latent Variables Analysis: Applications for Developmental Research, Sage, Thousand Oaks, CA: pp. 399-419.

Soyez, K., Hoffmann, S., Wünschmann, S., Gelbrich, K. (2009): Proenvironmental value orientation across cultures. Social Psychology 40(4):222-233.
http://dx.doi.org/10.1027/1864-9335.40.4.222

Soyez, K. (2012): How national cultural values affect pro-environmental consumer behavior. International Marketing Review 29(6):623-646.
http://dx.doi.org/10.1108/02651331211277973

Yuan, K. H., Bentler, P. M. (2000). Three likelihood-based methods for mean and covariance structure analysis with nonnormal missing data. Sociological methodology, 30, 165-200.

Wang, Y.-C. (2013) Functional sensitivity of testing the environmental Kuznets curve hypothesis. Resource and Energy Economics 35: 451-466.
http://dx.doi.org/10.1016/j.reseneeco.2013.01.003

Yang, H., He, J., Chen, S. (2015) The fragility of the Environmental Kuznets Curve: Revisiting the hypothesis with Chinese data via an "Extreme Bound Analysis". Ecological Economics 109: 41-58.

TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät der Verkehrswissenschaften „Friedrich List“

Awareness of Global Warming

A MIMIC Approach

D. Khakimova [1] D. Wende [2] H. Wiesmeth [3,4] S. Lösch [3] O. Okhrin [3]

1 New Economic School in Moscow/Russia
2 WIG[2] GmbH in Leipzig/Germany
3 Technische Universität in Dresden/Germany
4 UrFU - Ural Federal University in Ekaterinburg/Russia

TECHNISCHE UNIVERSITÄT DRESDEN

Indicator Variables Y

	Sept./Oct. 2014		Dec./Jan. 2014/15	
	Env. Queries	all Queries	Env. Queries	all Queries
Min.	67	368800	70	319 300
1st Qu.	1 122	16 900 000	1 044	15 600 000
Median	1 904	36 180 000	1 961	34 240 000
Mean	4 415	77 050 000	4 335	66 400 000
3rd Qu.	3 320	60 660 000	3 274	53 990 000
Max.	125 571	1 913 000 000	123 954	1 555 220 000

Table 4: Statistics of the Yandex Queries