Has Communism's Collapse Greened Eastern Europe's Polluted Cities?

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April 12, 2002

Abstract

Under communism, Eastern Europe's cities were significantly more polluted than their Western European counterparts. An unintended consequence of communism's decline is to reduce national air emissions and to improve urban environmental quality. This paper uses a number of new data sets to measure these gains. It investigates the local public good improvement's incidence and impact on urban quality of life. A city level Environmental Kuznets Curve is estimated for three Eastern European nations.

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This paper was written for the NBER Environmental Conference on Advances in Empirical Environmental Policy Research to be presented May 17th 2002. I thank Melissa Ausman and Dora Costa for useful comments and Joanna Niedzialek and Krzystof Skotak for providing Polish ambient air quality data.

I. Introduction

Air pollution is a major urban disamenity. Over the last thirty years, major cities in Western Europe and the United States have experienced dramatic improvements in air quality. Ambient sulfur dioxide levels in Central London fell from 101 parts per billion in 1973 to 9 parts per billion by 1990.[1] In 1980, there were one hundred sixty-seven days in which the Los Angeles greater area's ozone level exceeded the national one hour ozone smog standard. By 1999, this standard was exceeded on only thirty-nine days.[2]

Eastern Europe's cities featured much higher pollution levels. In 1985, Prague's ambient sulfur dioxide level was four times higher than the average OECD city (Hertzman 1995 Table 3.11). In the 1990s, such cities have experienced a sharp pollution reduction. By the year 2000, every sulfur dioxide monitoring station's reading in Prague met the U.S National Ambient Air Quality Standard.

Pollution progress in Eastern Europe might surprise a strict believer in the Environmental Kuznets Curve. Eastern Europe's nations feature income levels to the left of the per-capita GNP Kuznets turning point estimated by Grossman and Krueger (1995). As these national economies grew starting after 1992, such scale effects could exacerbate pollution problems. The observed improvements in environmental conditions suggest that economic development and globalization have triggered environmentally friendly technique and composition effects.

[1] The data source is www.aeat.co.uk/netcen/airqual/.
[2] Based on a panel of U.S counties from 1995-2000 whose PM10 (particulate) levels were monitored and whose population was greater than 500,000 in 1990, the population elasticity of pollution production was 0.166 in 1995 and has declined by –0.011 per year.

This paper analyzes national emissions, energy consumption and urban ambient air pollution data to measure post-communist environmental progress in Eastern Europe relative to Western Europe.[3] Has convergence taken place such that pollution production per unit of economic activity is equal across Europe? A number of new urban ambient air quality data sets are assembled to test hypotheses concerning what types of cities have experienced the greatest pollution reductions and to provide new estimates of an Environmental Kuznets Curve for Eastern European cities.

The incidence of this urban local public goods improvement is examined. Air quality improvements in cultural centers such as Budapest, Krakow and Prague can improve their competitiveness as high amenity "consumer cities". As Eastern European nations join the European Union, their high quality of life cities will be better able to compete for tourists, footloose skilled workers, and the firms that hire them (Glaeser, Kolko and Saiz 2000). In contrast, smaller industrial cities will have improved air quality but will still be saddled with the communist legacy of deteriorating durable industrial infrastructure.

In the next section, national panel data from Eastern and Western Europe are used to test for post-communist convergence in emissions and energy intensity. Section III documents urban ambient air quality differentials across European cities. Section IV explores the incidence of the localized amenity improvements and Section V. concludes.

[3] Previous work on the environmental consequences of the communist transition includes Hertzman (1995), Krupnick, Harrison, Nickel and Toman (1996), Viguier (1999) and Hughes and Lovei (1999).

II. National Level Evidence of an Environmental Regime Shift in Eastern Europe

Communist nations produced output using energy and pollution intensive production processes. In 1993, Poland's carbon dioxide emissions per dollar of GNP produced was almost three times higher than England's (Klarer and Francis 1997 page 10). In the immediate aftermath of communism's collapse, pollution declined due to recession. Complementing this short run effect, the transition from communism to capitalism induced composition and technique effects that greatly reduced energy consumption and environmental degradation (Carter and Turnock 1993, Manser 1993, Klarer and Francis 1997, Hughes and Lovei 1999).[4]

This paper document the environmental regime shift in Eastern Europe using national panel data reported officially by the Parties to the Convention on Long-Range Transboundary Air Pollution.[5] The data are from 1980-1999 and cover emissions of sulfur dioxide, nitrogen oxide, volatile organic chemicals, and lead. Equation (1) presents the national emissions regression.

$$\begin{aligned} Y = \text{nation} &+ B1*(\text{Time Trend Pre-1990}) + B2*(\text{Time Trend starting in 1990}) + \\ &B3*(\text{Time Trend pre-1990})*(\text{East}) + B4*(\text{Time Trend starting in 1990})*\text{East} + U \end{aligned} \tag{1}$$

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[4] Between 1990 and 1999, Poland's service sector (as a share of GNP) grew from 42% to 60% and the Czech Republic's service sector grew from 45% to 55% (source World Bank).

[5] The data are available at http://www.emep.int/. The data set was created because of the Convention on Long Range Transboundary Air Pollution (LRTAP), signed in 1979. The convention establishes a broad framework for cooperative action on reducing the impact of air pollution and sets up a process for negotiating concrete measures to control emissions of air pollutants through legally binding protocols.

In equation (1), the dependent variable is the log of a nation's emissions in a given year. The dependent variable is regressed on a nation fixed effect and a splined time trend with the knot at the year 1990. The spline is interacted with an Eastern Europe dummy (East).

Table One reports four regression estimates of equation (1) to test the hypothesis that before the transition Eastern European emissions trended up, while after the transition nations have converged (i.e B2 is positive and B4 is negative).[6] This pattern is found for sulfur dioxide and nitrogen dioxide emissions but not for volatile organic compounds. The top two rows of Table One present the time trend in emissions for Western European nations. During the 1980s, emissions fell by 4.9% a year, and in the 1990s, the downward trend became steeper as emissions declined by 9.6% a year. Relative to Western European nations, the Eastern European nations experienced slower sulfur dioxide reductions before 1990 and steeper emissions reductions afterward. During the 1990s, sulfur dioxide emissions in Eastern European nations fell by 13.5% a year.

Perhaps not surprising, the two emissions associated mainly with driving (volatile organic compounds and lead) have not decreased as quickly in Eastern European nations relative to Western Europe. Increased car utilization using may explain why during the 1990s, lead emissions fell by 26% per year in the West and by 17% per year in the East.

To study within variation among the Eastern Block, Eastern Europe is divided into advanced reform (Czech Republic, Hungary and Poland) and slower reform nations.[7] The second column of Table Two shows that the slow reform nations have experienced a

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[6] To simplify the national regression tables, Eastern Europe is treated as a homogenous set. In the raw data, East and West Germany are unified in the 1980s. The regression results are robust to dropping Germany from the sample.

[7] Hughes and Lovei (1999) focus on trends from 1989 to 1995 for these two sets of nations.

steeper negative trend in sulfur dioxide emissions during the 1990s. This reflects the greater growth in economic activity in these economies.

Why Have National Emissions Fallen?

Emissions may be declining due to reductions in economic activity or shifts in industrial structure or changes in the methods of production and emissions from consumer goods.[8] To investigate the relative importance of these factors, national panel data from 1992 to 1999 is used to estimate equation (2):

Y = nation+b1*GNP+ b2*GNP^2+b3*log(energy)+b4*log(steel)+ b5*trend + U (2)

In equation (2), Y equals log(emissions per-capita) and "nation" is a vector of nation fixed effects and trend is the time trend. The other explanatory variables are all measured in per-capita terms. They include GNP and its square, energy consumption, and steel production.[9] The coefficients B3 and B4 measure how the scale of energy consumption and the scale of polluting production, steel, impact national emissions. The GNP coefficients allow for a test of whether a Kuznets Curve is observed in Europe.

[8] Recent empirical studies have parsed the gains in reducing lead emissions and ambient sulfur dioxide emissions into components related to scale, composition and technique (Hilton and Levinson 1998 and Antweiler, Copeland and Taylor 2001).

[9] The data source for steel production in Table Two is the International Iron and Steel Institute (see http://www.worldsteel.org/). The web site provides annual production data for major steel producers. There has been a sharp decline in steel production in the Eastern Bloc relative to the rest of the world. Between 1992 and 1999, steel production in the United States increased by 15.4% while for Bulgaria, Czech Poland, Romania, Russia, Slovakia and Ukraine; production during this time fell by 24.3%.
The data source for energy consumption, national annual population and GNP is the U.S Energy Information Administration (see http://www.eia.doe.gov/emeu/international/total.html#Carbon).

Table Two reports three regressions. Rising national income reduces sulfur dioxide and nitrogen dioxide emissions. Increased energy and steel raise all three measures of emissions. [10] A surprising finding is that energy consumption does not have a statistically significant impact on sulfur dioxide emissions (see IEA 1996). In the sulfur dioxide and nitrogen oxide regressions, the emissions elasticity with respect to steel production is large. To measure how much of the observed progress in sulfur dioxide emissions is due to changes in GNP, steel consumption, and energy consumption, the change in each of these variables between 1992 and 1999 was multiplied by its respective regression coefficient and summed. Changes in these observables can only explain 20% of the overall reduction in sulfur dioxide in Eastern European nations. This suggests that scale effects are not the major explanation for national emissions' dynamics. Holding scale constant, there is a large negative time trend for sulfur dioxide. This trend reflects a greening of technique effects.[11]

Energy Efficiency Convergence Between Eastern and Western Europe

Recent research by Schmalense, Stoker and Judson (1998) has estimated world environmental energy consumption Kuznets curves to test how the relationship between

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[10] Factors that have contributed to the greening of these economies include: economic reforms that eliminates price controls and subsidies, privatization and favorable conditions for foreign investments, trade and market liberalization (Hughes and Lovei 1999).

[11] To test for differential technique effects and for evidence of technique "convergence", equation (2) was also estimated including interactions with an Eastern Europe dummy and stratifications with respect to time (i.e early 1990s versus late 1990s). These regressions yielded few statistically significant results.

per-capita energy consumption per-capita and national per-capita GNP differs between poor nations, middle income, and rich nations. This section mimics their methodology but focuses solely on nations in Eastern and Western Europe. Was Eastern Europe more energy intensive than Western Europe in the early 1990s but by the late 1990s has convergence taken place such that there is no statistical difference in energy consumption between East and West for two economies with equal GNP per-capita?[12]

To test this hypothesis, equation (3) is estimated using national panel data on energy estimates from the U.S Energy Information Administration.

$$\text{Log(energy per-capita)} = \text{nation} + \text{year} + f(\text{GNP per-capita,East}) + U \qquad (3)$$

In equation (3), the log of energy consumption per-capita is regressed on nation, year fixed effects, a per-capita GNP polynomial, and its interactions with an Eastern Europe dummy.[13]

Table Three reports four regressions. Regression 1 is for the whole sample. The Eastern Europe interaction on GNP is statistically significant at the 5% level and thus we reject the hypothesis that the two sets of nations are using similar techniques in consumption and production. Evaluated at the sample median of $9,300, Eastern Europe's marginal propensity to consume energy is much higher than Western Europe's. Also in Table Three, the income "turning points" are calculated for both sets of nations. Eastern Europe reaches its turning point at a much lower income level than Western

[12] For details on energy intensity in Eastern Europe under communism see Hughes (1991).

Europe. This evidence supports the view that recently developing nations reach the turning point at lower levels of GNP per-capita. Regression 2 re-estimates equation (3) using data from 1996 and later. The key finding is evidence of convergence. The Eastern Europe polynomial's coefficients shrink in magnitude and are jointly statistically insignificant. The hypothesis that Eastern and Western Europe have similar technique effects in the latter half of the decade cannot be rejected.

Regressions 3 and 4 use a nation's annual carbon dioxide emissions per-capita as the dependent variable and find very similar results as the energy consumption findings. One interpretation of these results is that over the 1990s, composition and technique effects have converged such that scale of economic activity has equal effects on energy consumption in the two regions. Regression 5 uses a different data source for estimated national per-capita carbon dioxide emissions (Marland, Boden and Andres 2001). This is the data source used by Schmalense, Stoker and Judson (1998). The results are qualitatively similar to those reported in Regression 4 based on the EIA data.

III. Ambient Air Pollution Progress in Major Eastern and Western European Cities

Since economic activity is not uniformly distributed within nations, national emissions trends mask significant within-nation heterogeneity. In this section, ambient pollution data are used to test hypotheses concerning air pollution progress in Eastern Europe. Since no one large panel data set on European ambient air pollution exists, this section's results are based on assembling several data sets. One contribution of this

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[13] They spline GNP. Since there are a smaller set of nations in these regressions choose to work with a polynomial.

section is to analyze trends over a longer time horizon than previous studies of Eastern Europe.

Large cities in Eastern Europe are more polluted than large cities in Western Europe. Particulate levels were high due to coal burning by domestic sources, power and heating plants, and metallurgical plants. Sulfur dioxide levels were high due to power and industrial plants and household burning high sulfur coal and fuel oil (Hughes and Lovei 1999). Based on 1995 particulates data, the average particulate level across nine major Eastern European cities was 92 micrograms per cubic meter, while in twenty-one Western European cities it was 59 micrograms per cubic meter.[14] To study why this large differential exists, Table Four reports six cross-sectional regressions of equation (4).

$$\text{Log(ambient pollutant)} = \text{east} + \text{capital} + \log(\text{population}) + \log(\text{GNP}) + U \qquad (4)$$

In equation (4), the log of ambient air pollution is regressed on a city's log of its population, log of national per-capita GNP in 1995, a capital dummy, and an Eastern Europe dummy. The results are presented with and without log(GNP). Controlling for city population, particulates and sulfur dioxide are twice as high in Eastern European cities as in Western European cities.[15] Controlling for national GNP flips the sign on the Eastern Europe dummies. Based on this cross-sectional regression, richer nations have

[14] The data source is the 2001 World Development Indicators Report available at: http://www.worldbank.org/data/wdi2001/pdfs/tab3_13.pdf.

[15] City population is from Bergmann and the UN Statistics Division Cities Population Database (www.un.org/Depts/unsd/demog/ctry.htm).

cleaner cities.[16] Capital cities are significantly cleaner than non-capital cities.[17] While the small sample size in this regression must be kept in mind, controlling for city population and national income, Eastern European capital cities are much cleaner than their Western capital counter-parts.

Air Pollution in Eastern European Cities Has Fallen Faster than in Western European Cities

The European Economic Agency has collected ambient particulate and sulfur dioxide data for 40 European cities in 1988 and 1995.[18] Here, the data are used to test for evidence in convergence of air quality over time. Table Four reports five regressions. In regression 1, the log of ambient particulates is regressed on city fixed effect and a time trend and a time trend interacted with the Eastern Europe dummy. The average Western European city's particulates decreased by 3.5% per year during this time while the average Eastern European city's particulates decreased by 8.9%. Regression 2 reports the same regression but is weighted for each observation by city population. In this case, the Western European trend grows more negative (-6% per year) but the differential Eastern European effect vanishes. Given the higher level of pollution in Eastern European cities, the similar percentage decline is bringing about convergence of ambient pollution levels. Regression 3 and 4 report unweighted particulate regressions using the winter mean and the 24 hour high reading. Based on the 24 hour reading, there is no differential trend in

[16] An interaction of Eastern Europe multiplied by log(GNP) was statistically insignificant.
[17] The East capitals in the data set are: Bratislava Bucharest, Budapest , Kiev, Moscow , Prague, Sofia, Warsaw, Zagreb.

[18] The data were collected for the publication Europe's Environment: The Second Assessment (see http://air-climate.eionet.eu.int/databases/dobris.html).

percentage terms. Regression 5 reports the trend regression where the log of ambient sulfur dioxide is the dependent variable. In Western European cities, this pollutant has declined by 4.9% per year while in Eastern European cities it has declined by 6.5% per year.

Differences in Pollution Progress By City Type

Budapest, Krakow and Prague are three major Eastern European cities whose culture and architecture make them tourist magnets. Reduced air pollution will have the greatest quality of life impact in cities where people want to visit and work because pollution limits the time people spend outside and their enjoyment from being outdoors (Bresnahan, Dickie and Gerking 1997).

Hungary's Ministry of the Environment has collected data for ambient sulfur dioxide and nitrogen dioxide for twenty-one cities covering the years 1990-1998. Table Six reports time trends in pollution for these different city types. The largest declines in sulfur dioxide concentrations have taken place in smaller cities. While Budapest is the largest city in Hungary, in 1990 its ambient sulfur dioxide level placed it in the middle of the city sulfur dioxide distribution. The cities with the highest sulfur dioxide levels were Salgotarjan, Pecs, and, Tatabanya. Budapest's sulfur dioxide level actually increased from 1990 to 1998 such that by 1998 it was the third dirtiest city in Hungary. While its sulfur dioxide levels increased, Budapest's nitrogen dioxide level did not change between 1990 and 1998. In both years, Budapest was the 6th (out of 21) most polluted city in

Hungary. The dirtiest city in Hungary in 1990, Tatabanya, featured an annual sulfur dioxide mean of 76. By 1998, its pollution level had fallen to 12.

Krakow is considered to be Poland's most beautiful city and with a population of over 750,000 it is its largest city after Warsaw. The city has an excellent air pollution monitoring and reporting system. Monthly data is available for seven monitoring stations from 1995 to 2000. The top row of Table Seven documents the sharp improvement across ambient pollutants during this time period. Krakow has experienced on average a 7.4% annual reduction in particulates and an 11% annual reduction in sulfur dioxide, and has achieved significant progress in the "old downtown".[19] However, there has been little gains in reducing nitrogen dioxide levels.

The bottom half of Table Seven compares progress in Krakow to progress across thirty-one cities in Poland. The panel database covers the years 1994-2000 for these cities across fifty-one monitoring stations. The data are from the National Network of Basic Stations (NNBS), coordinated by the state inspectorate for environmental protection. Relative to Krakow, Poland's other cities have made less progress in reducing particulates and more progress in reducing sulfur dioxide. In Poland overall, ambient sulfur dioxide levels have fallen by 16.4% a year, and ozone levels are rising at 3.4% a year. Similar to Hungary, the greatest pollution gains are taking place in smaller cities. The bottom two rows of Table Seven report estimates of the regression:

$$\text{Log(pollutant)} = c + b^*\log(\text{city population}) + U \qquad (5)$$

[19] Polish authorities attribute the progress in reducing Krakow's pollution levels to emissions control technology at the The Sendzimir Steelworks, one of the largest Poland's industrial plants, and the phase out of coal fired boilers and stoves through incentive programs.

Poland's pollution elasticity for both particulates and sulfur dioxide is .25, rather large when compared to the United States. As shown in the bottom row of the table, this elasticity is not falling over time.

Prague is the only central European city left untouched by World War II. It was named one of the European Union's Cities of Culture in 2000. Of the nine cities named, the only two from Eastern Europe are Krakow and Prague. High quality monitoring level data is available for the Czech Republic but only for the years 1997 and 2000 for ambient particulate matter and sulfur dioxide. There are roughly one hundred monitoring stations across the nation.[20] As reported in Table Eight, between 1997 and 2000, urban sulfur dioxide concentrations fell by over 63% and particulates declined by over 20%. Prague has experienced sharp sulfur dioxide reductions but not as impressive particulate reductions. One monitoring station outlier has caused the less impressive particulate reductions in the Czech Republic. In 1997, three monitoring stations in Prague featured particulate levels that exceeded NAAQS (National Ambient Air Quality Standards). By the year 2000 all were below the NAAQS standard.

By the year 2000, the three major cultural cities in the Czech Republic, Hungary, and Poland (Budapest, Krakow, and Prague) are clean cities. Based on U.S NAAQS, all of the monitoring stations are now in compliance. Slight ozone degradation, probably caused by increased car use, has taken place in Poland. While the major cities in these nations are clean, the steepest pollution reductions have taken place in smaller cities

[20] The data can be accessed at www.chmi.cz/uoco/isko/tab_roc/1997_enh/ENG.

The improvements in Eastern European cities are especially notable because these nations feature GNP per-capita levels that are lower than the income "turning point" identified by Grossman and Krueger (1995). Using Global Environmental Monitoring Systems data (GEMS), it is not possible to test whether ex-communist cities lie on the same Kuznets curve as Western European cities.[21] The data stop in 1992 and only four cities in Eastern Europe are included in the GEMS. The sample of Prague, Wroclaw, Jarczew, and Zagreb, is both small and unlikely to be representative of major communist cities.[22]

While an ex-communist air quality panel does not exist, it can be approximated by pooling the ambient sulfur dioxide data by city/year from Poland, Czech, and Hungary data for the years 1994-2000. In Table Nine, the unit of observation is the monitoring station in Poland, the Czech Republic, and the city in Hungary. The table reports three regression estimates of equation (6):

$$\text{Log}(so2) = \text{nation} + \text{capital} + B1*\log(\text{population}) + B2*\log(\text{GNP}) + B3*\text{Trend}+U \qquad (6)$$

In equation (6), population is the city's population, and GNP is the nation's per-capita GNP by year. Since GNP does not vary by city, the standard errors are clustered within nation. The three regressions are identical accept that in the left column no nation fixed effects are included, in the middle column nation fixed are included, and in the right

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[21] The GEMS data has been used in several prominent Environmental Kuznets Curves studies including Grossman and Krueger (1995), Harbaugh, Levinson and Wilson (2002) and Antweiler, Copeland and Taylor (2001).

[22] Using the GEMS data through 1992, Antweiler, Copeland and Taylor (2001) find that the marginal impact of GNP on ambient sulfur dioxide is statistically different in communist cities versus non-communist cities.

column city fixed effects are included. The key finding from this table is the very large positive income effect. Without nation fixed effects, the pollution/income elasticity is 1.38 and this grows to 2.92 when national fixed effects or city fixed effects are included. These cities are to the left of the Kuznets "turning point". Despite the fact that pollution rises with income, the time trend is very large (-17% per year). These two facts support the hypothesis advanced by Dasgupta, Laplante, Wang, and Wheeler (2002); that for developing countries, the Kuznets curve is shifting down over time.

Communist leaders had the power to zone areas to achieve a spatial separation of production and residential location. Since air pollution is a local public bad, the only way that the leaders could consume good air quality is to make sure that the whole city is clean. Table Nine's bottom row indicates that for the Czech Republic, Hungary, and Poland, the capital cities were significantly cleaner than comparable non-capital cities.

IV. The Incidence of the Urban Pollution Reduction

Using a variety of methods, the valuation literature has confirmed that people value reductions in urban ambient air pollution. [23] Willingness to pay for a reduction in pollution will differ by city. People would be willing to pay more for a pollution reduction in a city with temperate climate and cultural opportunities where people want to spend time outside. Willingness to pay for a pollution reduction would be much lower

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[23] This has been documented using hedonics, (Smith and Hwang (1995) and Chay and Greenstone (1998)), health production function estimates (Chay and Greenstone 1999 and using contingent valuation (Alberini and Krupnick 1999). Recently, public health researchers have measured the health gains in specific transition cities see Ebert, Brauer, Cyrys, Tuch, Kreyling, Wichmann and Heinrich (2001).

if the improvement were to take place in a bleak industrial city. Even if air quality improves, the rusting industrial infrastructure and communist housing stock would remain. Disposing of such undesirable infrastructure is costly and would slow the redevelopment of the newly cleaner city. Since the greatest pollution gains are taking place in such cities, the quality of life gains from the transition may be smaller than the percentage reductions in measured pollution. This hypothesis merits further research.[24]

Who gains from the improvement in air quality in major urban areas such as Krakow and Prague? In an open economy featuring low migration costs, landowners would be the major beneficiaries. But, Deichmann and Henderson (1999) point out that the new housing construction market in Poland is not functioning well. If people cannot migrate in from other cities, then workers and renters who already live in the city would receive a windfall. Whether changes within the metropolitan area in air pollution have significantly affected residential location patterns could be investigated using the methods developed in Sieg, Smith, Banzhaf, and Walsh (2000).

V. Conclusion

Communism's demise has reduced national emissions and energy intensity in Eastern Europe. Sulfur dioxide emissions fell by 4% more per year in Eastern Europe than in Western Europe during the 1990s. Over the 1990s, energy intensity per dollar of GNP has equalized between Western and Eastern Europe. This national progress has led to a sharp reduction in ambient air pollution in major cities. In the year 2000, cultural centers such as Budapest, Krakow, and Prague met U.S pollution standards.

[24] In the United States, the greatest pollution reductions have taken place in the Los Angeles region, a growing area where home prices are very high.

Improvements in air quality will have its largest effects on these "consumer cities". In such areas, GNP growth over the 1990s represents a lower bound on standard of living improvements as the externality has been lifted.

Progress in the Czech Republic, Hungary, and Poland is especially notable because these nations have incomes less than the Grossman and Krueger "turning point". As shown in Table Nine, for these three countries, increasing GNP raises pollution levels but air pollution is trending down over time.

While air pollution is a significant urban disamenity, its reduction is unlikely to be sufficient to transform dreary communist industrial cities into high quality of life areas where high skilled service sector workers want to live and work. The durability of communist industrial and residential infrastructure will limit the opportunities for such cities to become quality of life hubs.

At least two caveats apply to this study. First, due to data limitations, the urban ambient pollution analysis focused on advanced reform nations. In slow reform nations such as Romania, urban particulate levels slightly increased between 1990 and 1996 (REC 1999). Second, this paper has not attempted to measure cross-boundary spillovers mitigated by the death of communism. Given that Hungary and Poland have been major exporters of sulfur dioxide emissions to Western European nations such as Finland, France and Germany, future research might investigate western environmental gains.

References

Alberini, Anna and Alan Krupnick. Air Quality and Episodes of Acute Respiratory Illness in Taiwan Cities: Evidence from Survey Data. *Journal of Urban Economics*, vol. 44, no. 1, July 1998, 68-92.

Antweiler, Werner, Brian Copeland and Scott Taylor. Is Free Trade Good For the Environment? *American Economic Review*, September 2001 91(4) 877-908.

Aslund, Anders. Building Capitalism. The Transformation of the Former Soviet Bloc, Cambridge University Press 2002.

Bresnahan, Brian, Mark Dickie and Shelby Gerking. Averting Behavior and Urban Air Pollution. *Land Economics,* vol. 73, no. 3, August 1997, 340-57.

Brinkhoff, Thomas. City Population. www.citypopulation.de

Carter, Francis and D. Turnock Environmental Problems in Eastern Europe edited by Francis Carter and D. Turnock Routledge 1993.

Chay, Kenneth and Michael Greenstone. The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced by a Recession. NBER Working Paper No. W7442 December 1999.

Chay, Kenneth and Michael Greenstone. Does Air Quality Matter? Evidence from the Housing Market NBER Working Paper No. W6826 December 1998.

Dasgupta, Susmita and Benoit Laplante, Hua Wang and David Wheeler. Confronting the Environmental Kuznets Curve. *Journal of Economic Perspectives*, 16(1) Winter 2002, 147-168.

Deichmann, Uwe and Vernon Henderson. Urban and Regional Dynamics in Poland. 1999 World Bank.

Ebert, Stefanie, Michael Brauer, Josef Cyrys, Thomas Tuch, Wolfgang Kreyling, H.E Wichmann and Joachim Heinrich. Air Quality in Postunifiation Erfurt, East Germany: Associating Changes in Pollutant Concentrations with Changes in Emissions. *Environmental Health Perspectives* 109(4), April 2001, 325-333.

European Environment Agency. Europe's Environment: The Second Assessment. Elsevier Science. 1998

Glaeser, Edward and Jed Kolko, Albert Saiz, Consumer City. NBER Working Paper No.w7790 Issued in July 2000

Grossman, Gene and Alan Krueger. Economic Growth and the Environment. *Quarterly Journal of Economics*. 353-377, 1995.

Harbaugh, William and Arik Levinson and David Wilson. Reexamining the Empirical Evidence for an Environmental Kuznets Curve. *Review of Economics and Statistics*, forthcoming.

Hertzman, Clyde. Environment and Health in Central and Eastern Europe. World Bank 1995.

Hilton, F. G. Hank and Arik Levinson. Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions. *Journal of Environmental Economics and Management* v35, n2 March 1998.

Hughes, Gordon. The Energy Sector and Problems of Energy Policy in Eastern Europe, *Oxford Review of Economic Policy*, vol. 7, no. 2, Summer 1991, 77-98.

Hughes, Gordon and Magda Lovei. Economic Reform and Environmental Performance in Transition Economies. Technical Paper, no. 446. Eastern Europe and Central Asia Pollution Management Series. Washington, D.C.: World Bank, 1999.

International Energy Agency. Air Pollution Control for Coal Fired Power Stations in Eastern Europe. IEAPER/24. April 1996.

Klarer, Jurg and Patric Francis. The Environmental Challenge for Central European Economies in Transition 1997. Wiley Press.

Krupnick, Alan, Kenneth Harrison, Eric Nickel and Michael Toman. The Value of Health Benefits from Ambient Air Quality Improvements in Central and Eastern Europe: An Exercise in Benefits Transfer. *Environmental and Resource Economics* v7, n4 June 1996: 307-32.

Manser, Roger. Failed Transitions: The Eastern European Economy and Environment since the fall of communism. The New Press, New York 1993.

Marland, G, T.A Boden and R.J Andres, 2001. Global, Regional and National CO2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S Department of Energy (cdiac.ornl.gov/trends/emis/tre_coun.htm).

Ministry for Environment; Data on Hungary's Environment. Budapest 2001.

Regional Economic Center. Reduction of So2 and Particulate Emissions Synthesis Report. Sofia Initiative on Local Air Quality. 1999. (www.rec.org).

Schmalensee, Richard, Thomas Stoker and Ruth Judson. World Carbon Dioxide Emissions: 1950-2050. *Review of Economics and Statistics* 1998 15-28.

Sieg, Holger, V. Kerry Smith, H. Spencer Banzhaf, and Randy Walsh. Estimating the General Equilibrium Benefits of Large Policy Changes: The Clean Air Act Revisited. NBER Working Paper No.w7744, 2000.

Smith, V Kerry; Huang, Ju-Chin. Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models. *Journal of Political Economy*, vol. 103, no. 1, February 1995, 209-27.

Viguier, Laurent. Emissions of SO2, NOx and CO2 in Transition Economies: Emission Inventories and Divisia Indices. *Energy Journal* v20, n2 1999: 59-87

Table One

Trends in European National Emissions Before and After Communism

	Dependent Variables			
	Log(so2)		Log(voc)	Log(nox)
Pre-1990 time trend	-0.0490 (0.0091)	-0.0490 (0.0091)	0.0172 (0.0051)	0.0181 (0.0038)
Time trend starting in 1990	-0.0961 (0.0122)	-0.0961 (0.0122)	-0.0433 (0.0049)	-0.0348 (0.0050)
Pre-1990 time trend * Eastern Europe Dummy	0.0309 (0.0106)	0.0346 (0.0112)	-0.0525 (0.0162)	-0.0115 (0.0067)
Time trend starting in 1990*Eastern Europe Dummy	-0.0396 (0.0167)	-0.0481 (0.0187)	-0.0299 (0.0132)	-0.0283 (0.0086)
Pre-1990 time trend * Advanced Reform Dummy		-0.0164 (0.0098)		
Time trend starting in 1990*Advanced Reform Dummy		0.0334 (0.0220)		
Observations	664	664	527	649
Adjusted R2	0.9281	0.9280	0.9543	0.9722

Each column reports a separate regression estimate of equation (1) in the text. Emissions are measured in thousands of tons of emissions. The data set covers the years 1980 to 1999. In each regression, national fixed effects are included. Robust standard errors are reported in parentheses. The time trend is splined with the knot at 1990. The nations included in the sample are; Armenia, Austria, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg , Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, and Yugoslavia. The Eastern Europe Nations are: Belarus, Bulgaria, Czech Republic, Georgia, Hungary, Latvia, Moldova, Poland, Romania, Russian Federation, Slovakia, Slovenia , Ukraine, and Yugoslavia. The advanced reform dummy equals one if the nation is the Czech Republic, Hungary or Poland and equals zero otherwise.

Table Two

National Emissions and the Economy's Scale and Industrial Composition

	Dependent Variable is:		
	Log(so2 per-capita)	Log(voc per-capita)	Log(nox per-capita)
Regression	1	2	3
GNP per-capita	-0.1940 (0.0873)	0.0310 (0.0518)	-0.1415 (0.0405)
GNP per-capita squared	0.0034 (0.0015)	-0.0004 (0.0009)	0.0022 (0.0007)
Log(steel production per-capita)	0.7323 (0.2462)	0.0136 (0.1035)	0.2631 (0.0699)
Log(energy consumption per-capita)	0.3239 (0.3976)	0.0931 (0.1804)	0.3308 (0.1759)
Time Trend	-0.0876 (0.0132)	-0.04682 (0.0056)	-0.0265 (0.0041)
Observations	116	110	116
Adjusted R2	0.9726	0.9758	0.9653
Nation fixed effects	Yes	Yes	Yes

Each column reports a separate regression estimate of equation (2) in the text. The unit of observation is a nation/year. The dependent variables are measured in tons of emissions per thousand people. The data set covers the years 1992 to 1999. Robust standard errors are reported in parentheses. GNP per-capita is measured in thousands of U.S 1990 $. Steel production's units are metric tons per person. The nations in the sample include: Austria, Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Netherlands, Poland, Romania, Russia, Slovakia, Spain, Sweden, and the United Kingdom. The constant is suppressed in each regression.

Table Three

Eastern European Energy Efficiency Progress in the 1990s

	Dependent Variables				
	Log(Energy per-capita)		Log(CO2 per-capita)		
Regression	1	2	3	4	5
	1991-1999	1996-1999	1991-1999	1996-1999	1991-1998
GNP per-capita	0.1259 (0.0181)	0.1271 (0.0423)	0.1471 (0.0268)	0.2040 (0.0618)	.1154188 .0320935
GNP per-capita squared	-0.0016 (0.0003)	-0.0014 (0.0008)	-0.0019 (0.0005)	-0.0031 (0.0012)	-.0014156 .0006593
Eastern Europe* GNP per-capita	0.2887 (0.2648)	0.1416 (0.2113)	0.3610 (0.3393)	0.1025 (0.2576)	1.024781 .5578533
Eastern Europe* GNP per-capita squared	-0.0258 (0.0387)	-0.0116 (0.0284)	-0.0361 (0.0495)	-0.0124 (0.0324)	-.1446988 .084246
F-test for joint significance of Eastern Europe GNP interaction terms	5.91**	0.52	4.39*	0.08	2.59~
Observations	277	130	277	130	225
$ Income Turning Point in Western Europe	39,340	45,400	38,700	32,900	40,766
$ Income Tuming Point in Eastern Europe	7,570	10,330	6,690	9,890	3,900
Adjusted R2	0.9824	0.9946	0.9723	0.9938	0.9736

Each column reports a separate regression estimate of equation (3) in the text. Carbon dioxide is measured as metric tons of carbon equivalent per-capita and energy is measured as consumption in billion BTU per capita. In each regression, national fixed effects and year fixed effects are included. Robust standard errors are reported in parentheses. GNP per-capita is measured in thousands of U.S 1990 $. The nations included in the sample are: Albania, Armenia, Austria, Belarus, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg , Macedonia, Netherlands, Norway, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, and United Kingdom. The omitted category is a nation in Western Europe. The constant is suppressed in each regression. Regressions 1-4 are based on EIA data while Regression 5 is based on Oak Ridge National Labs data. ** indicates statistical significance at the 1% level,
* indicates statistical significance at the 5% level, ~ indicates statistical significance at the 10% level.

Table Four

Ambient Pollution Levels Across Major European Cities and Capitals

	Dependent Variables					
	Log(particulates) in 1995		Log(so2) in 1998		Log(nox) in 1998	
Eastern Europe Dummy	0.7086 (0.2320)	-0.5721 (0.5954)	0.6620 (0.2532)	-0.2715 (0.4938)	-0.0256 (0.1826)	-0.3710 (0.3302)
Capital Dummy	-0.3452 (0.2798)	-0.5111 (0.2609)	-0.0775 (0.2460)	-0.1362 (0.2335)	-0.0476 (0.1833)	-0.0905 (0.1829)
Log(city population)	0.1310 (0.1440)	0.0122 (0.1278)	0.4811 (0.1259)	0.3654 (0.1115)	0.1191 (0.0937)	0.0856 (0.1043)
Log(GNP per-capita)		-0.6415 (0.2902)		-0.4876 (0.2112)		-.01712 (0.1600)
Constant	3.995 (0.2365)	6.0337 (0.9458)	2.3539 (0.2045)	3.8401 (0.6910)	3.8384 (0.1707)	4.3824 (0.5072)
Observations	29	29	35	35	32	32
Adjusted R2	0.2436	0.4335	0.3947	0.4879	0.0583	0.0816

Each column of the table reports a separate regression estimate of equation (4) in the text. Robust standard errors are reported in parentheses. The pollutant's units are micrograms per cubic meter. Population data is from the year 2000. The omitted category is a non-capital city in Western Europe.

Table Five

Ambient Pollution Trends in Major European Cities 1988 to 1995

	Dependent Variables				
	Particulates				So2
regression	1	2	3	4	5
	Log(annual average)	Log(annual average)	Log(winter average)	Log(24 hour max)	Log(annual average)
Time Trend	-0.0318 (0.0118)	-0.0624 (0.0208)	-0.0471 (0.0189)	-0.0666 (0.0210)	-0.0494 (0.0400)
Time Trend*Eastern Europe Dummy	-0.0548 (0.0275)	-0.0041 (0.0325)	-0.0524 (0.0340)	0.0234 (0.0367)	-0.0162 (0.0696)
Observations	80	80	63	73	73
Adjusted R2	0.8857	0.8758	0.8216	0.8221	0.2235
Weighted by City population	No	Yes	No	No	No
Each column reports a separate OLS regression of log(pollutant) = monitor+ b1*trend + b2*east*trend+ U. The dependent variables' units are micrograms per cubic meter. In each regression, monitoring station fixed effects are included. Robust standard errors are reported in parentheses.					

Table Six

Ambient Air Pollution Trends in Hungary's Cities 1990-1998

	Dependent Variables	
	Log(so2)	Log(no2)
Time trend	-0.0810 (0.0182)	-0.0052 (0.0098)
Time trend in cities with population<=150000	-0.0903 (0.0210)	-0.0030 (0.0120)
Time trend in cities with population>150000	-0.0510 (0.0359)	-0.0121 (0.0147)
Each time trend entry in the table reports a OLS estimate of "b" in the regression: Log(pollutant) = monitor + b*trend + U. Robust standard errors are reported in parentheses. 150,000 is the median city population for the sample. The data set covers 21 cities over nine years 1990 to 1998.		

Table Seven

Ambient Air Pollution Trends in Poland’s Cities 1994-2000

	Log(tsp)	Log(so2)	Log(no2)	Log(ozone)
Data from the Krakow Monitoring Network covering the years 1995-2000				
Time trend across all seven Krakow monitors	-0.0740 (0.0112)	-0.1097 (0.0087)	-0.0025 (0.0056)	
Time trend for Center city the heart of Old Town of Krakow	-0.0702 (0.0269)	-0.1835 (0.0164)	-0.0641 (0.0095)	
Data from Poland’s National Network of Basic Stations covering the years 1994-2000				
Time trend for Poland’s cities	-0.0353 (0.0112)	-0.1636 (0.0135)	-0.0349 (0.0081)	0.0343 (0.0147)
Time trend in cities with population <206,000	-0.0415 (0.0177)	-0.1971 (0.0206)	-0.0174 (0.0144)	0.0397 (0.0339)
Time trend in cities with population >=206,000	-0.0304 (0.0143)	-0.1434 (0.0173)	-0.0466 (0.0093)	0.0325 (0.0174)
Population elasticity	0.2522 (0.0857)	0.2574 (0.1062)	0.2221 (0.0621)	0.0492 (0.0687)
Population elasticity from 1997-2000	0.2349 (0.0877)	0.2690 (0.1501)	0.2043 (0.0765)	0.0616 (0.0728)

Each time trend entry in the table reports a OLS estimate of “b” in the regression: Log(pollutant) = monitor + b*trend + U. Robust standard errors are reported in parentheses. 206,000 is the median city population for the National Network of Basic Stations sample. This sample includes 51 monitoring stations over seven years. The bottom two rows of the table report population elasticity estimates from the regression: Log(pollutant) = constant + b*log(population) + U. In the last two rows, the standard errors are clustered by monitoring station. Year fixed effects are included in the second to last row.

Table Eight

Ambient Air Pollution in the Czech Republic's Cities Between 1997 and 2000

	Sulfur Dioxide	Ozone	PM10
Mean in 1997	25.0412	52.3421	32.1905
Mean in 2000	9.1443	55.5	25.5143
1997 to 2000 percent change	-0.6297	0.0662	-0.1921
1997 to 2000 percent change in Prague	-0.6456	0.0529	-0.0703
1997 to 2000 percent change in cities with population>150,000 excluding Prague	-0.5013	0.0448	-0.2092
1997 to 2000 percent change in cities with population<=150,000	-0.6460	0.0493	-0.2066
Monitoring stations	97	38	105
The monitoring station is the unit of analysis. Units in first two rows are micrograms per cubic meter.			

Table Nine

A "Kuznets Curve" for the Czech Republic, Hungary and Poland Between 1994 and 2000

	The dependent variable is the log of a city's ambient sulfur dioxide at a given monitoring station in a given year.		
Time trend	-0.1701 (0.0332)	-0.2957 (0.0137)	-0.2941 (0.0151)
Log(GNP per-capita)	1.3849 (0.5947)	2.9206 (0.3735)	2.9268 (0.3603)
Log(city population)	0.2305 (0.0904)	0.2562 (0.1004)	
City is the Nation's Capital Dummy	-0.2917 (0.2234)	-0.4409 (0.2538)	
Observations	518	518	518
Adjusted R2	0.1462	0.2998	0.7448
Fixed effects	None	Nation	City
Each column reports a separate regression of equation (6) in the text using data from 1994 to 2000. Robust standard errors are in parentheses. City population does not change over time. The omitted category is a city that is not a nation's capital.			