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Economic Inequality and Environmental Quality: Evidence of Pollution Shifting in Russia

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Abstract

This paper utilizes the Russian Statistical Agency's data on air pollution in Russia to analyze the impact of economic inequalities among Russia's regions on environmental degradation. Controlling for the absolute level of income, we find that regions with lower incomes *relative* to those of neighboring regions have more uncontrolled air pollution. Differences in uncontrolled pollution do not appear to be attributable to differences in spending on pollution control, suggesting that facility siting provides the dominant explanation. In addition, we find that greater within-region inequalities in income and in the provision of public goods are associated with greater uncontrolled air pollution.

Keywords: Air pollution; environmental inequality; pollution shifting; regional inequality; environmental Kuznets curve; Russia - environment.

JEL codes: P25, P28, Q53, Q56, R11

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1 Introduction

In recent years, a growing literature has examined how socio-economic variables affect environmental quality. Much of this research has focused on the impact of economic growth, in particular on whether an "environmental Kuznets curve" exists such that pollution initially rises with higher per capita income but then diminishes once a certain income threshold has been reached.

This paper adds to this literature by examining inter-regional variation in air pollution in Russia in the period 2000-2005. In addition to per capita income, we analyze how economic inequalities within and across regions are correlated with environmental outcomes.

The results suggest that economic inequalities affect air pollution in Russia. Greater income inequality within a region is associated with more pollution, implying that it is not only the level of income that matters but also its distribution. Inter-regional inequality, here measured as the difference between per capita income in the region and in the larger federal district to which it belongs, has a significant adverse effect, suggesting that "pollution shifting" plays an important role in Russia's environmental outcomes. In addition, regions with fewer hospital beds per person tend to have greater air pollution, suggesting that the same imbalances that underlie uneven provision of public goods also contribute to environmental disparities.

The paper is organized as follows. Section 2 reviews the literature on the relationship between economic inequality and environmental quality. Section 3 discusses the Russian case and the data used in this study. Section 4 presents our econometric model, and Section 5 reports the results of the analysis. Section 6 offers concluding remarks.

2 Economic Inequality and Environmental Quality

The extent to which economic activity generates pollution varies across time and space. If pollution per unit income were a fixed coefficient, the "scale effect" of higher incomes would map directly into lower environmental quality. But two other variables complicate the picture.

The first is changes in economic structure that accompany growth. For example, if during the growth process the share of services rises relative to that of industry, and services are less pollution-intensive, this "composition effect" will reduce the pollution/income ratio. Yet unless the size of pollution-intensive sectors declines absolutely – not simply relative to other sectors – total pollution will continue to rise with income, albeit at a diminishing rate.

The second variable is technological change that alters per-unit pollution associated with a given good or service. If pollution-reducing innovations occur, this "technology effect" could lead to declines not only in the pollution/income ratio but also in the total amount of pollution.

The relative magnitudes of the scale, composition, and technology effects of income growth underpin debates on the environmental Kuznets curve (EKC), which maps an inverted U-shaped relation between pollution and per capita income. In an international study, Grossman and Krueger (1995) found that a number of pollutants display this pattern. They hypothesized that pollution reductions at higher per capita income levels are driven primarily by an "induced policy response" in the form of environmental regulations that spur the technology effect. In a subsequent paper, Grossman and Krueger (1996) spell out a key implication: environmental improvements require "vigilance and advocacy in each and every location" to bring about the policies that mediate the income-environment relation.

The empirical studies inspired by the EKC hypothesis have produced mixed results, with the findings apparently dependent, among other things, on the set of countries, econometric specifications, and the chosen measures of environmental quality (for reviews, see Stern 2004 and Dinda 2004).

Some researchers have also examined other socio-economic factors that may affect environmental quality. Pursuing the Grossman-Krueger insight as to the role of "vigilance and advocacy," a number of studies have examined the impact of governance variables. Torras and Boyce (1998) found that literacy, political rights and civil liberties have strong positive impacts on environmental quality, particularly in low-income countries. Barrett and Graddy (2000) similarly conclude that an increase in civil and political liberties significantly improves environmental quality. Farzin and Bond (2006) find that democracy and associated freedoms contribute to decreased pollution.

In an analysis of the 50 U.S. states, Boyce *et al.* (1999) find that unequal distribution of power – proxied by data on voter participation, educational attainment, and fiscal policies – adversely affects the strength of environmental policies and environmental quality. Torras (2006) obtains similar results in an international analysis of the impact of power inequalities, and McPherson and Nieswiadomy (2005) find that birds and mammals are more threatened in countries with weaker protections of political rights and civil liberties, and greater political instability. Other studies have found a link between corruption and pollution (Lopez and Mitra 2000; Dasgupta *et al.* 2006).

Economic inequality is another socio-economic variable that may help to explain variations in environmental quality. Consumers of goods and services that are produced by polluting industries often are spatially and socially separated from the people who bear the impacts of the pollution – phenomena that Princen (1997) terms “distancing” and “shading.” In general, we can expect those who benefit from the production and consumption of these goods and services to be more affluent than those on the receiving end of the resulting pollution (for discussion, see Boyce 2007). Ownership of productive assets and household consumption both are highly correlated with income; hence gains from cost externalization that accrue via producer surplus and consumer surplus are correlated with income, too. On the other hand, a number of studies have found that low-income communities and minorities often bear disproportionate pollution burdens (see, for example, Ash and Fetter 2004; Pastor 2007).

If the net benefits (benefits minus costs) of environmentally degrading activities tend to be positively correlated with income and wealth, we can expect wider economic inequalities to be associated with more pollution. Insofar as policymakers follow the prescriptions of cost-benefit analysis – as opposed to being swayed by considerations of equity or the right to a clean and safe environment – wider income inequalities serve to magnify benefits to consumers, as measured by willingness to pay for the products of polluting industries, while diminishing the costs of pollution, as measured by the willingness of impacted communities to pay for a cleaner environment. Furthermore, if policymakers are influenced by the distribution of political power, and this is correlated with the distribution of income and wealth, economic inequalities also may weaken the extent of effective “vigilance and advocacy” for pollution control.

Several empirical studies have found that income inequality adversely affects environmental quality, although the topic has yet to receive attention comparable to that given to per capita income. Magnani (2000) finds that reductions in pollution are more likely if a country's economic growth is accompanied by improvements in income equality. In a study of tropical countries, Koop and Tole (2001) conclude that inequalities of income and landownership tend to exacerbate deforestation. Mikkelson *et al.* (2007) and Holland *et al.* (2009) find income inequality to be a statistically significant predictor of biodiversity loss.

Inequalities exist not only within countries and regions, however, but also among them. International and inter-regional trade can significantly affect the composition of production, and hence the associated environmental impacts. In particular, trade opens the possibility of “pollution shifting,” whereby consumers rely increasingly upon imports of goods whose production generates pollution elsewhere.[1]

[1] In one of the few empirical studies of this issue, Heil and Selden (2001) interact trade measures with income and find evidence of pollution shifting from high-income to lower-income countries in the case of carbon emissions. For further discussion of the environmental impacts of international trade, see Boyce (2009).

In this paper, we develop a framework that considers inter-regional as well as intra-regional inequalities. One problem that such an analysis must confront is the difficulty of distinguishing between absolute income and relative income. If the latter is understood as income relative to all other locations in the sample, the two income variables become indistinguishable. Our solution to this problem is to define relative income not in relation to the sample as a whole (in this case, all Russian regions) but rather in relation to the subset of contiguous regions that belong to the same federal district. The rationale for this focus on "neighborhood effects" is that decisions with regard to the siting of industrial facilities often are constrained by geographical considerations such as proximity to inputs and product markets (for discussion, see Pastor 2007). If so, what matters may not be a location's income relative to that of the nation as a whole, but rather its income relative to that of alternative sites within a more restricted range.

3 Pollution, Income, and Inequality in Russia

3.1 Why Russia?

The Russian Federation consists of 83 politically equal subjects. Specifically, there are 21 national territorial entities (republics), two federal cities (Moscow and St. Petersburg), 46 provinces (oblasts), 9 territories, and 5 autonomous districts. In this paper these subjects are called "regions".[2] Each region is assigned to one of seven federal districts (Figure 1). Prior to the

[2] The Constitution of 1993 established 89 regions, several of which were merged in 2003, 2005, 2006, and 2007. In this paper we use the 1993 classification system which is consistent with data published for 2000, 2004, and 2005.

break-up of the Soviet Union, economic disparities among these regions were muted by central government policies, including universal healthcare and education. Income inequality was relatively low by international standards, with a Gini coefficient of 0.26 in 1991.[3]

Figure 1: Russian Federation: Federal Districts (Goskomstat, 2006)

The post-Soviet period has been marked by dramatic increases in inequalities. By the turn of the century, the Gini coefficient of income distribution had risen to 0.40. Across regions, average per capita annual incomes in 2005 ranged from 10,008 rubles in the Republic of Ingushetiya to 141,977 rubles in the City of Moscow[4] (see Figure 2). Inequalities within regions ranged from 0.31 in Ivanovskaya Oblast to 0.57 in the City of Moscow (see Figure 3 for regional differences in the income share of the poorest quintile).

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[3] Source: Goskomstat (Federal State Statistics Service of Russia). Gini coefficients available online at http://www.demogr.mpg.de/cgi-bin/databases/cdb/cdb.php?vi=203&ci=6&di=2&id=0.

[4] These values have been adjusted for inflation.

Figure 2: Inter-regional Differences in Average Incomes in 2005 (Goskomstat, 2006)

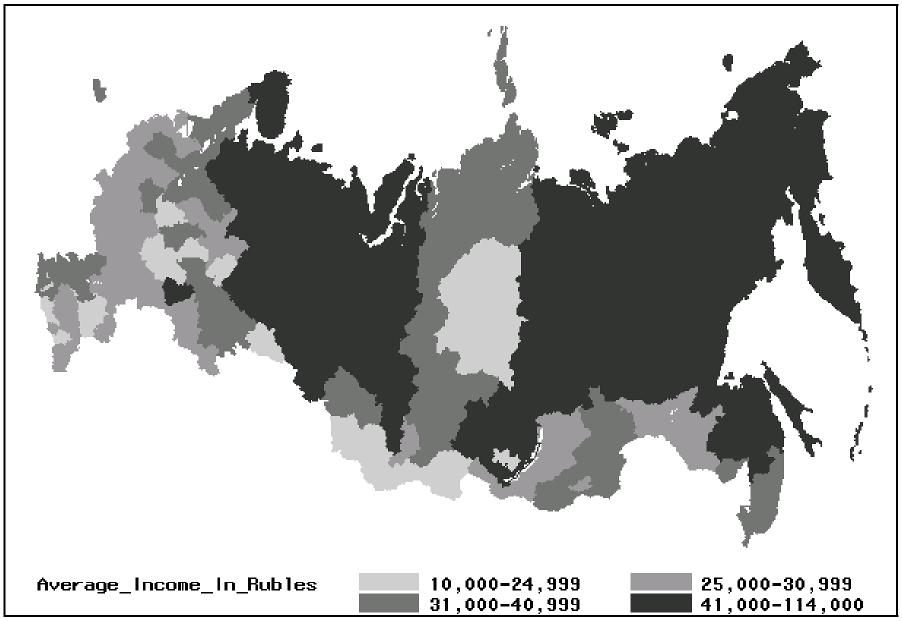
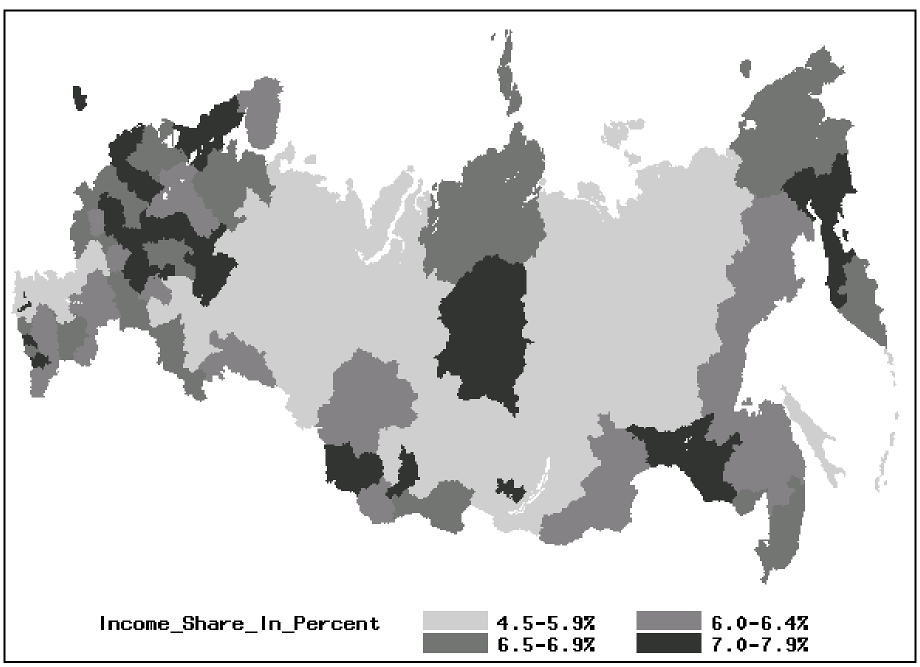


Figure 3: Inter-regional Differences in the Income Share of the Poorest Quintile (Goskomstat, 2006)



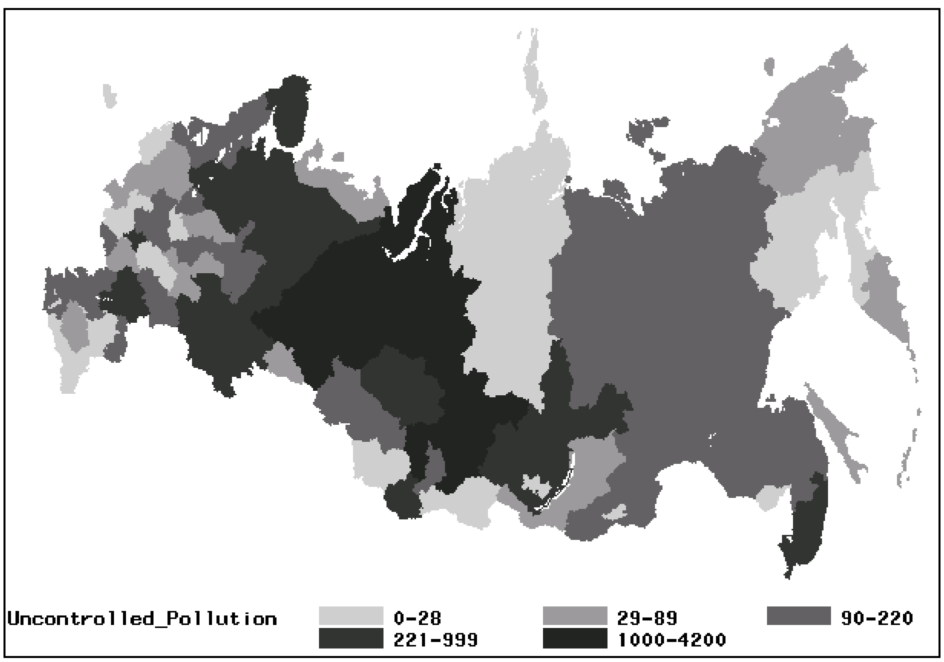
Several studies have examined the role of inter-regional disparities in the increasing income inequality in post-Soviet Russia. Fedorov (2002) found that polarization is taking place between the capital city and "export region" and the rest of the country. Yemtsov (2003) reported that inequality among Russian regions accounts for a large and increasing share of overall inequality. Zubarevich (2005) similarly concluded that inequalities among regions are large and continue to increase.

A study by the World Bank (2005) found that inter-regional inequality declined somewhat in the 1999–2002 period, although this convergence was not statistically significant. This period immediately followed the Russian economic crisis of 1998, when devaluation of the ruble gave a strong boost to the previously struggling domestic industries and thereby slowed inter-regional divergence. However, soon thereafter the rise of oil prices reversed this trend. Bradshaw and Vartapetov (2003) find that while there existed a short period of convergence between 1998 and 2000, inter-regional inequality has increased thereafter. In particular, they find that inter-regional income inequality increased thereafter.

These changes in income distribution in the post-Soviet period have been accompanied by striking changes in environmental conditions. For example, between 1993 and 2005 the emissions of primary pollutants for the Smolenskiy region decreased by 73 percent, while the emissions for the Orenburg region increased by 236 percent in the same period (Goskomstat 1998, 2001). The production of toxic wastes increased 37 times in the Republic of Komi (from 144,000 tons to 5.38 million tons) between 1997 and 2000, while in other regions it fell dramatically (for example, in the Ulianovsk region it decreased from 587,600 tons to 80,700 tons) (ibid).

Data on uncontrolled air pollution in Russia show significant differences among the regions (see Figure 4). In the Tyumen Oblast and Hanty-Mansiiskiy Autonomous Region emissions exceeded 3000 thousand tons. In the Republic of Ingushetiya and the Republic of Adygeya emissions were less than 3 thousand tons.

Figure 4: Uncontrolled Air Pollution in Russia in 2005 (Goskomstat, 2006)



For these reasons, the Russian Federation offers fertile ground for the analysis of linkages between environmental degradation and inequality.

3.2 Data

The data for this study come from the Federal State Statistics Service of Russia (Goskomstat). The variables and their definitions are listed in Table 1. Descriptive statistics are provided in Table 2. Environmental data at the regional level are scarce, and are published only sporadically. The only years for which air pollution data are available are 2000, 2004, and 2005. In this period, data on industry share of gross regional product (GRP) and income share of the poorest quintile are available only for the year 2005.

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Table 1: Variable Names and Definitions

Variable name	**Variable notation**	**Variable definition**	**Unit of measurement**	**Year(s)**
Uncontrolled air pollution	m_{it}	Total air pollution – controlled air pollution	Thousands of tons	2000, 2004, 2005
Absolute per capita income	y_{it}	Average monthly income	Constant 2000 rubles	2000, 2004, 2005
Income inequality	$INEQ_i$	Income share of the bottom quintile	Percent	2005
People per hospital bed	$PPHB_{it}$	Number of people per 1 hospital bed		2000, 2004, 2005
Land area	$LAND_i$	Land area of the region	Thousands of square kilometers	2005
Industry share of GRP	$INDUSTRY_i$	Share of industry in region's Gross Regional Product	Percent	2005

Table 2: Descriptive Statistics

Variable name	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Uncontrolled air pollution	282.2	633.3	1.4	4,178.8
Absolute income per capita	3240.8	1921.3	834.0	11,831.4
Income inequality	6.4	0.83	2.9	7.9
People per hospital bed	86.9	24.3	33.6	250.2
Land area	236.1	463.5	1.1	3,083.5
Industry share of GRP	29.9	15.2	2.7	69.2

3.3 Relative income measure

To measure each region's relative status, Russia's regions were divided into seven groups, corresponding to the seven federal districts of the Russian Federation (see Figure 1). The population-weighted average income was then calculated for each group for each year. To calculate the relative income in region *i* in year *t*, $DIFF_{it}$, each region's average income was subtracted from the average income of its federal district:

$$DIFF_{it} = \sum_{j=1}^{n}(w_j y_{jt}) - (y_{it}) \qquad \text{(Equation 1)}$$

where w_j = region *j* 's share of the total population in its federal district; y_{jt} = region *j* 's average income in time *t*; y_{it} = region *i* 's average income in time *t*; and $i \in j$. Thus a negative value of $DIFF_{it}$ indicates that region *i* has a higher per capita income relative to the other regions in the same federal district in year *t*.

The decision to use the federal districts, as opposed (for example) to immediately adjacent regions, to calculate $DIFF_{it}$ is based on the fact that production (and hence, pollution-shifting) decisions in Russia are increasingly made at levels that supersede the authority of the individual region. There are two major reasons for this. The first is that holding companies have become more common in Russia, with a few individuals (typically based in Moscow or a major regional center) holding majority stakes in a number of large industrial enterprises with operational units that are not necessarily located in adjacent regions.

The second reason concerns the changing role of the federal government in the Russian economy. In 2000, Vladimir Putin reinstated the system of federal districts and deployed special presidential envoys to serve as liaisons between regional governments and the federal government. This system has allowed the federal government to exercise increasing control over regions. At the same time, the ownership stake of the federal government in many holding companies (and in some cases, entire industries) has been increasing, with high-ranking government officials sitting on their boards of directors (for example, Dmitriy Medvedev, current president of Russia, formerly chaired the board of directors of Gazprom, the natural gas conglomerate).

4 Model and Econometric Issues

The focus of this study is the relationship between pollution, average income, and relative income. Our basic econometric model is:

$$m_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 (y_{it})^2 + \beta_3 DIFF_{it} + \beta_4 INEQ_i + \beta_5 PPHB_{it} + \beta_6 INDUSTRY_i + \beta_7 LAND_i + e_{it}$$

(Equation 2)

where m_{it} = uncontrolled air pollution in region i in year t; y_{it} and y_{it}^2 are average monthly income and average monthly income squared; $DIFF_{it}$ = region i 's relative income in year t; $INEQ_i$ = the income share of the bottom quintile; and $PPHB_{it}$ = the number of people per hospital bed, serving as a proxy for inter-regional inequalities in the provision of public goods. The right-hand side variables $LAND_i$ (land area) and $INDUSTRY_i$ (share of industry in GRP) are included to control for the fact that larger and more industrialized regions are expected to have more uncontrolled pollution, holding other variables constant. Finally, ε_{it} = a random error term.

The variables y_{it} and y_{it}^2 are traditionally included in EKC model specifications. Uncontrolled pollution exhibits an inverted U-shaped relationship with average income if $\beta_1 > 0$, $\beta_2 < 0$, and the turning point, $-\beta_1/2\beta_2$, occurs within the income range. The signs of β_3, β_4, and β_5 are of particular interest. If $\beta_3 > 0$, higher incomes in the other regions in the same federal district are associated with more uncontrolled pollution in region *i*. If $\beta_4 < 0$ and $\beta_5 > 0$, regions with greater intra-regional income inequality and lower provision of public goods, respectively, have more uncontrolled pollution.

To address the possibility that omitted variables account for some of the heterogeneity among Russia's regions, an error components model is estimated:

$$\varepsilon_{it} = c_i + v_t + u_{it} \qquad \textit{(Equation 3)}$$

where c_i is a region effect, v_t is a year effect, and u_{it} is the remaining error term. Dummy variables are included to capture the year effect. To control for the region effect, both fixed-effects and random-effects versions of Equation 2 are estimated.

The fixed-effects model does not allow the estimation of coefficients associated with time-invariant variables (Wooldridge, 2002, Hsiao, 2003, Plumpter and Troeger, 2007). To deal with this problem, the fixed-effects model is estimated using Fixed Effects Vector Decomposition (FEVD), a three-stage procedure that allows us to estimate the coefficients for time-invariant variables.

5 Results

The results are reported in Table 3. In the fixed-effects model (column 2), the null hypothesis of homogeneity among the regions is rejected, implying that pooled cross-sectional estimators (in column 1) are inefficient and may be biased. There is no evidence of first-order autocorrelation among the error terms u_{it}.

The first observation that can be made based on these results is that there is no evidence that the relationship between uncontrolled air pollution and average income follows an inverted U-shaped curve in Russia: instead, holding other variables constant, uncontrolled pollution increases monotonically with income (this is illustrated in Figure 5).

Table 3: Inequality and Uncontrolled Air Pollution: Econometric Results

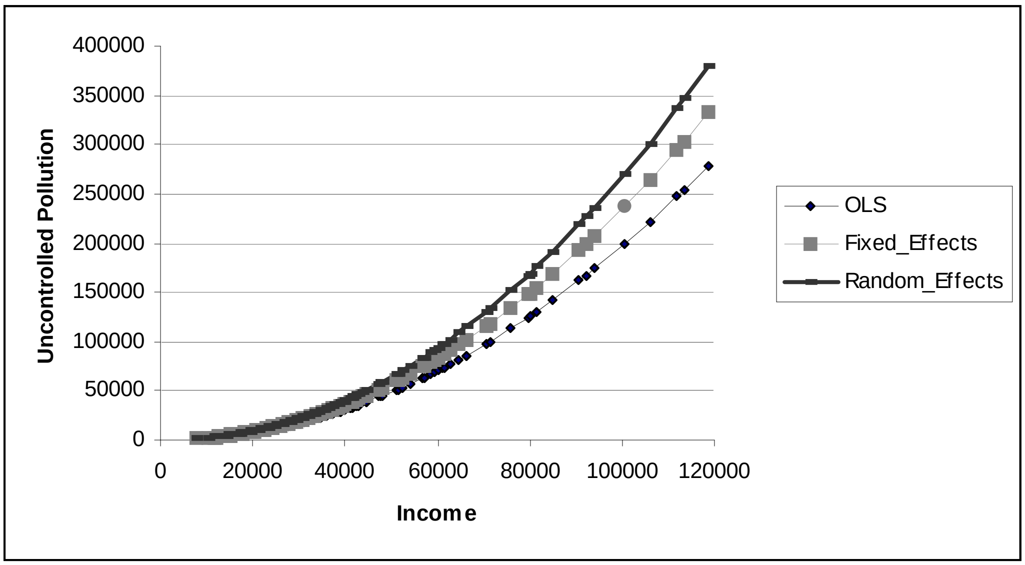
	(1) Cross Section	(2) Fixed Effects	(3) Random Effects

Constant	654.97 (510.08)	336.01 (502.15)	1130.04 (645.60)
Absolute per capita income	-0.04 (0.08)	-0.06 (0.08)	-0.14** (0.07)
(Absolute per capita income)^2	2.0E-5* (7.2E-6)	2.4E-5* (6.9E-6)	2.8E-5 (5.1E-6)
$DIFF_{it}$	0.21* (0.04)	0.18* (0.04)	0.15* (0.04)
Income share of the bottom quintile	-210.02* (51.06)	-167.31* (50.65)	-232.45* (72.09)
People per hospital bed	5.59* (1.92)	6.73* (1.86)	3.73 (2.42)
Industry share of GRP	11.24* (1.97)	9.91* (1.91)	10.96* (3.09)
Land area	0.44* (0.06)	0.41* (0.06)	0.42* (0.10)
Unexplained part of the FE vector	-	18.18* (3.69)	-
Period effect (2004 = 1)	-44.14 (73.62)	-59.07 (71.19)	6.09 (48.99)
Period effect (2005 = 1)	-95.93 (82.35)	-107.53 (79.63)	-23.67 (62.90)
Adjusted R^2	0.5060	0.5493	0.3537
Homogeneity test (DF)	-	25.21 (1, 245)	-
RSS	39879922	36158299	6770310
n	255	255	255

Note: Standard errors in parentheses.
* statistically significant at the 0.01 level
** statistically significant at the 0.05 level

The estimated coefficient on $DIFF_{it}$ is positive, indicating that holding absolute income and other variables constant, higher values of income in other regions in the same federal district are associated with more uncontrolled pollution in region *i*. This result is quite robust: the coefficient is positive and statistically significant at the 0.01 level under all three specifications.

Figure 5: The Relationship between Income and Uncontrolled Pollution
under Alternative Model Specifications



The estimated coefficients on the income share of the bottom quintile ($INEQ_i$) and people per hospital bed ($PPHB_{it}$) are also of expected signs, and statistically significant in all but one case. These results are consistent with the hypotheses that regions characterized by greater within-region income equality and greater provision of public goods have less uncontrolled air pollution.

6 Concluding Remarks

The objective of this paper has been to investigate whether a region's income *relative to that of its neighbors* has an impact on its environmental quality. We test this hypothesis by using a method that distinguishes between the effects of changes in the absolute level of income and the effects of changes in the relative level of income, controlling for the former. The results are strongly supportive of the hypothesis that higher incomes in the other regions in the same federal district are associated with more uncontrolled air pollution in a given region. This finding suggests that pollution shifting has been a significant factor in the spatial distribution of air pollution in Russia.

We also find that intra-regional income inequality has an adverse effect on air pollution. This finding is consistent with the results of several international studies that have examined this aspect of the relationship between economic inequality and environmental quality. Our results suggest that further research on the environmental impacts of income inequality in general, and inter-regional inequality in particular, is warranted. It would be interesting to examine whether the relationship between inter-regional and intra-regional income inequalities and air pollution can be found for other aspects of environmental quality in Russia, a task currently hindered by the paucity of Russian environmental data at the regional level. It would also be interesting to document the specific mechanisms through which inequalities affect environmental quality in a specific industry or a set of industries. Finally, given the significant and persistent international inequalities that exist in the world today, more research is needed to shed light on the question of whether pollution shifting among countries in the world is contributing to environmental improvements in the relatively high-income countries at the expense of environmental quality elsewhere.

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