Understanding China's Urban Pollution Dynamics[†]

Siqi Zheng and Matthew E. Kahn[*]

China's ongoing urban economic growth has sharply increased the population's per capita income, lowered the count of people living below the poverty line, and caused major environmental problems. We survey the growing literature investigating the causes and consequences of China's urban pollution challenges. We begin by studying how urban population and industrial growth impacts local pollution levels and greenhouse gas production. As the urban population grows richer, its demand for private transportation and electricity sharply increases. Such privately beneficial activity exacerbates urban pollution externalities. Facing these severe environmental challenges, China's urbanites increasingly demand quality of life progress. We survey the emerging literature investigating the demand for environmental progress in China. Progress in mitigating externalities hinges on whether the powerful central and local governments choose to address these issues. We analyze the political economy of whether government officials have strong incentives to tackle lingering urban externalities. We conclude by discussing future research opportunities at the intersection of environmental and urban economics. (JEL O18, P25, P28, Q53, R23, R41, R58)

1. Introduction

In 1960, 33.0 percent of the world's population lived in cities. In 2010, this share grew to 50.5 percent and will continue to rise as urbanization in the developing world takes place. Urbanization offers market opportunities that rural areas cannot match. The potential to learn, specialize and trade in cities raises per capita income (Glaeser 1998, 1999, 2011).

Over the last thirty years, one quarter of the rural people who entered cities worldwide were in China.[1] In China's cities, tens

of thousands of new housing and commercial office towers are being built in months to accommodate such huge urban growth. Millions of new vehicles are being registered. A YouTube video shows the construction of a fifteen-story hotel erected in six days.[2] China is gearing up to supply a massive amount of electricity to meet the demands of growing cities featuring higher income urbanites. China's electricity consumption in 2011 was roughly 4.5 trillion kilowatt hours.[3] Ongoing economic development has reduced China's poverty rate from 84.02 percent in 1981 to 13.06 percent in 2008.[4]

There are significant environmental consequences caused by this urban growth (for trend evidence see Vennemo et al. 2009). Two leading indicators of city pollution are local air pollution and greenhouse gas production (GHG). Today, many cities in China have extremely high air pollution levels. Based on an ambient particulate concentration criterion of PM_{10}, twelve of the twenty most polluted cities in the world are located in China (World Bank 2007b). In 2003, 53 percent of the 341 monitored cities—accounting for 58 percent of the country's urban population—reported annual average PM_{10} levels above 100 $\mu g/m^3$, and 21 percent of China's cities reported PM_{10} levels above 150 $\mu g/m^{3}$.[5] Only one percent of China's urban population lives in cities that meet the European Union's air quality standard of 40 $\mu g/m^3$ (World Bank 2007a). Unless ambitious policy action is taken, GHG emissions from the BRIC nations, i.e., Brazil, Russia, India, and China, are expected to grow by

46 percent from 2005 to 2030, and in total could roughly equal emissions from the thirty OECD countries combined by 2030 (OECD Environmental Outlook to 2030, 2008).[6]

This article surveys the recent literature on the environmental consequences of urban growth with a focus on pollution dynamics in China's cities. We will be careful to contrast urban pollution dynamics that affect local environmental criteria such as ambient air pollution, water pollution, and sanitation versus the global challenge of climate change.

If urban environmental quality is sacrificed as economic growth takes place, then per capita income growth over-states improvements in the standard of living (Nordhaus and Tobin 1971). Easterlin et al. (2012) document that self reported life satisfaction indicators have not increased in China as much as would be expected during a time of annual 8 percent economic growth.

A long-run urban environmental history for developed nations suggests that local environmental problems could improve in Chinese cities. Optimists can point to a variety of examples ranging from air to water pollution. In each of these cases, the urban externality first became worse over time and then sharply improved. U.S. studies such as Cain and Rotella (2001), Clay, Troesken, and Haines (2006, 2010), Cutler and Miller (2005), Ferrie and Troesken (2005), and Haines (2001) have each highlighted the role that government investment and regulation played in taming urban environmental externalities. The transition from relying on dirty coal to cleaner fuels such as natural gas for cooking and heating has reduced urban particulate levels in U.S and European cities (Clay and Troesken 2010). The U.S. experience also highlights the role that federal legislation such as the Clean Air Act has played in reducing urban pollution (Chay and

---

[2] http://www.youtube.com/watch?v=E76uJi744Do.
[3] http://www.bloomberg.com/news/2011-01-28/china-s-power-demand-growth-may-slow-to-9-this-year-nea-says.html.
[4] http://databank.worldbank.org/ddp/home.do (Poverty and Inequality Database). In their database, poverty line is set as the daily income below 1.25 U.S. dollars.
[5] Particulate matter less than $10\mu m$ in diameter, i.e., finer particles, are typically used in health damage assessments.

[6] http://www.oecd.org/document/26/0,3746,en_2649_3 4283_40243802_1_1_1_1,00.html.

Greenstone 2005, Reyes 2008). These examples demonstrate the key role that the central government plays in mitigating urban environmental externalities. In a one party nation such as China, whether the central and local governments pursue aggressive antipollution regulations will be a crucial factor determining China's environmental quality dynamics.

These long-run trends documenting the rise and fall of urban pollution levels in developed countries bear a similarity with the Environmental Kuznets Curve (EKC) literature. Building on the influential Grossman and Krueger (1995) study, an entire subfield of environmental economics has emerged that focuses on the association between national per capita income and different indicators of pollution (see Hilton and Levinson 1998 and Harbaugh, Levinson, and Wilson 2002).

In this survey, we will examine several factors that determine a city's environmental quality at a point in time and over time. Per capita income will be one of these factors but we will not embrace the EKC as a unique "law of physics" that offers a deterministic law of motion for pollution in every city at every point in time. Unlike the typical EKC study, we will focus on the incentives and choices of individuals, firms, and governments and how the byproduct of these choices determines local pollution levels and population exposure.

We focus on cities instead of the whole country mainly for three reasons. First, cities are centers of production and consumption. Second, with the fast urbanization taking place in China, more and more people are moving to cities and thus are exposed to elevated pollution levels. Third, understanding the trade-off between the positive (agglomeration) and negative (congestion and pollution) externalities of urban growth has long been the core issue in urban and environmental economics (Tolley 1974; Glaeser 1998). Our review contributes to this ongoing

literature by presenting a detailed analysis of China's urban dynamics.

To organize our survey, in section 2 we present a conceptual framework that sketches how urban pollution and exposure to this pollution arises within a spatial equilibrium model featuring optimizing firms and households. This approach allows us to preview the various supply side and demand side factors that we will discuss in detail in later sections of this survey. On the supply side (section 3), we provide a detailed overview of the roles of the industrial sector, power generation sector, transportation, and urban form in determining pollution production. On the demand side (section 4), we predict that many of China's cities featuring rising educational attainment and per capita income levels will aspire to become the high quality of life consumer cities we observe in the United States and Western Europe (Glaeser, Kolko, and Saiz 2001).

Growing cities face a fundamental tragedy of the commons problem. In the absence of a Coasian bargaining solution, government has a central role in mitigating pollution externalities. In section 5, we will pay careful attention to China's unique political structure at the national and local levels with an emphasis on the incentives and constraints that politicians face in supplying "green cities."

While this survey will focus on the environmental consequences of China's recent urban growth, we will be careful to point out when we are confident that the results generalize to other LDC cities. At the end of this survey, we present topics that merit future research.

2. *Conceptual Framework and Data Sources*

In this section, we present a conceptual overview of urban pollution production, the demand for environmental protection, and the government's role in mitigating pollution

externalities. This section seeks to highlight how the various detailed subsections we present below fit together into a coherent framework. At the end of this section, we will discuss the various sources of pollution data in China and the quality of those data sets.

We start with two well-known theoretical models that provide micro foundations for the EKC (Andreoni and Levinson 2001; Stokey 1998). In Stokey's (1998) model, pollution is a function of the scale of aggregate economic activity but it can be reduced by investing in costly cleaner technology. For very poor nations, the social planner chooses to use the dirtiest technology and pollution increases as income rises. As income rises above a critical level, the planner chooses to sacrifice some consumption in order to use the costly cleaner technology and an EKC can emerge. Andreoni and Levinson (2001) offer a simple parametric example. The representative consumer gains utility (U) from consumption (C), and loses utility from exposure to pollution (P). This representative agent spends resources (M) on consumption (C) and emissions control (E), with the latter reducing pollution (P). The algebra can be expressed as:

$$(1) \qquad U = U(C, P) = c - z^*P$$

$$(2) \qquad P = P(C, E) = C - C^\alpha E^\beta$$

$$(3) \qquad M = C + E.$$

Pollution has two components, C and $-C^\alpha E^\beta$. The former term is directly proportional to consumption, and the latter term represents "abatement," which is related to consumption (C) and resources spent on environmental effort (E). The latter term has a standard Cobb–Douglas form ($0 < \alpha,\ \beta < 1$). Andreoni and Levinson (2001) solve for the closed form solution of optimal pollution production and study how

pollution evolves as a function of income (M). In this pareto planner's problem, an Environmental Kuznets Curve (EKC) emerges if $\alpha + \beta > 1$.

This association between national per capita income and different indicators of air and water pollution was documented in a cross-national study by Grossman and Krueger (1995). A continuing research agenda seeks to study the empirical validity of this hypothesis. In some cases such as lead emissions it emerges (Hilton and Levinson 1998), while subsequent cross-national research by Harbaugh, Levinson, and Wilson (2002) suggests the EKC is a fragile empirical result.

These models of the relationship between pollution and economic activity do not explicitly incorporate geography. A straightforward way to introduce spatial considerations is to incorporate ideas from two classic urban models—the Rosen (1979)—Roback (1982) open system of cities model and the classic urban monocentric model developed by Alonso (1964), Muth (1969) and Mills (1967). Those spatial approaches allow us to analyze the possibility that households and firms can migrate across cities and within a single city. We will first discuss the blending of the nonspatial and spatial models on the supply side (pollution production), and then move to the demand side (i.e., the demand for greenness). We then discuss how local and national government choices over regulations and public goods provision are likely to affect key outcomes.

2.1 Pollution Production in Cities

A long tradition in urban economics, starting with Alonso, Muth, and Mills (together called the AMM model), and Rosen and Roback, models the spatial compensating differentials equilibrium across and within cities. Factor prices for labor and land adjust so that the marginal household/worker is indifferent across locations (Rosen 2002). If

a city suffers from low quality of life, then its wages and rents will adjust to compensate workers for such disamenities (Albouy 2009). Within cities, if a specific neighborhood suffers from low quality of life, then rents will be lower.

In the classic AMM model, all employment is located downtown in the city center. This urban model does not introduce industrial pollution but an easy way to introduce pollution is to posit that industrial emissions are proportional to industrial employment and the pollution is more heavily concentrated in geographical areas closer to the downtown factories. In this case, the residential communities close to the city center will offer a trade-off of short commute times but higher pollution levels. If jobs and housing are more spread out throughout the metropolitan area, then pollution "hot spots" in the city center are less likely to exist as the jobs and population will be more uniformly distributed.

Andreoni and Levinson's (2001) and Stokey's (1998) models adopt a single sector production function approach. While greatly simplifying the problem, they abstract away from introducing heterogeneity with respect to industrial structure, vintages of capital, and the spatial distribution of industrial activities and households. These specific details play a key role in our analysis below.

In section 3, we will blend the core ideas of the above spatial and nonspatial models and set up an accounting framework to track the main sources of urban pollution. There are two key pieces to this framework. The first dimension is to examine pollution sources in two basic categories—production based (such as industrial production) and consumption based (such as residential electricity consumption and private vehicle driving) externalities. The second dimension categorizes pollution indicators that are local (such as air pollution) and global externalities (greenhouse gas emission).

2.2 *Demand for Green Cities*

Avoiding pollution represents an input in the production of health capital. Human capital and health capital are complements (Currie 2009), so urban environmental quality is a key determinant of urban earnings and people's happiness. The Grossman (1972) model of health production can be augmented to include location-specific attributes such as local air and water pollution levels. A household will recognize that everyone within the household is exposed to similar pollution levels once a residential location choice has been made. If households differ with respect to their susceptibility then the most vulnerable households will choose to self-protect by living in low pollution cities and cleaner parts of a specific city. In this sense, this location choice is a type of self-protection investment (Ehrlich and Becker 1972).

As the average household in Chinese cities becomes richer and better educated, there will be rising demand for living in "green cities." Such households will seek information and products that help them to reduce their exposure to health risks. The core idea of the Rosen–Roback model is that urbanites are able to "vote with their feet" in an open system of cities. This migration leads to local wages and rents adjusting so that high quality of life cities will feature relatively lower wages and higher rents. In section 4, we discuss recent empirical findings based on revealed preference techniques for studying the demand for "green cities" in China.

2.3 *Introducing Government*

To simplify the discussion, we have not introduced a national or local government in the above demand-side and supply-side discussion. But the urban air and water are common property and it is costly to monitor who is emitting what into the commons. At any point in time, there are millions of urban actors who are taking privately beneficial

actions such as driving or turning on the air conditioning that have social consequences. In the absence of pollution pricing, no one has an incentive to internalize such externalities and transaction costs preclude a Coasian bargaining solution.

Standard public finance economics highlights the role that government can play in taming Pigouvian externalities and providing public goods. Given China's sharp economic growth and rising educational attainment, it is noteworthy that the J-Curve theory conjectures that the intensity of environmental regulation increases as per capita income rises (Selden and Song 1995). The J-Curve hypothesis provides a government induced micro foundation for an observed EKC relationship. Hilton and Levinson's (1998) work on urban lead emissions highlights that as nations grow richer they reduce the allowable lead content per gallon of gasoline.

La Porta et al. (1999) and Botero, Ponce, and Shleifer (2012) argue that the quality of governance and hence its capacity to supply public goods increases when a nation's per capita income and educational attainment rises. Such governments have the resources to collect information and hire competent people to enforce laws. In democracies, politicians who seek reelection have an incentive to pursue policies that the median voter demands. Whether a one party nation's leaders are also responsive to citizen preferences remains an open research question (see Mulligan, Gill, and Sala-i-Martin 2004 for some cross-national evidence).

In section 5, we will discuss China's governance structure, its public finance system and analyze the objectives and priorities of officials at different levels of government. The central and local governments have different incentives for pursuing the green agenda. The central government is keen to address domestic energy security concerns and seeks to be a global leader in the nascent green technology market. A desire to achieve increased "legitimacy" with the Chinese people and to raise China's image in the international community may further motivate the central government to pursue "environmentally friendly" policies. The central government has recently shifted the local officials' promotion criteria from solely focusing on economic growth to "harmony development" and this latter criteria places increased importance on tangible environmental goals. Urban officials who seek promotion within the system now have stronger incentives to meet environmental targets. While this could create incentives to cheat and fudge reporting data, the rise of information technology and micro blogging and the reduction in the cost of collecting up to date environmental data reduces the concern about strategic misreporting.

2.4 Data Sources and Data Quality

Data on pollution in China is relatively scarce compared to developed countries, and questions about the data quality have been raised. Here we provide a brief overview of pollution data sources and discuss their reliability. There are two broad sources of pollution data. One is the official pollution data released by the Chinese government, and the other is data collected by researchers and nongovernmental organizations. The former category includes pollution indicators published in a series of yearbooks, and on the websites (or reports) of China's Ministry of the Environmental Protection (MEP) and local environmental authorities. Table 1 provides a brief summary of the major sources of publicly available key environmental indicators in China. Two main data collection methodologies are employed for generating these data sets. One is bottom–up accounting—summing up the self-reported numbers from individual firms to cities, provinces and then to the national level. Examples include solid waste disposal, waste water discharge,

TABLE 1
MAJOR DATA SOURCES OF KEY QUALITY OF LIFE INDICATORS IN CHINA

Name	Data level	Period available	Data source
Public health			
Life expectancy	By province	From 2003, by year	China Statistical Yearbook of Health
	National-level	From 1995, by year	International Statistical Yearbook
Infant mortality	By province	From 2003, by year	China Statistical Yearbook of Health
	National-level	From 1994, by year	International Statistical Yearbook
U5MR	National-level	From 2005, by year	China Statistical Yearbook of Health
Mortality at birth	National-level and by province	From 2003, by year	China Statistical Yearbook of Health
Tuberculosis incidence rate	National-level	From 1997, by year	China Statistical Yearbook
Tuberculosis and heart disease death rate	National-level	From 2001, by year	Annual Statistical Report of Health in China
Pollution			
Ambient air pollution: PM_{10}	86 major cities	From 2006, by day	Data Center, Ministry of Environmental Protection, available online
	31 major cities	From 2003, by year	China Statistical Yearbook of Environment
Water quality of main flows	By water flow	From 2004, by week	Data Center, Ministry of Environmental Protection, available online
Water quality of major river systems	By river	From 2002, by year	Annual Statistical Report on Environment in China
Generation and discharge of industrial solid waste	By province and by city (all municipality-level cities)	From 2003, by year	China Statistical Yearbook of Environment, and China Statistical Yearbook
Emission/discharge and treatment of industrial smoke, SO_2, waste water	By province and by city (all prefecture-level cities)	From 2003, by year	China Statistical Yearbook of Environment, and China Statistical Yearbook
Urban garbage disposal and treatment	By province	From 2005, by year	China Statistical Yearbook of Environment
Urban road traffic noise	30 major cities	From 2005, by year	China Statistical Yearbook of Environment
Energy consumption			
Total electricity consumption	By industry and by province	From 1990, by year	China Energy Statistical Yearbook
Total coal consumption	By industry and by province	From 1990, by year	China Energy Statistical Yearbook
Total natural gas and LPG consumption	By industry and by province	From 1990, by year	China Energy Statistical Yearbook
Residential coal, natural gas and LPG consumption per capita	All prefecture-level cities	From 1985, by year	China City Statistical Yearbook
Residential electricity and water consumption per capita	All prefecture-level cities	From 1995, by year	China City Statistical Yearbook
Number of civil vehicles	By province	From 1985, by year	China Statistical Yearbook
Total gasoline and diesel consumption	By industry and by province	From 1995, by year	China Energy Statistical Yearbook
Gasoline price	National-level	From 2000, by year	International Statistical Yearbook

smoke emissions, sulfur dioxide emissions, and pollution control investment by city and by province. Such data are less reliable because firms and local governments both have the incentive to underreport their emissions but overreport their economic outputs and pollution-mitigating efforts.

Official pollution data are also collected from ambient pollution monitors. Examples include readings of ambient particulates concentration and water quality by city. These data sets are posted on the MEP's website. Such monitors are controlled by MEP, the province or the city's environmental authorities, so it is hard for individual firms to influence them. Therefore such monitoring data is more reliable (especially those controlled by MEP), though some scholars also point out that some city governments have the incentive to manipulate such data (Wang et al. 2009; Andrews 2008).

Skeptics have questioned the quality of data produced by China's government. They argue that the statistical approach to data collection, reporting and validation is opaque. Similar to the questions raised about the statistics released by the Soviet Union, when a one party state controls information releases it may systematically choose to release information that helps it to achieve its political goals and may suppress negative information (Liu and Yang 2009; Guan et al. 2012). There have been some controversies on the disparities between publicly released and privately collected pollution data, such as the Beijing air quality readings from the Beijing environmental authorities and the U.S. Embassy (see our detailed discussion in section 4). Due to the rise of information technology, the Chinese government has been losing its data provision monopoly. Improvements in remote sensing and cheaper pollution monitors have allowed others to measure China's pollution levels (Akimoto et al. 2006; Sinton 2001; Zhang et. al. 2007). We predict that

the quality of Chinese data will continue to improve attributed to technological innovations that foster data supply competition, and also due to the increased demand for pollution related information by educated Chinese urbanites (see section 4).
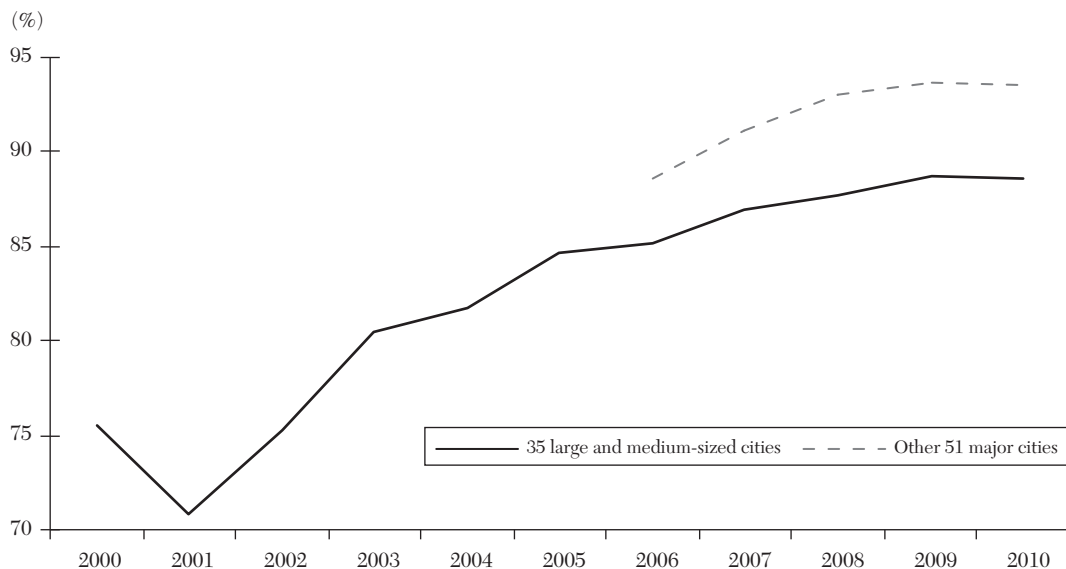
Figure 1 highlights some recent trends in ambient air pollution between 2003 and 2010 for thirty-five major cities and fifty-one medium-sized cities using data from the MEP's website. Though the absolute PM_{10} concentration level is still quite high, a regression with city fixed effects yields a time trend decline by 2.19 percent per year. This declining trend is larger for large cities (3.09 percent). Figure 2 presents some time trends between 2001 and 2010 in surface water quality. Similar to the air quality trends, the time trend suggests significant progress but indicates that water pollution still remains a serious challenge.

Figure 3 displays the trends in per capita CO_2 for the world, India and China, based on data from the World Development Indicators. China's sharply sloping per capita line starting in 2001 highlights the serious global pollution consequences of China's sharp recent economic growth.

3. *Understanding the Causes of China's Urban Pollution Growth*

In this section, we employ an accounting framework to discuss the major causes of China's urban pollution, including city population growth, industrial activity, driving and urban form, power generation and winter heating. At the end of this section, we will discuss the global externalities—natural resource extraction and GHG emissions. In each category, we emphasize the role of scale, composition and technique effects (Copeland and Taylor 2004). Scale refers to the sheer count of people and jobs located in a city while composition refers to a city's industrial composition and the vintage of its

Panel A. Annual percentage of days with air quality at or above grade II (defined by MEP) in Chinese major cities (2000 to 2010)

Panel B. PM$_{10}$ Concentration (mg/m^3) in Chinese major cities (2003 to 2010)

All cities (with city fixed effects):
$\ln(PM_{10}) = -0.0219 \times$ year trend -2.382
Large cities (with city fixed effects):
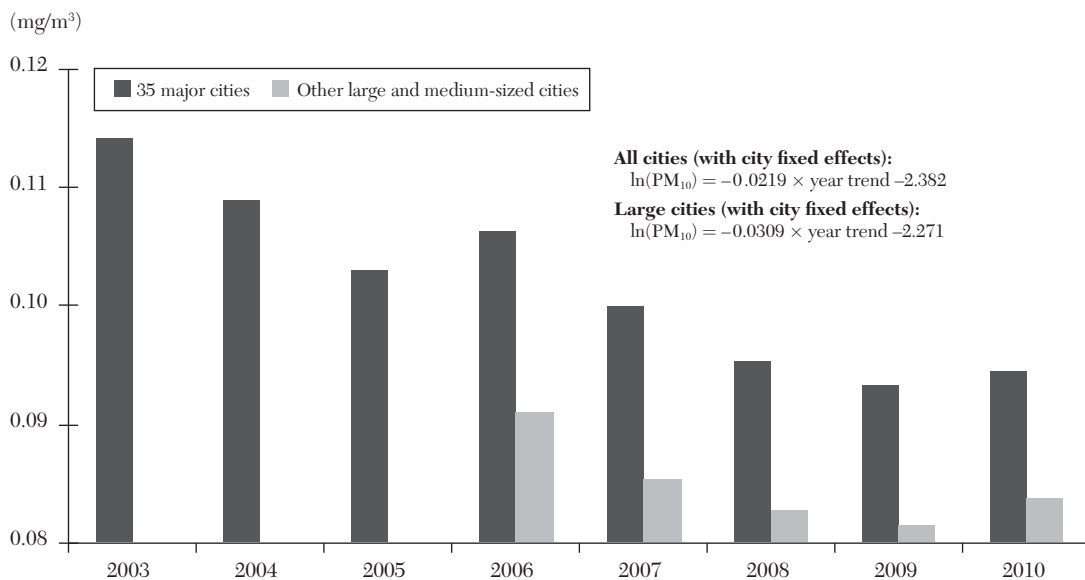$\ln(PM_{10}) = -0.0309 \times$ year trend -2.271

Figure 1. Air Quality Indicators in Chinese Cities

Source: China Statistical Yearbook, Data Center of Ministry of Environmental Protection (MEP) of the People's Republic of China.
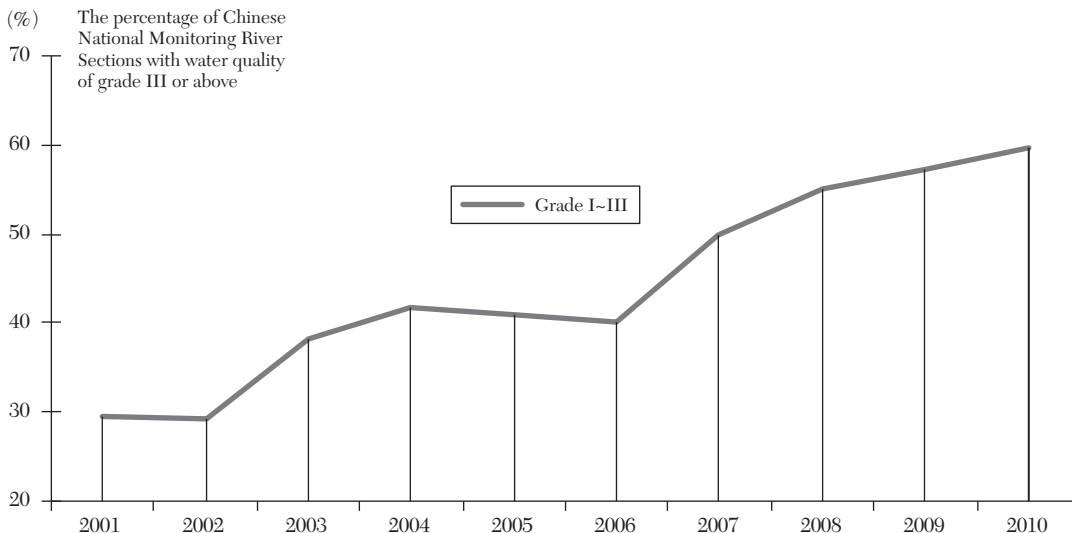
Figure 2. Surface Water Quality in China (2001–2010)

Source: Status of China Environment reports 2001–2010.

capital stock. Technique represents emissions per unit of economic activity.

Those sectors in the economy all contribute to a city's overall public health externality. Particulate matter (PM) is an important indicator of local air pollution that raises mortality risk as highlighted in U.S studies (Chay and Greenstone 2003). One $PM_{2.5}$ emissions inventory study for China (Cao et al. 2011) indicates that on average, industrial activity is responsible for 68.6 percent of total $PM_{2.5}$ emission, 4.5 percent is from transportation, and 20.4 percent is from the residential sector. In the case of sulfur dioxide emission, 30.5 percent is from power generation, 63.2 percent from industrial sector, and 5 percent from the residential sector. Individual cities have quite different emission inventory percentages.[7]

3.1 *City Population Growth*

There are hundreds of millions of rural Chinese households seeking the employment benefits of urbanization as well as nonwage benefits (quality of life and learning opportunities) (Harris and Todaro 1970). Geographers focusing on China have documented the migration trends (Fan 2005a, 2005b). The level of urbanization in China increased by about one percentage point a year from 26 percent in 1990 to 51 percent in 2010.[8] The 2010 census reveals that 78 percent of migrants originated from rural areas. The three biggest winners in

---

[7] In Beijing's PM_{10} inventory, 21.3 percent of this pollutant is from soil dust, 18.2 percent is from coal burning, 16.5 percent is from vehicles, 6.6 percent is from construction

sites, 14.7 percent is from other particles (such as SO_4^{2-}, NO_3^- and NH_4^+), and 22.7 percent is from nonidentified source (Chen et al. 2006). Hangzhou has a very different PM_{10} emission inventory with the respective shares being 17.0 percent, 13.9 percent, 16.9 percent, 8.0 percent, 29.1 percent, and 15.1 percent (Bao et al. 2010).

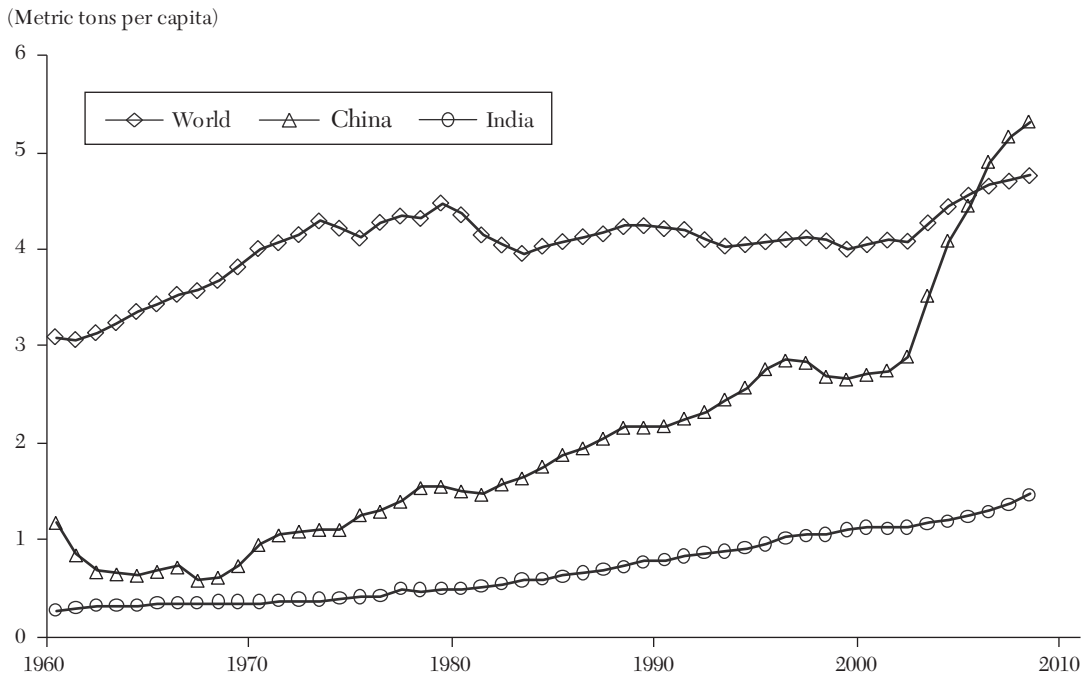[8] National Bureau of Statistics of China (2012).

(Metric tons per capita)

Figure 3. Time Trends in Per Capita Carbon Dioxide Emissions

Source: World Development Indicators, World Bank 2012 (http://databank.worldbank.org).

terms of population gains during 2005–10 as a percentage of their initial 2005 population were Zhejiang (a leading manufacturing belt in the coastal southeast), Beijing (the national capital) and Shanghai (China's emerging commercial center). They are all located in the eastern region. It is expected that 70–80 percent of Chinese people will live in cities by the year 2030.[9]

Moving people to cities introduces two offsetting environmental effects. In cities, there are more people living in a small geographic area (i.e., high population density) but they are richer. The former effect should

mean that urbanization reduces energy consumption while the latter effect suggests that urbanization increases energy consumption. Zheng et al. (2011) documents both of these effects and show that the income effect dominates in China. Given that the average rural person only consumes one third of the energy consumed by the average urban person in China, this vast migration flow will result in significant increases in energy consumption.[10] Past U.S. research has found that urbanization offers environmental

[9] http://www.bis.gov.uk/assets/foresight/docs/migration/11-1116-migration-and-global-environmental-change.pdf.

[10] In 2000, the annual total energy consumption of an average urban person was 210 kg standard coal, while that of an average rural person was 76 kg standard coal, about 36 percent of the former (China Energy Statistic Yearbook 2011).

benefits for rural areas that depopulate. Pfaff (1999) documents the reforestation of the Northeast as people urbanized during the nineteenth century. In China, however, Ebenstein et al. (2011) document the negative environmental impacts caused by China's massive rural to urban migration. As rural workers have urbanized, farmers have faced labor shortages and have responded to this by substituting chemical fertilizer as an input in production. Such chemicals raise local nitrogen levels and this increases water pollution.

Despite the huge migration flow taking place, the Chinese *hukou* system has restricted domestic migration. Au and Henderson (2006) estimate an econometric model to explain city GDP as a function of the city's population, and generate empirical estimates of the GDP-maximizing city size. They find that most Chinese cities are undersized due to the *hukou* constraint.[11] Though *hukou* status is no longer a constraint for finding a job in cities, it remains an important tool for rationing access to local public services such as school, healthcare and social security benefits. Based on a cross Chinese city real estate price regression, Zheng et al. (forthcoming) document that in those cities where the *hukou* permit is a binding entry constraint that local quality of life factors are not capitalized to the same extent into real estate prices relative to other cities featuring lower cross-city migration costs.[12]

3.2 *Urban Industrial Production and Pollution Growth*

China's phenomenal industrial growth over the last twenty years is well documented. For example, 40 percent of the world's clothes are "Made in China."[13] Most trade studies focus on how China's exports impact consumer prices, labor markets, and firm structure in importing nations (Broda, Leibtag, and Weinstein 2009; Feenstra and Wei 2009; Bloom, Draca, and Van Reenen 2011). In contrast, our focus is on how such industrial production affects China's pollution levels. China's Energy Statistics Yearbooks show that in 2010 the industrial sector was responsible for 89.1 percent of total energy consumption (end use) while the residential sector only consumed the left 10.9 percent. Industrial production contributes emissions to the air and water. Two other major industrial emissions are lead and mercury, and public health researchers have documented the health consequences of exposure to these toxics (Ratcliffe, Swanson, and Fischer 1996).

The geographic concentration of manufacturing and mining activities has significant local environmental consequences. During the 1970s, black smoke from stacks became the characteristic of Chinese industrial cities; in later years, many southern cities began to suffer from extremely high levels of acid rain pollution (He, Huo, and Zhang 2002).

---

[11] The *hukou* system, put in place in the 1950s, was to register people by their hometown origin and by urban versus rural status for the purpose of regulating migration. In the wake of transition to a market economy, the *hukou's* regulation on population mobility was largely relaxed. Population mobility, especially rural to urban migration, was substantially elevated in the 1990s when urban housing market and labor market were liberalized and private sector employment grew rapidly with the inflow of foreign direct investment (FDI) to Chinese cities. Nevertheless, residents without local urban *hukou* can be denied access to public schools, public health care, public pensions, and unemployment benefits in the city.

[12] Zheng et al. (forthcoming) estimate a cross-city hedonic real estate regression using data for 86 Chinese cities and include interactions between a vector of city quality of life attributes such as average air pollution and a dummy variable that equals one if the city has a binding *hukou* permit system. Since migrants cannot easily enter cities with binding *hukou*, the spatial equilibrium is such that there can be cities with high quality of life without very high home prices because external migrants cannot easily move to such cities.

[13] China National Textile and Apparel Council (2011).

Ebenstein (2012) finds that industrial activity has led to a severe deterioration in water quality in China's lakes and rivers. He estimates that a deterioration of water quality by a single grade (on a six-grade scale) increases the digestive cancer death rate by 9.7 percent. His econometric strategy contrasts OLS estimates of site specific death rates on local water quality with IV estimates where he instruments for a site's water quality using variation in precipitation across the sites and variation in the distance from the site to the nearest river's headwaters.

Cai, Chen, and Qing (2012) document cross-boundary river pollution effects in China caused by seven main industries: agricultural products and byproducts, textile, garments manufacturing, pulp and paper, petroleum and nuclear fuel processing, chemical industry, and nonferrous metals smelting and pressing. They find qualitatively similar results as Sigman (2002). Both water pollution studies document that polluting sources are located at political boundaries so that the social costs of industrial activity are borne by downstream adjacent political units. Hong Kong's residents suffer from cross-boundary spillovers of industrial smoke from nearby manufacturing regions such as Zhaoqing, Qingyuan, and Heyuan in Guangdong Province (Zheng et al. forthcoming).

Rare earths mining and processing is a widely publicized example of a profitable industrial activity with significant environmental consequences. Rare earth is a key component in "green products" such as hybrid vehicles, wind turbines, and solar panels but extracting them causes major environmental problems in the areas where such rare metals can be found such as Baotou city in Inner Mongolia and Liangzhou in Sichuan.[14]

The links between industrial production and local pollution are well known from U.S. experience. Consider the rise of the U.S. steel industry and its impact on ambient pollution levels in Pittsburgh, and Gary, Indiana, or oil refining activity in Richmond, California. Empirical research has documented how the scale of urban industrial activity contributed to significant levels of ambient air pollution (Kahn 1999; Chay and Greenstone 2005). Major U.S. cities have been deindustrializing as improvements in transportation, cheaper land and differential regulatory standards have all pushed dirty manufacturing outside of these cities towards the areas that are not pro-union and have low electricity prices (Henderson 1997; Holmes 1998; Becker and Henderson 2000; Greenstone 2002; Kahn and Mansur 2013). Such deindustrialization has contributed significantly to recent gains in local air and water quality.

In China, manufacturing activity is moving to the second and third tier cities due to the increasing costs of labor, land, and stricter environmental regulations in large cities. Overall, the more developed cities in the coastal region have the most stringent environmental regulations (Van Rooij and Lo 2010). Compared to the United States, national and urban policies play an even larger role in shaping China's economic geography. We will discuss this in section 4.

A literature has examined the role that foreign direct investment (FDI) plays in determining China's industrial pollution levels (Dean, Lovely, and Wang 2009). In China in the 1980s, attracting FDI meant more factories and thus more pollution. Conversely, it is possible that FDI provides the financial capital and access to developed nations' technologies that allows cleaner factories to be built. The existing literature has generated mixed findings on the FDI flows' environmental consequences. Wang and Jin (2007) find that foreign firms exhibit better environmental performance

---

[14] Henderson (1988) stresses the importance of natural resource endowments as driving a city's industrial base. For example, in China, a city such as Lanzhou specializes in primary metals.

than state-owned and privately owned firms because the foreign firms use cleaner technology and are more energy efficient. Zheng, Kahn, and Liu (2010) use data across thirty-five major Chinese cities over the years 2003 to 2006 and report a negative correlation between a city's FDI inflows and its ambient air pollution level. Using data from 1990s and early 2000s, He (2006, 2009) finds evidence that pollution and FDI are positively correlated. One possible explanation for these facts is that, up until the early 2000s, FDI increased the scale of industrial activity in China's cities and this increased pollution, while in recent years FDI has improved the techniques used in China's industrial sector such that pollution per unit of industrial production has declined.

Two other key determinants of a given manufacturing plant's pollution production are its management quality and its ownership status. A promising trend in China is the rising quality of its universities and the professionalization of the managerial class as more MBAs graduate from elite universities. If energy prices rise in China, then there will be a premium for managers who figure out strategies for economizing on energy consumption. Bloom, Draca, and Van Reenen (2011) document a negative correlation between manager quality and energy intensity in the United Kingdom. This suggestive result has powerful implications for the future emissions of Chinese industry.

A special feature of Chinese manufacturers is that many of the major traditionally dirty industries are state owned enterprises (SOEs).[15] SOE managers are regarded as politicians in various layers in China's government system. This ownership structure implies that there are very close connections between SOEs and the governments they are owned by. They have access to cheap loans and land. Whether SOE managers have strong incentives for reducing pollution hinges on their promotion criteria. The old criteria usually emphasized short-term targets such as output and profit (Lee 2009), thus they had little incentive to engage in precautionary investment that lowers future environmental risk. On the other hand, SOE managers are aware that the government now also judges them on a company's "green performance," and environmental disasters will destroy their political career.[16] This provides an incentive for them to clean up pollution because it is relatively easy for governments to monitor SOEs' environmental performance.

3.3 *Driving and Urban Form*

The growth of private car ownership in China has been an international news topic. The overall car ownership rate in China is still not high (18 percent of households own cars in 2010), but with vast road construction investments and rising per capita income, an unprecedented increase in private vehicle ownership has taken place in Chinese cities over the last decade. The number of private cars in Chinese cities increased from 6.25 million in 2000 to 73.27 million in 2011, with an average annual growth rate of 22.76 percent (see figure 4). In Beijing in 2010, there were 900,000 civilian registered vehicles.[17]

Both cross-national studies such as Dargay, Gately, and Sommer (2007), Ingram and Liu (1999) and within-China studies such as Zheng, Wang, Glaeser and Kahn

---

[15] The SOE's sales share was 34.5 percent in 1998 and it fell to 9 percent in 2007. Many of the small and less efficient plants have been closed or merged during the SOE reform in late 1990s and early 2000s.

[16] According to the requirement by the Organization Department of China Communist Party (CCP), which is in charge of the appointments of government officials and SOE senior managers, environmental performance (measured by the number of pollution accidents, or pollutant indicators reported by environmental authorities) is included in the promotion criteria for SOE managers.

[17] China Vehicle Technology Research Center and the China Association of Automobile Manufacturers (2012).
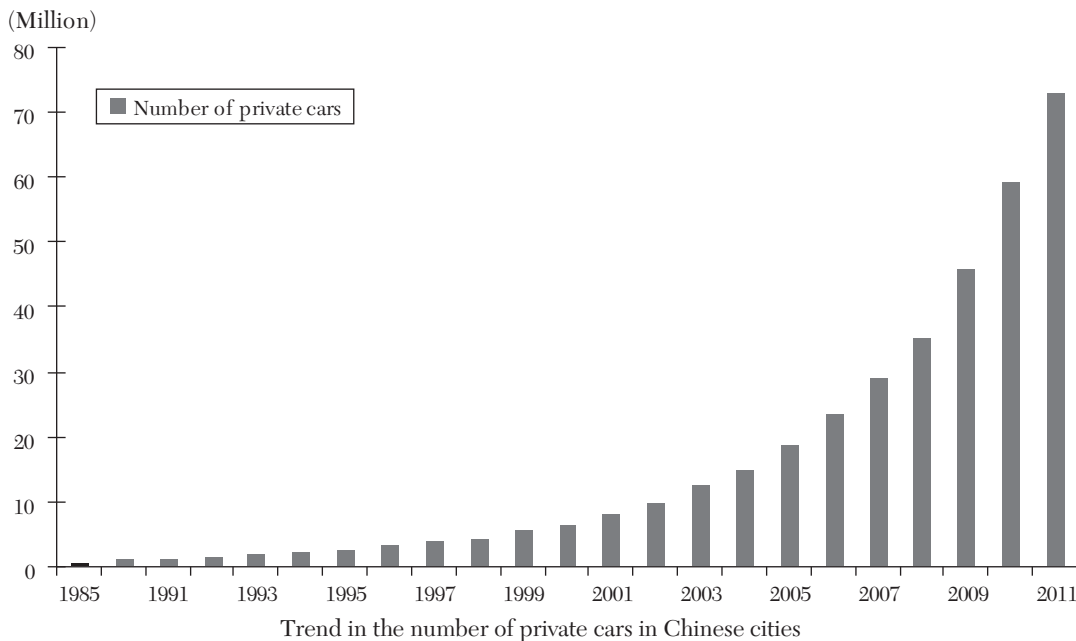
(Million)

Trend in the number of private cars in Chinese cities

Figure 4. The Number of Private Cars in Chinese Cities

Source: China Automotive Industry Yearbook 2010.

(2011) have documented that richer people are more likely to own vehicles. In the case of the United States, Goldberg (1998) jointly models the vehicle purchase and vehicle utilization decision. Similar estimates using micro data from China would be quite useful for predicting how gasoline consumption will evolve over time and for predicting what types of vehicles will be intensively driven. One example in this research line is Anas, Timilsina, and Zheng's study (2009) that employs a nested multinomial logit model of car ownership and personal travel in Beijing circa 2005 to compare the effectiveness of different policy instruments aiming to reduce traffic congestion and carbon dioxide emissions. They find that a congestion toll is more efficient than a fuel tax in reducing traffic congestion, whereas a fuel tax is more

effective as a policy instrument for reducing gasoline consumption and emissions. Such findings are crucial for predicting how changes in Chinese public policies directed to increase the cost of driving will affect the pollution produced by the vehicle sector.

The full price of driving depends on the price of the vehicle, gasoline, insurance and parking and the time required for a trip. The price of domestic-produced vehicles in China is roughly $16,000–$24,000 U.S. dollars or about 1.8–2.5 times of annual household income. There are large tariffs applied to imported new cars from other countries such as Japan and Europe. In China, many carmakers are joint ventures with international companies. Examples include Yiqi–Volkswagen and Guangzhou–Honda. Before 2005, gas prices in China had been much

lower than that in the West, but the price has been rising in recent years. Today, the gas price in China is roughly 30 percent higher than that in the United States, but it is still lower than that in Japan, South Korea, the United Kingdom, and France (International Energy Agency 2011). Parry and Small (2005) argue that the optimal gas tax (to minimize Pigouvian externalities) is greater than the U.S. tax and less than Europe's gasoline tax. The share of various taxes (added-value tax, consumption tax, urban maintenance and construction tax, education surcharge, etc.) in the total price of a gallon of gasoline is about 45 percent in China, which is about twice of that in the United States but is lower than that in the Europe.[18]

The local air pollution implications of more vehicles driving more miles hinges on the emissions technology bundled into the vehicle. Regulation determines new vehicles' emissions per mile. China has implemented four versions of its emissions standards, which are equivalent to the Euro I, II, III, and IV standards respectively (Song, He, and Lei 2012).[19] Beijing introduced the new National Standard V (equivalent to Euro V) in 2012. All vehicles are required to have an inspection every two years. Such inspections require investments in emissions control technology if the vehicle fails the smog test. Perhaps surprisingly, vehicle manufacturers in China have not lobbied against these regulations. Instead, they express concern that gasoline is not clean enough to comply with the new standard, so that the buyers are not willing to pay a price premium for cars that have high

technology emission controls installed. We know of no research estimating the benefits and costs of vehicle environmental regulation compliance in China. Greenstone and Hanna (2011) evaluate how India's introduction of air pollution regulation has affected air quality dynamics. In the late 1990s, the air quality in those Indian cities that required catalytic converters for new vehicles jumped sharply and death rates in these cities fell over the medium term. Studies using U.S. data show that regulation's impact on reducing ambient air pollution should rise with time as the share of pre-regulation cohort vehicles on the roads declines (Kahn 1996; Kahn and Schwartz 2008).

Technological advance and the diffusion of existing technologies could break the link between private motorization growth and increased pollution (Acemoglu et al. 2012). After all, if electric vehicles replaced gasoline vehicles and if the electricity is generated using renewable energy sources then miles driven would not lead to large amounts of local air pollution or greenhouse gases. Such technological progress would shift the classic EKC curve down so that less pollution is produced during the early phase of economic growth (Dasgupta et al. 2002).

Households simultaneously choose their residential location and commuting mode. In Beijing, 48 percent of all jobs were located within three miles from the city center in the year of 2004 (calculated by the authors using 2004 Economic Census data). In the United States, New York City is the only metropolitan area with such job concentration downtown (Glaeser and Kahn 2001, 2004). People are much more likely to commute using public transit when they work in the center city (Baum-Snow and Kahn 2005).

Zheng, Fu, and Liu (2006) find that the rich live downtown in major Chinese cities. The rich's willingness-to-pay for downtown locations is significantly higher than that of

[18] See: http://news.163.com/special/reviews/youjiagaige.html.

[19] They are National Standard I (initiated in 1999 for light vehicles), II (2004), III (2007), and IV (2008, but only applied in selected cities). For each standard, the implementation date for heavy vehicles was always later than that for light vehicles. The implementation date of each standard version was always 2–3 years earlier in large cities such as Beijing and Shanghai.

the poor, due to the fact that most job opportunities and high-quality public services (such as schools, hospitals) are concentrated in the central city. This finding is similar to the work documenting that the rich tend to live close to the city center in leading European cities such as Paris (Brueckner, Thisse, and Zenou 1999). Population and employment are both decentralizing in Beijing. The population density gradient with respective to the distance to CBD was –0.156 in 2000, and it shrank to –0.123 in 2010. The job density gradients were –0.204 in 2001 and –0.159 in 2004.[20]

Given that private vehicles are significant contributors to local air pollution, the introduction of subways and other high quality public transit can sharply improve urban environmental performance. In an analysis of the impact of Taiwan's recent investments in subways, Chen and Whalley (2012) conclude that the introduction of rapid public transit can offer significant public health benefits if people substitute from cars and buses to traveling by subway.

China is in the midst of a major subway construction period. In 1980, only Beijing had two subway lines. In 2000, three cities had subways. In 2010, twelve cities have subways and another sixteen cities have lines under construction. In the case of Beijing, the construction of new subways has attracted private developers and new restaurants to locate in close proximity and this reinforces the desire to live close to public transit (Zheng and Kahn 2013).

Transportation investment in suburban highways encourages suburbanization.[21] Research using U.S. data has documented the causal role that new highways have played in causing suburbanization in the United States (Baum-Snow 2007). Baum-Snow et al. (2012) study how China's urban form has been affected by its highway investment. They report evidence that urban compactness is reduced by radial and ring road construction, but enhanced by public transport.

Common sense suggests that suburbanization reduces public transit use and increases the demand for private vehicle driving. Given that households are not randomly assigned to live in suburban locations, whether the association between suburbanization and miles driven is a selection effect or a treatment effect remains an open question. If suburbanization causes increased driving, then this trend contributes to local air emissions and greenhouse gas production (Glaeser and Kahn 2010).

A unique factor affecting Chinese cities' ability to suburbanize is the price of land at the urban fringe. Given the absence of a property tax in China and the fact that many cities rely on land sales for a large share of their annual revenues (around 60 percent), city mayors have a strong incentive to acquire rural land. We will return to this point below in the government section.

3.4 *Fossil Fuel Consumption for Power Generation and Winter Heating*

There has been an incredible growth of demand for electricity in the entire developing world and in China (Wolfram, Shelef, and Gertler 2012). China's total

---

[20] We estimate the following regression to recover the job density gradient parameter a_1: $\log(\text{density}) = a_0 + a_1 \times$ distance to CBD $+ u$. Density is measured in ten thousand people (or jobs) per square kilometer. Distance to CBD is measured in kilometers. The density gradient measures the decrease of population/job density (in percentage) as the distance to CBD increases by 1 kilometer. The data for population density comes from 2000 and 2010 Population Census. The data sources for the employment density are Basic Unit Census 2001 and 2004 Economic Census.

[21] Unlike in the United States, "flight from blight" has not been mentioned as a cause of China's suburbanization (Mieszkowski and Mills 1993). Neither center city crime nor race relations have arisen as causal factors encouraging Chinese suburbanization.

electricity consumption in 2010 was 3.11 times that in 2000. In 2010, the average urban household owned 1.22 air conditioners compared to 0.31 in 2000.[22]

This sharp rise in electricity demand poses local environmental challenges when such power is supplied using nearby power plants that rely on fossil fuels such as coal. Coal plays a vital role in electricity generation worldwide. Coal-fired power plants currently fuel 41 percent of global electricity, and China generates 79 percent of its electricity using coal.[23]

Coal burning releases large quantities of polycyclic aromatic hydrocarbons (PAHs) and other pollutants. PAHs are reproductive and developmental toxicants, mutagens, and carcinogens.[24] Muller, Mendelsohn, and Nordhaus (2011) estimate that coal fired power plants are responsible for 25 percent of total U.S. industrial pollution damage or $53 billion dollars of environmental damage each year. Tang et al. (2008) exploit a natural experiment in which a coal fired power plant in Tongliang, Chongqing of China was shut down in May 2004 by examining health outcomes for two identical prospective cohorts of nonsmoking women and their newborns in 2002 (before shutdown) and 2005 (after shutdown). Their findings indicate that neurobehavioral development in Tongliang

children benefited by the elimination of PAH exposure from the coal-burning plant. A public health literature has examined how the geography of China's coal fired power plants affects public health (Zhou et al. 2006). The total damage is larger if more people live close to a large coal fired power plant with high emissions. Based on U.S. data, Davis (2011) finds that there is a 5 percent real estate price discount for homes located within two miles of a new fossil fuel fired power plant.

Based on our calculations using geographical data on the location of China's power plants, 46 percent of coal-fueled power plants are built around the median- and large-size cities with five million people or above. The good news is that China has invested extensively in sulfur dioxide scrubbers since 2006, and new policies were enacted in 2007 to increase the likelihood that installed scrubbers actually operate (Xu, Williams, and Socolow 2009).[25] Electric utilities are point sources that export pollution to nearby cities. In the cases of water pollution (Cai, Chen, and Qing 2012; Sigman 2002), ambient air pollution in the United States (Bayer, Keohane, and Timmins 2009) and ambient air pollution China (Zheng et al. forthcoming), empirical studies have documented the importance of accounting for cross-boundary pollution flows.

Millions of Chinese urbanites rely on coal for winter heating. The United States and

---

[22] National Bureau of Statistics of China (2012).

[23] http://www.worldcoal.org/coal/uses-of-coal/coal-electricity/.

[24] "Power plants also emit low levels of uranium, thorium, and other radioactive elements as well as mercury, and other heavy metals. These toxic pollutants have been associated with serious health problems including cognitive impairment, mental retardation, autism and blindness. . . . Power plants also generate immense quantities of ash and other residues. When fossil fuels are burned the noncombustible portion of the fuel is left behind along with residues from dust-collecting systems, sulfur dioxide scrubbers and other emissions abatement equipment. These residues consist mostly of silicon, aluminum, and iron, but also contain lead, cadmium, arsenic, selenium, and mercury. Many plants landfill these residues on site. If managed improperly, particles can be picked up by wind and transported locally or enter drinking water supplies" (Davis 2011).

[25] Xu, Williams, and Socolow (2009) shows that China installed over 100 GWe of SO_2 scrubbers in coal power plants in 2006 and again in 2007. The share of coal power plants with SO_2 scrubbers increased from 10 percent to 48 percent from 2005 to the end of 2007. Under current regulatory policies, all coal power plants with SO_2 scrubbers must install continuous monitoring systems and transfer real-time data to the government. Second, electric utilities are incentivized to install scrubbers. For power plants that operate at 100 percent capacity, they can sell electricity to the grid at a $2.0/MWh price premium compared to a plant without scrubbers, but the premium falls to zero at an 80 percent operation rate.

Europe followed this strategy in the mid-twentieth century (Clay and Troesken 2010). There were major environmental costs of relying on this cheap but dirty fuel. Today, China is facing similar issues. Winter heating is subsidized for homes and offices in northern China above the Huai River and Qinling Mountains where the average January temperature is roughly 0° Celsius. This sector creates high level of emissions because heating's main energy source is coal (Almond et al. 2009). Accordingly, during the winter heating season, the contributions from coal combustion and biomass aerosol to $PM_{2.5}$ mass increased in northern cities (Zheng et al. 2005).

Roughly 15 percent of China's electricity is generated using hydropower. Environmentalists have been deeply concerned about the consequences of building the Three Gorges Dam along the Yangtze River. While hydropower is "green" in terms of greenhouse gas and local air pollution emissions, such dam construction has implications for local communities and downstream areas (Duflo and Pande 2007).

China's central and local governments are also investing in promoting the "green economy" because this is viewed as a promising new export market (Boyd 2012). Anticipating the rising international demand for electricity and the desire to reduce greenhouse gas emissions associated with power generation, developing nations such as China and India are playing a leading role in increasing their production capacity for producing renewable power equipment such as wind turbines and solar panels. Sawhney and Kahn (2012) document the role of China and India as growing players in the nascent green economy supply chains for renewable power equipment. Those types of equipment are both exported globally and are also sold in the domestic market. China is now the world's largest exporter of solar panels, with over 40 percent of global market share.[26] On the other hand, the growth of China's wind turbine production has focused in the domestic market, and the export share is only 1.2 percent in terms of total installed capacity in 2011.[27]

3.5 *Natural Resource Extraction and GHG Emissions*

Throughout this section, we have focused on how China's urban growth affects local environmental quality but many externalities feature degradation of regional and global public goods. For example, the creation of greenhouse gas emissions (see figure 3) is a global public bad.

Rising demand for meat, electricity, wood, and fish takes place as a direct consequence of economic growth. An active research field on sustainability seeks to measure "ecological footprint." It is a construct that translates total annual resource consumption into a physical land required to create and offset those flows. Wackernagel et al. (2002) document the sharp rise in the earth's ecological footprint during a time of ongoing growth in China and other developing nations.

Consider the example of shark fin soup. If this delicacy is increasingly in demand in a richer China, then there can be an overshoot of extracting sharks from the world's oceans.[28] Diamond (2006) argues that an unintended consequence of the developing world achieving U.S. consumption levels could have devastating implications for our natural capital stocks especially when such capital is public property. In this case,

---

[26] See http://yaleglobal.yale.edu/content/chinas-green-ambition-us-sees-red.

[27] Li et al. (2012).

[28] Taylor (2011) presents an economic model of bison extraction and extinction. He emphasizes that extinction's likelihood hinges on the price for buffalo products that was largely invariant to changes in supply; open access conditions with no regulation of the buffalo kill; and, finally, a newly invented tanning process that made buffalo hides into valuable commercial leather.

economic growth fueled by urbanization exacerbates the classic tragedy of the commons problems. An optimist would posit that an awareness of the challenge caused by growth creates a push to change the property rights regime to encourage conservation (Smith et al. 2010).

In a growing economy, the only way to reduce overall emissions is to reduce emissions per dollar of GDP. Since greenhouse gas emissions are a global public bad, there has been great concern that no individual nation has an incentive to reduce its own emissions. National level panel studies of carbon emissions such as Schmalensee, Stoker, and Judson (1998) conclude that the marginal effect of income on increasing carbon dioxide emissions declines with economic development. China has emerged as the largest energy consumer and GHG emitter in the world (Netherlands Environmental Assessment Agency 2012). Auffhammer and Carson (2008) use panel data for China's twenty-five provinces in twenty years and proxy for GHG using waste gas emissions. Their forecasting model yields a pessimistic prediction of considerable expected growth in China's GHG emissions. The good news is that the Chinese government's policy response to climate change has also shifted markedly. At the Copenhagen Climate Summit in 2009, China pledged to achieve a carbon intensity reduction of 40–45 percent by 2020 (Department of Climate Change, NDRC, 2010). In the current 12th Five Years Plan (FYP), China is targeting a 17 percent reduction in CO_2 intensity (tons of carbon dioxide emitted per unit of GDP output) between 2011 and 2015 (Government of the People's Republic of China 2011, National Development and Reform Commission 2007). This means that, on average, energy intensity (energy consumption per unit of GDP output) should decline by an annual rate of about 3 percent–3.5 percent between 2011 and 2015. In the year 2011, there was a

2.01 percent reduction[29] and this is expected to decline further by 5 percent in 2012.[30] Whether these targets can be achieved remains an open question.

3.6 *Summary*

In the previous subsections, we have surveyed recent work discussing the environmental impact of population growth, the transportation, industrial, household and power generation sectors in China. For each of these sectors, pollution production is an unintended byproduct of economic growth. The extent of the urban environmental impact hinges on each sector's scale, composition and technique effects, as well as the geography of where the activity is concentrated. The common factor linking these spatial externalities is the tragedy of the commons. While hundreds of millions of Chinese urbanites suffer from the pollution's consequences, the powerful central and local governments have been slow to address these issues. Until recently, such officials have focused on economic growth maximization and the scale effects associated with growth only exacerbate the externalities we have discussed in this section. As we will discuss below, there are reasons to believe that a transition is taking place in China's environmental governance such that more effort will be invested in protecting the public's health.

4. *Rising Demand for "Green Cities" in Chinese Cities*

In Chinese cities, the new cohorts of urbanites are richer and better educated. This section explores the association between household income and education in increasing the demand to live in "green cities."

---

[29] http://www.stats.gov.cn/english/pressrelease/t20120817_402828531.htm.
[30] http://www.wantchinatimes.com/news-sublcass-cnt.aspx?id=20121205000083&cid=1105.

Such cities offer direct aesthetic benefits and "greenness" also represents an input in the production of health capital. We first discuss the driving forces behind the rising demand for environmental quality in China, and then survey recent evidence of this rising demand. We then discuss the implications of this trend for home owners and the poor.

4.1 *Rising Demand for Risk Reduction*

Death rates in China's cities are declining due to improvements in medical care, and better diets. The infant mortality rate had decreased sharply from 1.73 percent in 1991 to 0.58 percent in 2010 in Chinese cities. Life expectancy at birth (in years) had improved from 66 to 73.3 during this thirty-year period. As death risk from other diseases declines, the benefits of pollution control increases (Dow, Philipson, and Sala-i-Martin 1999; Murphy and Topel 2006).

Educational attainment in major Chinese cities is rising sharply over time. In year 2000, 11.0 percent of people above 25 years old had college or above degrees in Chinese cities, while in 2010 this share increased to 21.2 percent.[31] Education's role in producing health capital remains an active research topic (Conti, Heckman, and Urzua 2010). Urban researchers such as Moretti (2004) and Glaeser (1998, 2011) have documented the social benefits of highly educated cities. More educated people are more likely to support environmental protection (Kahn 2002, Kahn and Matsusaka 1997). One explanation for this fact is that education may make us more patient and future focused (Becker and Mulligan 1997).

There are clear complementarities between human capital and health capital (Currie 2011). In a Becker household production function approach, altruistic parents who seek to develop the human capital of

their children are likely to seek out safe and clean communities in order to reduce risks to health capital. Skill is a key determinant of urban earnings in both developed and developing nations (Glaeser 2011; Moretti 2012). A major research effort in human capital research today is to improve our understanding of skill formation over the life-cycle. Heckman's (2007) work has emphasized the importance of early life investments in children and has posited a dynamic complementarity model such that learning begets learning and skill begets skill. Pollution exposure at early ages lowers the likelihood of later life development (Currie 2011; Currie and Almond 2011; Currie and Schmieder 2009; Currie and Walker 2011). Recent cohort studies such as Almond (2006), and Almond, Edlund, and Palme (2009) have documented the role that early life events such as exposure to influenza or exposure to Chernobyl nuclear radiation play in long-term human development. Reyes (2008) documents the impact of early lead exposure on the propensity of young adults to have attention deficit disorder and lower IQs.

Chinese urbanites are aware of the risks they face due to pollution exposure and risks from day to day products such as smoking, milk, and the food supply. Richer people are willing to pay more to avoid risk. U.S. research on measuring the value of a statistical life has documented that it rises faster over time than per capita GNP (Costa and Kahn 2004).[32] If this finding also applies in Chinese cities, the population's demand for risk reduction will rise sharply over time. Kenkel, Lillard, and Liu (2009) documents that from the 1950s to the 1990s, smoking rates in China generally increased, while

---

[31] Statistical analysis based on the data of Population Census of China in 2000 and 2010.

[32] Costa and Kahn (2004) combine IPUMS Census data with data from the BLS with respect to industrial fatality risk. Based on repeat hedonic wage OLS regressions from 1940, 1960, 1970, 1980, 1990, and 2000, they find that the value of a statistical life has increased by a larger percentage than national GNP growth.

starting in the mid-1990s smoking rates for all education groups began to drop. Chinese urban households are increasingly investing in self-protection as revealed by paying a higher price premium for imports from the United States and Hong Kong such as imported baby milk that is perceived to be safer.

Given the importance of early childhood development, pollution is a crucial public policy issue (Chay and Greenstone 2003, Currie and Neidell 2005). China's unique one child policy creates the incentive for households to invest more time and resources in their one child (Becker and Lewis 1974).[33] After China's tainted baby milk scandal (Yang et al. 2009), more than 60 percent of the baby milk Chinese parents bought were from oversea places, and they paid a price premium of roughly 33 percent.[34] Such a price premium means that urbanites are sacrificing other consumption in order to produce healthy children. Urban parents also put political pressure on the government to reduce risk. While the concept of the "median voter" may not apply in China, below we will argue that politicians are responsive to households' desires.

4.2 *Rising Demand for Information and Accountability*

A recent U.S. literature has documented that access to high quality, up to date information on local pollution challenges leads to self protection investments that break the link between ambient pollution and exposure. Jin and Leslie (2003) find that the provision of restaurant public hygiene report cards improved California public health by causing

changes in behaviors on both the demand and supply sides. Neidell (2009) exploits a regression discontinuity design to study how Smog Alerts affect household behavior and documents statistically significant evidence that attendance drops at the Los Angeles Zoo and Dodger Stadium (both are located in polluted parts of Los Angeles) when a Smog Alert is announced.[35] For evidence on the persistence of these behavioral responses, see Graff-Zivin and Neidell (2009).

Recent research set in India, Brazil, Indonesia, and China highlights the power of the media and information disclosure to mitigate classic principal–agent problems and to nudge government officials to supply public goods. Besley and Burgess (2002) report evidence from India that in those states where there is greater literacy, media coverage disciplines politicians to act in the public's interest and minimizes agency concerns as politicians are more likely to be held accountable if they do not deliver public goods. Ferraz and Finan (2008) document that Brazilian voters responded to information about their municipalities' expenditures of federally transferred funds. They show that the release of the audit outcomes had a significant impact on incumbents' electoral performance, and that these effects were more pronounced in municipalities where

---

[33] This "one child policy" is more binding in the public sector (governments, public institutions and SOEs), but less binding in the private sector (private and foreign invested companies). Households that violate this rule must pay a considerably high fine. In addition, the parents will be fired if they are employed in the public sector.

[34] For more background information, see http://topics.nytimes.com/top/reference/timestopics/subjects/m/melamine/index.html.

[35] Moretti and Neidell (2011) recognize that the population is likely to invest in self protection when they anticipate high levels of ambient pollution. This suggests that the correlation of sickness and unanticipated pollution will be higher than the correlation between sickness and anticipated pollution. In the former case, the population is less able to self protect against a threat they do not anticipate. Moretti and Neidell exploit cargo boat arrivals into the Port of Los Angeles as a plausibly exogenous instrumental variable that affects local ambient air pollution. They document that in a regression of health on pollution exposure that the IV results are larger than the OLS results, which provides strong evidence that the affected population is taking self protective steps to minimize the impact of expected high pollution levels. Intuitively, their IV strategy captures surprise shocks to pollution for which the public is less able to protect against. In this case, pollution causes more health damage.

local radio was present to divulge the information. Pargal and Wheeler (1996) present evidence from Indonesia highlighting the role that information disclosure plays in nudging polluting firms to change their behavior. Jin, Wang, and Wheeler (2010) report that China's Green Watch ratings program implemented in four cities of Jiangsu province (Huaian, Wuxi, Yangzhou, and Zhenjiang) was effective in reducing firms' emissions.[36] The percentage of firms with positive ratings increased from 75 percent in 1999 to 85 percent in 2000 while the percentage of extremely noncompliant firms declined from 11 percent in 1999 to 2 percent in 2000. This program has been scaled up over time.

In the past, the Chinese state monopolized news coverage and this meant that environmental disasters caused by industrial negligence would not generate the same attention as if a similar event took place in the United States or Europe. In the absence of media attention and public outrage, officials would have less of an incentive to nudge polluting industries to invest in costly precautions.[37] As the new urban cohorts in China become richer and more educated, they have a greater willingness to pay to avoid risk, thus their demand for information and political accountability is likely to rise.

The rise of demand for environmental information creates incentives for the media to cover such stories (Gentzkow and Shapiro

2010). In recent years, the Chinese media has devoted much greater attention to environmental issues. For instance, the number of Google news on this topic in year 2011 is 240 times than ten years ago. With the modern media and IT technologies such as blogs, micro blogs (*weibo*, Chinese version of Twitter), and mobile phone messages, the government does not have a monopoly allowing for a suppression of information any longer.[38] This should incentivize politicians to invest more effort in supplying environmental regulation.

Martinez-Bravo et al. (2012) find that the introduction of competitive election in China's rural villages significantly increases the village leaders' accountability, and thus increase public goods expenditure and provision. Competitive elections have not been introduced into China's urban sector. However, the power of the media and information disclosure encourages city mayors to supply environmental regulations.

One salient example is the recent Internet criticism that pushed China's government to report on $PM_{2.5}$ air pollution.[39] In fall 2011, some skepticism was raised in the media and micro blogs on the authenticity of the official Air Pollution Index (API) reported in

---

[36] The Green Watch program seeks to reduce industrial pollution by rating the environmental performance (air, water, and toxic pollutants) of approximately 2,500 polluting enterprises in thirteen municipalities of Jiangsu Province. The ratings are publicly released. Those "green" enterprises with better ratings are able to access lower-interest loans from banks. "Brown" enterprises will receive local governments' strict supervision and face significant pressure from the public.

[37] If individuals (the victims) cannot identify the pollution source or be aware of the pollution then they cannot take ex ante precautions or seek restitution through ex post liability suits. In such a case, the polluter faces no accountability for its actions and this encourages malfeasance.

[38] In Western countries, the media devotes ample attention to environmental disasters. Examples include the Exxon Valdez Oil Spill or the BP Oil Spill in 2010. This media attention affects interest group competition and gives pro-regulation forces the upper hand to potentially overcome the asymmetric interest group problem noted by Olson (1965).

[39] Total suspended particles (TSP) measure the mass concentration of particulate matter in the air. Within TSP, PM_{10} stands for particles with a diameter of 10 micrometers or less, and $PM_{2.5}$ stands for those with a diameter of 2.5 micrometers or less. Particulates that are ten micrometers or greater are filtered and generally do not enter the lungs. Particulates smaller than ten micrometers are likely to enter the lungs. Particulate matter that is smaller than 2.5 micrometers ($PM_{2.5}$) can enter into the Alveoli where gas exchange occurs. Throughout the world, ambient monitoring now focuses on PM_{10} and $PM_{2.5}$. See http://www.epa.gov/ttnamti1/contmont.html and http://www.aidic.it/aaas08/webpapers/44Lanzani.pdf.

Beijing. This Index mainly measures PM_{10}, which stands for particles with a diameter of 10 micrometers or less.[40] The most recent public concern has focused on the divergence between the officially released PM_{10} readings in Beijing versus the daily $PM_{2.5}$ readings reported by the U.S. Embassy in Beijing. On a foggy day of Oct. 9, 2011, the U.S. Embassy's $PM_{2.5}$ reading was so high compared with the standards set by the U.S. Environmental Protection Agency that it was listed as "beyond index." But China's own assessment based on PM_{10} was merely "slightly polluted."[41] This large divergence took place several times in that month and this triggered a debate in the media and micro blogs. At first, the Beijing local officials argued that these two readings measured different sized particulates so that a direct comparison was not valid, but the public was not convinced. Later the central government stepped in and expressed the opinion that "air quality monitoring reports should be consistent with people's real feeling." It also required that all municipalities and provincial capital cities should start to monitor and report $PM_{2.5}$ starting in 2012, and all prefecture-level cities should start this in 2015.

High-profile industrial accidents in China offer a second example of the role of mobilizing public opinion. In August 2011, messages widely spread through micro blogs, Twitter, and other Internet forums that a Dalian PX (paraxylene) chemical factory (a joint venture between the city and a private company) was at high risk to flood the town with the highly toxic chemical. Twelve thousand Dalian residents organized a peaceful public protest in Dalian's People's Square on August 14th, demanding that the factory be immediately shut down and relocated, and that the details about the investigation into the factory should be made public. The Dalian government forbade the factory from opening.

An optimistic hypothesis is that environmental officials who anticipate ex post accountability for disasters will be more pro active to take regulatory actions that reduce the probability that industrial disasters occur in the first place. An alternative view is that media competition does not necessarily lead to greater accuracy of coverage. Gentzkow and Shapiro (2010) find evidence supporting a Hotelling differentiation theory that newspapers cater their stories to appeal to their base readers. Such a theory of ideological sorting could explain why the U.S. media differs (contrast Fox News with MSNBC) in its portrayal of the challenge of climate change. More rigorous studies are needed to test these hypotheses.

4.4 *Rising Demand for Green Cities: Evidence from Home Price Compensating Differentials*

The urban quality of life literature emphasizes that spatial variation in wages and rents represents a compensating differential for place based local public goods (Rosen 2002). This revealed preference methodology allows scholars to identify urban households' demand for nonmarket goods, including urban environmental amenities and allows researchers to rank areas' quality of life (Albouy 2008, Albouy and Lue 2011, Gyourko, Kahn, and Tracy 1999).

---

[40] In academic circles, serious questions have been raised about the quality of this API. For instance, Wang et al. (2009) find that their self-measured PM level in Beijing during the 2008 Olympics Game period is correlated with official API, but their readings are 30 percent higher. Andrews (2008) pointed out a likely systematic downward-bias around the "Blue Sky" standard (API less than or equal to 100), and also highlighted a sampling downward bias due to the dropping of monitoring stations in the more pollution concentrated traffic areas in Beijing. These studies triggered scholars' concerns about the measurement error embedded in Chinese official API data.

[41] For more background information, see http://articles.latimes.com/2011/oct/29/world/la-fg-china-air-quality-20111030.

Using standard revealed preference methods, new research is documenting local public goods demand in China's cities. An intraurban study by Zheng and Kahn (2008) finds that proximity to fast public transit, clean air, high-quality schools, major universities, and environmental amenities are capitalized into home prices in Beijing. An intercity study of thirty-five large Chinese cities by Zheng, Kahn, and Liu (2010) finds that home prices are lower in cities with higher ambient pollution levels, and the marginal valuation for green amenities is rising over time. They report evidence of an Environmental Kuznets Curve such that the richer cities are beyond the turning point at a much lower level of per capita income than has been estimated in cross-country work (Grossman and Krueger 1995).

All hedonic studies that rely on OLS potentially suffer from omitted variable bias (Gyourko and Tracy 1991, Chay and Greenstone 2005). For example, a city's air pollution could be high in cities featuring booming industrial industries. In this case, a hedonic researcher conducting a cross-city study may estimate a positive association between air pollution and local real estate prices because air pollution is positively correlated with the positive local industrial demand shock. In a U.S. study, Bayer, Keohane, and Timmins (2009) introduce a potentially credible instrument. They document in the first stage of an IV regression that cross-boundary air pollution externality spillovers are correlated with a city's ambient air pollution. Zheng et al. (forthcoming) use this same IV approach in China. They exploit the fact that the quantity of emissions that are imported into a city depending on the dominant wind direction and emissions from nearby cities and from the sandstorms from Inner Mongolia. Both of these exporting sources raise the "destination" city's ambient pollution level. They find that on average, a 10 percent decrease in imported neighbor pollution is associated with a 0.76 percent increase in local home prices.

4.5 *Gentrification Triggered by Quality of Life Improvements*

Standard economic incidence issues arise when local quality of life improves. When migration costs are low, arbitrage theory predicts that landowners will enjoy a windfall gain due to pollution reductions. In China, the home is the major asset for almost all home owners. The homeownership rate in Chinese cities is high (74.2 percent in 2010 Population Census). Given the capitalization of quality of life into local real estate prices, if the city's economic fortunes improve or if local amenities increase then home owners gain (Gyourko and Tracy 1991). Home owners become an interest group with a stake in enhancing quality of life.

Cities whose quality of life improves will be more likely to attract and retain the skilled, and this gentrification process will further bid up home prices (Glaeser, Kolko, and Saiz 2001; Shapiro 2006). Such gentrification has been documented in many cases in the United States. Sieg et al. (2004) show that an unintended consequence of successful Clean Air Act regulation in Los Angeles has been to trigger migration and gentrification in previously poor areas of the city whose air pollution has sharply decreased. In this case, a social multiplier effect occurs. The government's investment has a direct effect of improving the local area's quality of life. This is capitalized into higher rents. As gentrification takes place, the local area will self-select people who can afford to pay this rent premium. A type of snowball effect ensues as the gentrification of the neighborhood attracts better stores and restaurants and this in turn attracts more high skilled people to live nearby (Waldfogel 2008).

Today, a similar dynamic is playing out in China's cities. Using several new data sets documenting the location of new home sales

and upscale restaurant openings, Zheng and Kahn (2013) document evidence that place-based public investments such as new subways and the 2008 Olympics Park have also triggered gentrification in Beijing.

How are the urban poor affected by such gentrification? There are two groups of urban poor in Chinese cities. The first group is the local poor people with *hukou*. Many of them own old houses in good locations as a legacy from the former central planning era. At locations where infrastructure improvements and new real estate development are taking place, many of those old homes are demolished. The local poor households who own those houses would receive a windfall if developers purchase their old houses at fair price, but in some cases the government seizes their homes without compensation (Wu 2004). The second group is the floating migrants who spend ninety percent of a year working in cities and bring the earnings to their rural hometown during the Chinese New Year time. *Chengzhongcun* (urban villages) is a typical type of informal housing those rural migrants stay in (Zhang, Zhao, and Tian 2003; Wu 2007; Tian 2008). High crime rates, inadequate infrastructure and services, and poor living conditions are just some of the problems in urban villages that threaten public security and management (Zheng et al. 2009). City governments seek to demolish such informal housing and those rural migrants are pushed further out to the remote suburban areas. Such displaced rural migrants do not leave the city because they can find jobs here. The end result is that the displaced rural migrants resettle in fringe metropolitan area locations featuring a longer commute to their place of work.

5. Urban "Green" Governance in China

As the U.S. experience over the last thirty years highlights, government rules, regulations, and investments play a key role in creating "green cities." Cities such as Boston, Chicago, New York, and Pittsburgh are all much cleaner and offering better nonmarket environmental amenities than they were in the recent past. When the U.S. government enacted and enforced the Clean Air Act and Clean Water Act, urban air quality and water quality improved in U.S. cities.[42] In California, the Air Resources Board has taken aggressive steps that have contributed to improving the state's ambient air quality (Kahn and Schwartz 2008).[43] In contrast, greenhouse gas emissions in the United States continue to rise as the federal government has taken few actions to implement a hard incentive such as a carbon tax to directly address this global externality (Cragg et al. 2013). In this section, we discuss the incentives of Chinese politicians and the tradeoffs they face in pursuing "green cities" versus seeking to boost their local economy through attracting dirty industries.

5.1 China's Governance Structure and the Central–Local Relationship

We now investigate China's unique governance structure and its implications for mitigating urban pollution challenges. China has a strong one-party central government, but hundreds of local governments act as competing enterprises. The governance structure in China has five vertical hierarchies: the nation, province (or municipality, autonomous region), prefecture-level city (or

---

[42] Teasing out the causal effects of such regulations has been difficult because of the challenge of identifying credible control groups. Researchers have used regression discontinuity designs to study the role of particulate regulation (see Chay and Greenstone 2005). Henderson (1996) documents the effectiveness of ozone regulation but Greenstone (2004) concludes that U.S. sulfur dioxide regulation deserves only modest credit for improvements in this indicator of air pollution. In the case of water pollution, we have not been able to identify an economics paper that measures the causal effects of the Clean Water Act on urban water quality.

[43] See http://www.arb.ca.gov/aqd/almanac/almanac.htm.

prefecture-level district), county (or county-level district, county-level city), and township (or *jiedao*). In 2010, China had thirty-one provinces (including four municipalities and five autonomous regions), 283 prefecture-level and above cities, around 2,800 counties (including 370 county level cities, and 853 districts) and more than 40,000 townships (including 6,923 *jiedaos*).

The goals of the central government and the local governments sometimes conflict. Local governments have no incentive to internalize the pollution costs that their economic activity imposes on areas outside of their political boundaries. To encourage local governments to pursue the national interest, the central government sets incentives for local government, especially for local government officials. Two major incentives are the promotion of local officials, and the transfer payments from the central government to local governments.

Promotion refers to a routine through which a person rises in the bureaucratic institution (Zhou 2001, 2007). Unlike in the West where competitive elections are used to allocate government assignments, the upper-level governments, rather than voters, decide on the appointment and promotion of lower-level officials (Wu and Ma 2009).

For a long time, China's central government focused on economic growth with an emphasis on GDP as the key evaluation criteria of local officials' performance. Chen, Li, and Zhou (2005) estimated how the difference of GDP growth rate during the current governor's term and that during his/her predecessor's term affected his/her promotion in China by using the data from the year 1979–2002. They report a statistically significant and positive effect of GDP growth on promotion probabilities. Li and Zhou (2005) document using data from China from 1979 to 1995 that provincial leaders whose geographical areas boomed were more likely to be promoted.

Local governments need financial resource to build and maintain infrastructure such as public transit, sewers and water treatment, which allow a city to grow without exacerbating urban pollution problems. In Chinese cities, there is no property tax.[44] In the current tax-sharing system (*fen shui zhi*) established in 1994, the central government claims about half of all fiscal revenue (Loo and Chow 2006), but most financial obligations (infrastructure construction and public service provision) are still their responsibility (Bahl 1999; Zhou and Zhang 2008). Since then, a huge portion of local public expenditure comes from the central government's transfer payment (in 2010 this share was 43.8 percent). Earmarked transfer payments from the central government are set for compensating for local government expenditure on some specific programs, such as infrastructure construction and environmental protection expenditure. These transfer payments, especially earmarks, play an important role in "correcting" local government behavior. For example, Liu and Zhang (2011) find that the earmark encourages the local government to construct sewage treatment and is an incentive for local government's pollution-reducing investments.

Another major revenue source for local governments to finance infrastructure construction comes from land sales (Tao, Yuan, and Cao 2007). Urban land is owned by the state, but in practice, the local (city) land bureau is responsible for the allocations of land through auction sales of leasehold rights and keeps the land sale revenue (Cai, Henderson, and Zhang 2009).[45] The central government has long prohibited

---

[44] In 2010, Chongqing and Shanghai launched the pilot program of a property tax. This newly designed property tax is more like a luxury tax, under which only high-end properties (less than 5 percent of the total housing stock) will be taxed. There is no property tax in other cities.

[45] Such land leasehold rights provide the purchaser with 70 years for residential use, forty years for commercial use,

municipalities from issuing bonds to finance government projects, as American cities do as a matter of course. To overcome such rules, cities set up so-called municipal investment companies to borrow tens of billions of dollars mainly from state-run banks using land as collateral to finance infrastructure investments.[46] Large financial risks are also associated with this infrastructure-financing option which stems from municipal borrowing based on inflated land values offered as collateral to banks (Peterson 2006).

Today, about one third of the typical city's revenue is due to lump sum land sale revenue. Given the finite supply of land in cities, this public financing system is unlikely to persist. To develop a more sustainable local public finance system, as pilot programs, the Chinese central government allowed two cities to launch a property tax in 2010 and it further allowed four major Chinese cities to issue municipal bonds in 2011 (with the total bond amounts specified and monitored by the central government). If those pilot programs go well, such reforms are likely to expand to more cities.

5.2 *The Central Government's Incentives for Mitigating Pollution*

The Chinese central government has made attempts to protect the environment. The central government now proposes the concept of "Scientific Outlook on Development (*ke xue fa zhan guan*)" including greenness (Chow 2010). In the 12th Five-Year Plan, a target had been set of reducing energy consumption for every 10,000 yuan of GDP by 16 percent by 2015 (or 3.2 percent per year). There are four possible motivations behind the Chinese central government's ambitious and unprecedented shift to energy reform and climate change mitigation. First, the national government may be responding to the rising "green" demand of the urban middle class. Second, domestic energy security concerns have risen on the central government's agenda as a result of electricity shortages and rapidly rising energy consumption. Third, the central government believes that the rest of the world is embracing the low-carbon energy agenda has created a market imperative for China to become a technological and economic leader in this nascent field (Boyd 2012). The last explanation is that the central government seeks "legitimacy" with the Chinese people and also in the international arena, and making a commitment to pursuing environmental goals is one way to credibly signal to both domestic constituents and international actors that China is an international leader and that the Communist Party leadership cares about its own people (Wang forthcoming). The central government seeks to establish its "legitimacy" because it worries about the risk of social instability. If this last explanation is the main reason, then this raises the question of whether there are scenarios under which the central government may "change course."

To achieve its environmental and energy goals, the central government has adjusted local officials' promotion criteria accordingly from purely output-based to including more "green" indicators in its performance criteria. The National People's Congress enacted a law on energy conservation in October 2008 by stating that the energy conservation efforts made by local officials should be included into the assessment of their political performance. In 2011, China's State Council clearly restated that environmental protection is an important criterion in

---

and fifty years for industrial use. After the year 2004, leaseholds are, in principle, all sold through public auction.

[46] According to the statistics from China's National Audit Office, as of the end of 2010, the total balance of municipality loans was 10.7 trillion RMB for all cities. The number for Beijing is 374.5 billion RMB, accounting for 27.2 percent of Beijing's GDP in 2010. See http://www.audit.gov.cn/n1992130/n1992150/n1992500/2752208.html.

evaluating local officials' performance and is considered in promotion decisions. Explicit performance criteria are reported in Landry (2008).[47]

One way to achieve improvements in energy conservation is to raise fossil fuel prices. When choosing national resource pricing, the central government faces the trade-off between increasing consumer purchasing power and protecting the environment. Energy policies such as the subsidized winter heating policy north of the Huai River were intended to improve quality of life but have unintended consequences for the environment (Almond et al. 2009). Residential electricity and water use are also underpriced in Chinese cities. Fuel prices were once highly subsidized in China and this underpricing encouraged people to commute long distances from low-density suburban areas. Fuel prices have been rising quickly in recent years but no formal "gas tax" is collected. By setting resource prices low, it raises consumer purchasing power and lowers firms' costs of production, which aids growth but exacerbates externalities through encouraging consumption.

5.3 *Local Governments' Incentives for Protecting the Environment*

We now turn to local governments. Though laws were enacted and targets were set, the central government has seen serious failures to achieve these environmental objectives. A main reason for this failure is the typical principal–agent problem—local governments have little incentive to enforce such regulations in their own jurisdictions if that does not help the local official's political

career. Corruption is also a serious issue at the local level. Officials sometimes have a direct financial stake in factories or personal relationships with their owners. Such relationships provide financing and connections for private firms (Allen, Qian, and Qian 2005). In recent years, the Chinese media have uncovered cases in which local officials have put pressure on the courts, the press, or even hospitals to prevent the wrongdoings of factories from coming to light (Economy 2007). Wu et al. (2013) use data for more than 200 Chinese cities in 2001–09 to find that prefecture officials' spending on urban infrastructure strongly tilts toward transportation which help to boost economic growth and land value in their jurisdictions, but those officials spend much less on environment amenities that have not been sufficiently counted in their promotion criteria. Such officials also know that it is difficult for the central government to monitor and regulate their activities.

Under the regime shift pushed by the central government, recently city mayors are paying more attention to local environmental criteria. Using panel data in eighty-six Chinese cities during 2004 and 2009, Zheng et al. (2012) find that energy intensity (measured as a city's energy consumption per unit of GDP) and air pollution have begun to be reflected in the promotion criteria. They also find that information disclosure is nudging local officials to address local pollution problems. China's mayors now face increasing political pressure from local citizens and from the central government to pursue environmental sustainability goals. Future research should examine whether the upweighting of "green" performance criteria influences local government policies and enforcement efforts.

Improving urban living conditions requires mayors to focus more on the delivery of services to urban residents, and less on the outdated role of CEO in charge of

---

[47] The criteria include economic development, human capital, quality of life, and environmental protection and key infrastructure. Thirty points out of the total 100 points are environment related, including coverage of green areas, public green space per capita, waste water treatment, handling of garbage, and air pollution levels.

local economic development as in the planning era (Henderson 2009). Whether local mayors pursue national "green goals" hinges on what they perceive to be their "golden goose" for their political career. Some may choose to attract high-tax but dirty industries. Those cities that view their golden goose as high technology and skilled industries will be more likely to pass environmental regulations. The mayors in rich cities may put more weights on greenness because they face less pressure to deliver GDP growth. Tourist cities are also likely to do so since local environmental quality is an important input for their economy. A general conclusion from the U.S. manufacturing literature is that polluting firms are seeking out areas featuring less regulation (Berman and Bui 2001a, 2001b; Henderson 1996; Greenstone 2002; Becker and Henderson 2000; Kahn and Mansur 2013).[48] If China's superstar cities impose more stringent vehicle and industrial regulation, then this will displace dirty capital to domestic pollution havens.

Besides environmental regulation, Chinese urban planners also consider environmental protection in their practice. Residential and heavy industrial land uses are separated to reduce urban residents' exposure to industrial pollution; ecologically sensitive areas such as water sources and habitats of important species are restricted from development. Developers are required to provide green space and open space inside or around their projects. At the typical new residential complex, the green space accounts for roughly 30 percent of the complex's total land area. Home owners pay the maintenance fee for this green space as part of their condo fee. Development density is restricted around historical heritages.

Other urban planning principals include encouraging TOD (Transportation Oriented Development) and introducing BRT (Bus Rapid Transit) to reduce energy consumption and traffic congestion. However, those principles are neglected in some cases when they conflict with local governments' pursuit of economic output and fiscal revenue.

A distinctive feature in Chinese cities is that local governments have a "visible" hand in influencing firm location choices and urban expansion, with urban planning and land sales as the basic policy tools. One salient example is the growth of industrial parks in many suburbs. Local governments are keen to build large industrial parks at the city fringe with cheap land and favorable tax deduction policies to attract FDI and other firms that can produce high tax revenues.[49] The government provides infrastructure and cheap land to foster industrial clusters that can be regarded as a public–private partnership in urban development (Pereira 2004).[50] If those industrial zones are hosts for high-tax but dirty industries, this will have a negative quality of life impact on local people.

To balance the pollution control requirement and economic output, the coastal

---

[48] For a comprehensive review of the U.S. literature through the mid-1990s that studied how manufacturing was affected by environmental regulation, see Jaffe et al. (1995).

[49] For example, in Zhejiang Province's "new technology zones," the government spent 100 thousand Yuan per mu (US $96,000 per acre) on average to provide basic infrastructure to the industrial land, but the average sale price of such industrial land to firms was only 86 thousand Yuan per mu (US $83,000 per acre), even less than the infrastructure cost. Half of the industrial land parcels were sold at the price less than 50 percent of the infrastructure construction cost. In some inland provinces that are keen to attract FDI and high-tax-revenue industries, some "new technology zones" sold their industrial land at zero price. See http://www.snzg.cn/article/2011/0318/article_22780.html.

[50] An example is the Chengdu high tech zone—*Tianfu* New Area that has a planned construction area of 2.2 square kilometers. The Chengdu government provides infrastructure and public services. This investment has helped to attract over 200 firms including software, digital entertainment and telecommunications companies, such as IBM, NEC, Siemens, and Ericsson. See http://www.chinadaily.com.cn/regional/2012-01/18/content_14471407.htm.

provinces have shut down heavily polluted factories (Witte et al. 2009), and then relocated those highly earning but pollution intensive industries to the relatively poorer regions within the same province. For instance, Guangdong province is subsidizing polluting firms in the Pearl River Delta to relocate in the northern part of the province, and Jiangsu province is relocating those firms to the north-Jiangsu (*Subei*) area. This may be the provincial governments' intended strategy of trying to green the big city and trying to spread income to the poor underperforming areas within the region.

Chinese local governments also have strong influence over determining the allocation of the urban land supply through land sales. This affects the locational choices of firms and households. Given that the inner city has already been developed, there is a greater likelihood of finding available land by seizing it or purchasing it from agricultural communities at a very low price at the city fringe. The range of compensation for farmers for land taken is often based on income generated in agriculture use instead of being tied to the value of the land if allocated to urban use (Ding and Song 2005).[51] Farmers whose land is grabbed are dislocated from their old life and they are unable to receive enough job training to become urban workers. Recently there have been international media stories of farmers fighting hard to protect their rural land.[52] A salient example is the prominent recent fight in Wukan village, which is a suburb of Guangzhou in Guangdong Province.[53] If cities face a low opportunity

cost of taking agricultural land, then this is an implicit subsidy to suburban growth, and such cities will be more likely to sprawl.

On the other hand, reliance on land sale revenues in Chinese cities may also incentivize local governments to internalize quality of life effects because this will increase their land's value (Arnott 2008). While Chinese cities rely on land sales for revenue today, it is likely that cities will run out of land at some time point in the future. This will encourage such cities to introduce a property tax system. Those cities with high quality of life and high real estate prices could enjoy high revenues under this scheme.

As the restrictions of the *hukou* system on labor mobility have been largely removed, Chinese cities are moving toward a system of open cities (Zheng, Kahn, and Liu 2010). A Tiebout theory of competition would optimistically posit that those cities that do not supply such public goods will suffer a brain drain as they are unable to attract and retain the skilled. In this sense, mobility and "voting with feet" is a key way to potentially discipline politicians if they do not themselves have an environmentalist ideology.

---

[51] For more information, see: http://www.nytimes.com/2011/09/24/world/asia/land-dispute-stirs-riots-in-southern-china.html?ref=world.

[52] The likelihood that such protests erupt depends on such factors as the urban–rural land value gap, whether farmers are more educated, and whether the local officials have more experience in dealing with such conflicts.

[53] In September 2011, the Wukan village committee sold collective land to a real estate developer without properly compensating the villagers. Villagers went to

demonstrate but were repressed by the police. The protest escalated two months later. After the event attracted a high degree of attention, Lufeng city government and Guangdong province government stepped out and satisfied the villagers requests. In many other parts in rural China, villagers do not have the same firm grasp of the nuances of the news media. But Guangdong is China's wealthiest and most liberal province, and it has publications that are relatively freewheeling. More important, Cantonese speakers here gravitate to the uncensored news reports and cultural products of Hong Kong, on the province's southern edge. "People in Guangdong are close to Hong Kong," Yuan Weishi, a historian, now retired, who taught at Sun Yat-sen University in Guangzhou said in a telephone interview. "They watch Hong Kong TV, rarely China Central Television, and so have a better understanding of civil society and the rule of law." "Have you noticed how many Hong Kong reporters are in Wukan?" he added. "Being exposed to the Hong Kong media in their daily lives gives Guangdong people a better understanding of how the media works and what they can do." Source (http://www.nytimes.com/2011/12/23/world/asia/canny-wukan-villagers-grasp-keys-to-loosen-chinas-muzzle.html).

5.4 *Asymmetric Information Issues*

Throughout this section, we have assumed that the urban leaders and urbanites are aware of the environmental science of how economic activity maps into perverse health outcomes but in many cases there are "known unknowns." Dasgupta et al. (2002) argue that, in the case of new toxics, that economic development will be positively correlated with rising pollution because there will be no government response.

In China, local officials are often better informed than the central government or the people. Mayors have private information about their cities' environmental performance and may cover up environmental challenges to minimize concerns from the state. To monitor the local government and officials' behavior, China's central government has built channels to monitor local government officials. The traditional channels to collect information include government audits, a top–bottom way, and petition, a bottom–top way. But the effectiveness of these channels has been questioned. There have been many reports in the Western press of people being abducted and taken to "black jails" when they attempt to press petitions, or are intercepted on their way to Beijing so that they cannot file petitions.[54] However, environmental issues represent a more politically acceptable issue to protest relative to other more "hot button" subjects such as the Tibet issue or "political reform." Therefore, environmental protestors may have a greater chance to succeed. More rigorous studies are needed to support this hypothesis.

While the Chinese state controls leading newspapers, the rise of Internet media and micro blogs (the Chinese version of Twitter) have allowed individuals to express their concerns and displeasures with quality of life outcomes in China. The micro blog as a nascent web application emerged in 2009 in China, and its usage has surged since then. It had 250 million users by the end of 2011. The national government has also started to use Internet media strategically as an effective way to bring about accountability and transparency. Its role has been highlighted in Dalian PX protest in August 2011 and the Beijing $PM_{2.5}$ debate in October 2011.

In some cases, local governments lack enough information to monitor firms' polluting behaviors. Firms can move to areas where it is less likely to be enforced or they can simply shirk and hope to not be detected (Becker 1965; Ehrlich and Becker 1972). More industrial accidents are likely to take place in geographical areas where industry believes that it is unlikely to be monitored and it would face low fines if caught shirking on environmental protection. This is more likely to happen in China and other LDCs where the informal sector is an important part of the economy. The illegal rare earth mining in China is a typical example. China mines 99 percent of the global supply of heavy rare earths, with legal, state-owned mines accounting for only a small portion of China's output. Mayors are more likely to give mining permits to those mines in far suburban areas so that they can get the revenue from selling rare earth but also keep mining activity far away from dense population centers. There is an enormous black market for this output. China's national and provincial governments are working hard to crack down on the illegal mines to reduce their severe environmental impacts, to which local authorities have long turned a blind eye (Shen, Dai, and Gunson 2009).[55]

---

[54] In those cases, the petitioners are held in black jails—which could be anything from a hotel to an empty school—for weeks or even months before being sent home. See http://www.time.com/time/world/article/0,8599,1938515,00.html.

[55] See also http://www.nytimes.com/2010/12/30/business/global/30smuggle.html?pagewanted=all.

Part of the credit for pollution progress in the United States is due to the rise of active environmental NGOs as they provide an independent source of information and help to overcome free rider problems in the fight between asymmetric pressure groups (Olson 1965). In the United States, nonprofits such as Robert F. Kennedy Jr.'s Riverkeeper launch lawsuits against polluting firms to stop companies from degrading the commons. China is also providing more room for citizens to organize themselves and express their environmental concerns. A growing sector of (semi) independent nongovernmental organizations (NGOs) addresses environmental issues. There are now over ten thousand local, provincial, and national environmental NGOs in China. The truly independent Chinese NGOs, also called grassroots NGOs, have far less impacts than the so-called Chinese-based western NGOs, due to less funding and lower degrees of professionalization (Mol 2009). Those NGOs have begun to play a role in environmental protection in China. But the Chinese government mainly passively responds to such public demands on an ad hoc basis, with little institutional commitment for engaging more public participation on environmental issues (Li, Liu, and Li 2012). The number of successful environmental law cases is very small in China. The central government is making efforts to enforce the environmental laws and encourage people to launch lawsuits against pollution accidents, but local courts are influenced by local governments. The judges are appointed by the same-level government but are not elected.

6. *Future Research Opportunities*

China needs to accommodate 300 million future urbanites. Economic research can help to minimize the pollution consequences of this extraordinary anticipated growth. Here we list what we believe are the most pressing open research questions and sketch possible research designs for generating credible causal effects estimates. Chow (2010) provides an excellent survey of China's major environmental policies. Some of our proposed research topics are related to evaluating the consequences of those policies.

6.1 *Governments' Incentives*

One key issue focuses on the central government's continuing commitment to pursue environmental objectives. In a similar spirit as McFadden (1976), revealed preference tests could be conducted to study how the central government trade-offs improving environmental quality versus pursuing further economic growth. More research is needed to test whether local officials are responding to the central government's "green criteria" by engaging in "accounting tricks" or whether the new incentives embodied in the promotion criteria cause a change in local official behavior that leads to improved environmental performance based on objective criteria. Provincial-level guidelines for performance evaluation of city officials provide some variation in how city mayors are evaluated differently in different provinces. In this way, a control group of mayors who are not (or to a lesser extent) subject to "green criteria" can be identified.

6.2 *Supply-Side Research Topics*

On the supply side, each of the subsections in section 3 suggests promising research questions. Regarding population growth, from an environmental perspective what is the optimal city size for China's growing cities? Should migrants be directed to a few mega cities or spread out across multiple medium sized cities? In the case of industrial production, one major issue relates to China's medium term share of world industrial production. As wages rise in China and as China's cities enforce more

environmental regulations, will industrial production migrate within China to poorer cities (domestic pollution havens) or will it migrate out of China to poorer nations such as Vietnam and Pakistan? Will Chinese workers, firm shareholders, or final consumers bear the incidence of tightening environmental regulation in China?

Given the success of information regulation in the U.S. context, will the increased Chinese media attention paid to industrial pollution issues increase industrial polluter accountability? A possible field experiment can be run in which industrial cities are randomly assigned to the Green Watch program and others to the control group, and then their environmental performance are observed several years later. The external validity of this field experiment design depends on whether the central government has the power to randomly select a number of cities to enter this program.

Another promising research topic is to establish the role that FDI plays in determining industrial emissions in China. Zheng, Kahn, and Liu's (2010) study suggests that such investment is associated with reduced pollution per unit of output (a greening of technique). If this association represents a causal effect, then increased global capital flows could play an important role in bending in the EKC for developing nations. The key to testing this hypothesis that FDI causes an improvement in production techniques is to address the concern that FDI inflows are correlated with unobserved determinants of local pollution levels. Greenstone, Hornbeck, and Moretti (2010) provide a credible research design by comparing the before/after outcomes of "twin" geographical areas one of which happens to win the competition of recruiting the industrial plant while the other fails. A similar approach could be pursued in China if the internal information can be obtained from specific government departments on a list of city candidates who are pursuing major foreign firms, such as Samsung, Foxconn, and Hewlett Packard (HP).

The endogenous innovation literature has documented that research and development responds to anticipated aggregate demand shifts. If energy prices are high and expected to rise globally, then the induced innovation hypothesis would posit that firms will develop energy efficient products to serve this market (Newell, Jaffe, and Stavins 1999). In the case of China, as a legacy of communism, the central government has used its power to reduce the volatility of oil and electricity prices (Tan and Wolak 2009). However, recently the central government is increasingly willing to allow energy prices to fluctuate and this should stimulate more innovation and adoption of energy efficient products. Event studies can be conducted if the policy shift dates can be identified. Such research would build on U.S. studies of energy efficiency gains for air conditioners (Newell, Jaffe, and Stavins 1999) and cars (Knittel 2011).

6.3 *Demand-Side Research Topics*

An important demand-side question is whether the "American Dream" will be the "Chinese Dream"? As Chinese urban households grow richer, will cities with fast income growth become car cities like U.S. cities or public transit cities like European cities. Zheng et al. (2011) uses a cross-sectional micro dataset of 25 thousand urban households in China to find that the income elasticity of car ownership is 0.63, which suggests that car ownership growth will be lower than income growth. However this prediction merits future research, and longitudinal micro data can help to better identify the causal relationship between income growth and the transition to car ownership.

Households jointly choose where to live, where to work, and how to commute around the city. One open research topic is to test the central idea from the urban planning

literature that urban form has a causal impact on vehicle ownership and utilization. Put simply, when people live downtown at high density does this cause them to not buy a car and commute by foot and public transit? The observed correlation between living at high population density and driving little may be due to both selection and treatment effects. The most convincing work by Eid et al. (2008) has used longitudinal data to study the change in weight for people who move between the central city and the suburbs. China's strong urban planning policies offer one source of exogenous variation. One example is that, in some cities, local governments tear down old houses in the central city and build resettlement houses for those resettled households at random locations in the suburbs. This provides potentially exogenous variation in place of residence.

7. *Conclusion*

China's amazing recent economic performance has been fueled by urban industrial growth. Over the next thirty years, hundreds of millions of Chinese households are expected to urbanize. This survey has investigated the environmental consequences of this ongoing urban development. Throughout this survey, we have highlighted how China's institutional factors affect the incentives of its firms and governments to tackle local and global pollution externalities.

Our analysis of the supply side of urban pollution is likely to generalize across cities in the developing world. While we recognize that a specific city's geography will play a key role in determining pollution dynamics, all growing cities wrestle with the tragedy of the commons problem in the face of increasing population, industrial production, motorization and rising electricity consumption. In the absence of first best pollution taxes, the growth in the scale of this economic activity

can have severe environmental impacts such that rising per capita income overstates improvements in the overall standard of living.

The rise of China's "green cities" hinges on a combination of rising middle class demand for quality of life, increased information transparency that encourages the accountability of governments and firms, endogenous technological change, the inclusion of sustainability in local government politicians' performance criteria. Given the political power of China's central government, a key factor determining China's urban pollution dynamics is the central government's long-term commitment to improving urban quality of life.

REFERENCES

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. 2012. "The Environment and Directed Technical Change." *American Economic Review* 102 (1): 131–66.

Akimoto, Hajime, Toshimasa Ohara, Jun-ichi Kurokawa, and Nobuhiro Horii. 2006. "Verification of Energy Consumption in China during 1996–2003 by Using Satellite Observational Data." *Atmospheric Environment* 40 (40): 7663–67.

Albouy, David. 2008. "Are Big Cities Really Bad Places to Live? Improving Quality-of-Life Estimates across Cities." National Bureau of Economic Research Working Paper 14472.

Albouy, David. 2009. "What Are Cities Worth? Land Rents, Local Productivity, and the Capitalization of Amenity Values." National Bureau of Economic Research Working Paper 14981.

Albouy, David, and Bert Lue. 2011. "Driving to Opportunity: Local Wages, Commuting, and Sub-Metropolitan Quality of Life." http://www-personal.umich.edu/~albouy/QOL/localQOL.pdf.

Allen, Franklin, Jun Qian, and Meijun Qian. 2005. "Law, Finance, and Economic Growth in China." *Journal of Financial Economics* 77 (1): 57–116.

Almond, Douglas. 2006. "Is the 1918 Influenza Pandemic Over? Long-Term Effects of In Utero Exposure in the Post-1940 U.S. Population." *Journal of Political Economy* 114 (4): 672–712.

Almond, Douglas, Yuyu Chen, Michael Greenstone, and Hongbin Li. 2009. "Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy." *American Economic Review* 99 (2): 184–90.

Almond, Douglas, Lena Edlund, and Mårten Palme. 2009. "Chernobyl's Subclinical Legacy: Prenatal Exposure to Radioactive Fallout and School

Outcomes in Sweden." *Quarterly Journal of Economics* 124 (4): 1729–72.

Alonso, William. 1964. *Location and Land Use: Toward a General Theory of Land Rent*. Cambridge and London: Harvard University Press.

Anas, Alex, Govinda Timilsina, and Siqi Zheng. 2009. "An Analysis of Various Policy Instruments to Reduce Congestion, Fuel Consumption and CO_2 Emissions in Beijing." World Bank Policy Research Working Paper 5068.

Andreoni, James, and Arik Levinson. 2001. "The Simple Analytics of the Environmental Kuznets Curve." *Journal of Public Economics* 80 (2): 269–86.

Andrews, Steven Q. 2008. "Inconsistencies in Air Quality Metrics: 'Blue Sky' Days and PM_{10} Concentrations in Beijing." *Environmental Research Letters* 3 (3): 1–14.

Arnott, Richard. 2008. "Housing Policy in Developing Countries: The Importance of the Informal Economy." In *Urbanization and Growth*, edited by Michael Spence, Patricia Clark Annez, and Robert M. Buckley, 167–96. Washington, D.C.: World Bank.

Au, Chun-Chung, and J. Vernon Henderson. 2006. "Are Chinese Cities Too Small?" *Review of Economic Studies* 73 (3): 549–76.

Auffhammer, Maximilian, and Richard T. Carson. 2008. "Forecasting the Path of China's CO_2 Emissions Using Province-Level Information." *Journal of Environmental Economics and Management* 55 (3): 229–47.

Bahl, Roy. 1999. "Fiscal Decentralization as Development Policy." *Public Budgeting and Finance* 19 (2): 59–75.

Bao, Zhen, Yinchang Feng, Li Jiao, Shengmao Hong, and Wengao Liu. 2010. "Characterization and Source Apportionment of $PM_{2.5}$ and PM_{10} in Hangzhou." (In Chinese). *Environmental Monitoring in China* 2: 44–48.

Baum-Snow, Nathaniel. 2007. "Did Highways Cause Suburbanization?" *Quarterly Journal of Economics* 122 (2): 775–805.

Baum-Snow, Nathaniel, Loren Brandt, J. Vernon Henderson, Matthew A. Turner, and Qinghua Zhang. 2012. "Roads, Railroads and Decentralization of Chinese Cities." http://www.econ.brown.edu/fac/nathaniel_baum-snow/china_transport_all.pdf.

Baum-Snow, Nathaniel, and Matthew E. Kahn. 2005. "Effects of Urban Rail Transit Expansions: Evidence from Sixteen Cities, 1970–2000." *Brookings–Wharton Papers on Urban Affairs*: 147–206.

Bayer, Patrick, Nathaniel Keohane, and Christopher Timmins. 2009. "Migration and Hedonic Valuation: The Case of Air Quality." *Journal of Environmental Economics and Management* 58 (1): 1–14.

Becker, Gary S. 1965. "A Theory of the Allocation of Time." *Economic Journal* 75 (299): 493–517.

Becker, Gary S., and H. Gregg Lewis. 1974. "Interaction between Quantity and Quality of Children." In *Economics of the Family: Marriage, Children, and Human Capital*, edited by Theodore W. Schultz, 81–90. Chicago and London: University of Chicago

Press.

Becker, Gary S., and Casey B. Mulligan. 1997. "The Endogenous Determination of Time Preference." *Quarterly Journal of Economics* 112 (3): 729–58.

Becker, Randy and J. Vernon Henderson. 2000. "Effects of Air Quality Regulations on Polluting Industries." *Journal of Political Economy* 108 (2): 379–421.

Berman, Eli, and Linda T. M. Bui. 2001a. "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." *Journal of Public Economics* 79 (2): 265–95.

Berman, Eli, and Linda T. M. Bui. 2001b. "Environmental Regulation and Productivity: Evidence from Oil Refineries." *Review of Economics and Statistics* 83 (3): 498–510.

Besley, Timothy, and Robin Burgess. 2002. "The Political Economy of Government Responsiveness: Theory and Evidence from India." *Quarterly Journal of Economics* 117 (4): 1415–51.

Bloom, Nicholas, Mirko Draca, and John Van Reenen. 2011. "Traded Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity." National Bureau of Economic Research Working Paper 16717.

Botero, Juan, Alejandro Ponce, and Andrei Shleifer. 2012. "Education and the Quality of Government." National Bureau of Economic Research Working Paper 18119.

Boyd, Olivia T. 2012. "China's Energy Reform and Climate Policy: The Ideas Motivating Change." Australian National University Crawford School of Public Policy Centre for Climate Economics and Policy Working Paper 1205.

Broda, Christian, Ephraim Leibtag, and David E. Weinstein. 2009. "The Role of Prices in Measuring the Poor's Living Standards." *Journal of Economic Perspectives* 23 (2): 77–97.

Brueckner, Jan K., Jacques-Francois Thisse, and Yves Zenou. 1999. "Why Is Central Paris Rich and Downtown Detroit Poor? An Amenity-Based Theory." *European Economic Review* 43 (1): 91–107.

Cai, Hongbin, J. Vernon Henderson, and Qinghua Zhang. 2009. "China's Land Market Auctions: Evidence of Corruption." National Bureau of Economic Research Working Paper 15067.

Cai, Hongbin, Yuyu Chen, and Gong Qing. 2012. "Polluting They Neighbor: The Case of River Pollution in China." Unpublished.

Cain, Louis P., and Elyce J. Rotella. 2001. "Death and Spending: Urban Mortality and Municipal Expenditure on Sanitation." *Annales de démographie historique* 101: 139–54.

Cao, GuoLiang, XiaoYe Zhang, SunLing Gong, XinQin An, and YaQiang Wang. 2011. "Emission Inventories of Primary Particles and Pollutant Gases for China." *Chinese Science Bulletin* 56 (8): 781–88.

Chay, Kenneth Y., and Michael Greenstone. 2003. "The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced By a Recession." *Quarterly Journal of Economics* 118 (3): 1121–67.

Chay, Kenneth Y., and Michael Greenstone. 2005. "Does Air Quality Matter? Evidence from the Housing Market." *Journal of Political Economy* 113 (2): 376–424.

Chen, Tian, et al. 2006. "Research on PM_{10} Source Apportionment in Beijing" (In Chinese). *Environmental Monitoring in China* 22 (6): 59–63.

Chen, Ye, Hongbin Li, and Li-An Zhou. 2005. "Relative Performance Evaluation and the Turnover of Provincial Leaders in China." *Economics Letters* 88 (3): 421–25.

Chen, Yihsu, and Alexander Whalley. 2012. "Green Infrastructure: The Effects of Urban Rail Transit on Air Quality." *American Economic Journal: Economic Policy* 4 (1): 58–97.

China National Textile and Apparel Council. 2011. *China Textile Industry Development Report 2010–2011* (In Chinese). Beijing: China Textile and Apparel Press.

China Vehicle Technology Research Center and the China Association of Automobile Manufacturers. 2012. *China Automotive Industry Yearbook 2011* (In Chinese). Beijing: China Vehicle Technology Research Center and the China Association of Automobile Manufacturers.

Chow, Gregory. 2010. "China's Environmental Policy: A Critical Survey." Princeton University Center for Economic Policy Studies Working Paper 206.

Clay, Karen, and Werner Troesken. 2010. "Did Frederick Brodie Discover the World's First Environmental Kuznets Curve? Coal Smoke and the Rise and Fall of the London Fog." National Bureau of Economic Research Working Paper 15669.

Clay, Karen, Werner Troesken, and Michael R. Haines. 2006. "Lead Pipes and Child Mortality." National Bureau of Economic Research Working Paper 12603.

Clay, Karen, Werner Troesken, and Michael R. Haines. 2010. "Lead, Mortality, and Productivity." National Bureau of Economic Research Working Paper 16480.

Conti, Gabriella, James Heckman, and Sergio Urzua. 2010. "The Education–Health Gradient." *American Economic Review* 100 (2): 234–38.

Copeland, Brian R., and M. Scott Taylor. 2004. "Trade, Growth, and the Environment." *Journal of Economic Literature* 42 (1): 7–71.

Costa, Dora L., and Matthew E. Kahn. 2004. "Changes in the Value of Life, 1940–1980." *Journal of Risk and Uncertainty* 29 (2): 159–80.

Cragg, Michael I., Yuyu Zhou, Kevin Gurney, and Matthew E. Kahn. 2013. "Carbon Geography: The Political Economy of Congressional Support for Legislation Intended to Mitigate Greenhouse Gas Production." *Economic Inquiry* 51 (2): 1640–50.

Currie, Janet. 2009. "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development." *Journal of Economic Literature* 47 (1): 87–122.

Currie, Janet. 2011. "Inequality at Birth: Some Causes and Consequences." *American Economic Review* 101 (3): 1–22.

Currie, Janet, and Douglas Almond. 2011. "Human Capital Development before Age Five." In *Handbook of Labor Economics, Volume 4, Part B*, edited by David Card and Orley Ashenfelter, 1315–1486. Amsterdam and San Diego: Elsevier, North-Holland.

Currie, Janet, and Matthew Neidell. 2005. "Air Pollution and Infant Health: What Can We Learn from California's Recent Experience?" *Quarterly Journal of Economics* 120 (3): 1003–30.

Currie, Janet, and Johannes F. Schmieder. 2009. "Fetal Exposures to Toxic Releases and Infant Health." *American Economic Review* 99 (2): 177–83.

Currie, Janet, and Reed Walker. 2011. "Traffic Congestion and Infant Health: Evidence from E-ZPass." *American Economic Journal: Applied Economics* 3 (1): 65–90.

Cutler, David, and Grant Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography* 42 (1): 1–22.

Dargay, Joyce, Dermot Gately, and Martin Sommer. 2007. "Vehicle Ownership and Income Growth, Worldwide: 1960–2030." *Energy Journal* 28 (4): 143–70.

Dasgupta, Susmita, Benoit Laplante, Hua Wang, and David Wheeler. 2002. "Confronting the Environmental Kuznets Curve." *Journal of Economic Perspectives* 16 (1): 147–68.

Davis, Lucas W. 2011. "The Effect of Power Plants on Local Housing Values and Rents." *Review of Economics and Statistics* 93 (4): 1391–1402.

Dean, Judith Myrle, Mary E. Lovely, and Hua Wang. 2009. "Are Foreign Investors Attracted to Weak Environmental Regulations? Evaluating the Evidence from China." *Journal of Development Economics* 90 (1): 1–13.

Diamond, Jared. 2006. *Collapse: How Societies Choose to Fail or Succeed*. New York: Viking Penguin.

Ding, Chengri, and Yan Song, eds. 2005. *Emerging Land and Housing Markets in China*. Cambridge, Mass. Lincoln Institute of Land Policy.

Dow, William H., Tomas J. Philipson, and Xavier Sala-i-Martin. 1999. "Longevity Complementarities under Competing Risks." *American Economic Review* 89 (5): 1358–71.

Duflo, Esther, and Rohini Pande. 2007. "Dams." *Quarterly Journal of Economics* 122 (2): 601–46.

Easterlin, Richard A, Robson Morgan, Malgorzata Switek, and Fei Wang. 2012. "China's Life Satisfaction, 1990–2010." *Proceedings of the National Academy of Sciences* 109 (25): 9775–80.

Ebenstein, Avraham. 2012. "The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China." *Review of Economics and Statistics* 94 (1): 186–201.

Ebenstein, Avraham, Jian Zhang, Margaret McMillan, and Kevin Chen. 2011. "Chemical Fertilizer and Migration in China." http://pluto.huji.ac.il/~ebenstein/ChemicalFertilizer_Migration_June2011.pdf

Economy, Elizabeth C. 2007. "The Great Leap Backward? The Costs of China's Environmental Crisis."

Foreign Affairs 86 (5): 38–59.

Ehrlich, Isaac, and Gary S. Becker. 1972. "Market Insurance, Self-Insurance, and Self-Protection." *Journal of Political Economy* 80 (4): 623–48.

Eid, Jean, Henry G. Overman, Diego Puga, and Matthew A. Turner. 2008. "Fat City: Questioning the Relationship between Urban Sprawl and Obesity." *Journal of Urban Economics* 63 (2): 385–404.

Fan, C. Cindy. 2005a. "Interprovincial Migration, Population Redistribution, and Regional Development in China: 1990 and 2000 Census Comparisons." *The Professional Geographer* 57 (2): 295–311.

Fan, C. Cindy. 2005b. "Modeling Interprovincial Migration in China, 1985–2000." *Eurasian Geography and Economics* 46 (3): 165–84.

Feenstra, Robert C., and Shang-Jin Wei. 2009. "Introduction to 'China's Growing Role in World Trade'." National Bureau of Economic Research Working Paper 14716.

Ferraz, Claudio, and Frederico Finan. 2008. "Exposing Corrupt Politicians: The Effects of Brazil's Publicly Released Audits on Electoral Outcomes." *Quarterly Journal of Economics* 123 (2): 703–45.

Ferrie, Joseph P., and Werner Troesken. 2005. "Death and the City: Chicago's Mortality Transition, 1850–1925." National Bureau of Economic Research Working Paper 11427.

Gentzkow, Matthew, and Jessie M. Shapiro. 2010. "What Drives Media Slant? Evidence from U.S. Daily Newspapers." *Econometrica* 78 (1): 35–71.

Glaeser, Edward L. 1998. "Are Cities Dying?" *Journal of Economic Perspectives* 12 (2): 139–60.

Glaeser, Edward L. 1999. "Learning in Cities." *Journal of Urban Economics* 46 (2): 254–77.

Glaeser, Edward L. 2011. *Triumph of the City: How Our Greatest Invention Makes Us Richer, Smarter, Greener, Healthier, and Happier*. New York: Penguin Group, Penguin Press.

Glaeser, Edward L., and Matthew E. Kahn. 2001. "Decentralized Employment and the Transformation of the American City." National Bureau of Economic Research Working Paper 8117.

Glaeser, Edward L., and Matthew E. Kahn. 2004. "Sprawl and Urban Growth." In *Handbook of Regional and Urban Economics: Volume 4: Cities and Geography*, edited by J. Vernon Henderson and Jacques-Francois Thisse, 2481–2527. Amsterdam; San Diego and Oxford: Elsevier.

Glaeser, Edward L, and Matthew E. Kahn. 2010. "The Greenness of Cities: Carbon Dioxide Emissions and Urban Development." *Journal of Urban Economics* 67 (3): 404–18.

Glaeser, Edward L., Jed Kolko, and Albert Saiz. 2001. "Consumer City." *Journal of Economic Geography* 1 (1): 27–50.

Goldberg, Pinelopi Koujianou. 1998. "The Effects of the Corporate Average Fuel Efficiency Standards in the US." *Journal of Industrial Economics* 46 (1): 1–33.

Government of the People's Republic of China. 2011. "China's 12th Five-Year Plan on National and Economic Social Development." http://www.cbichina.org.cn/cbichina/upload/fckeditor/Full%20Translation%20of%20the%2012th%20Five-Year%20Plan.pdf.

Graff-Zivin, Joshua, and Matthew Neidell. 2009. "Days of Haze: Environmental Information Disclosure and Intertemporal Avoidance Behavior." *Journal of Environmental Economics and Management* 58 (2): 119–28.

Greenstone, Michael. 2002. "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." *Journal of Political Economy* 110 (6): 1175–1219.

Greenstone, Michael. 2004. "Did the Clean Air Act Cause the Remarkable Decline in Sulfur Dioxide Concentrations?" *Journal of Environmental Economics and Management* 47 (3): 585–611.

Greenstone, Michael, and Rema Hanna. 2011. "Environmental Regulations, Air and Water Pollution, and Infant Mortality in India." Massachusetts Institute of Technology Center for Energy and Environmental Policy Research Working Paper 2011-14.

Greenstone, Michael, Richard Hornbeck, and Enrico Moretti. 2010. "Identifying Agglomeration Spillovers: Evidence from Winners and Losers of Large Plant Openings." *Journal of Political Economy* 118 (3): 536–98.

Grossman, Gene M., and Alan B. Krueger. 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics* 110 (2): 353–77.

Grossman, Michael. 1972. "On the Concept of Health Capital and the Demand for Health." *Journal of Political Economy* 80 (2): 223–55.

Guan, Dabo, Zhu Liu, Yong Geng, Sören Lindner, and Klaus Hubacek. 2012. "The Gigatonne Gap in China's Carbon Dioxide Inventories." *Nature Climate Change* 2: 672–75.

Gyourko, Joseph, Matthew Kahn, and Joseph Tracy. 1999. "Quality of Life and Environmental Comparisons." In *Handbook of Regional and Urban Economics, Volume 3: Applied Urban Economics*, edited by Paul Cheshire and Edwin S. Mills, 1413–54. Amsterdam; New York and Oxford: Elsevier Science, North-Holland.

Gyourko, Joseph, and Joseph Tracy. 1991. "The Structure of Local Public Finance and the Quality of Life." *Journal of Political Economy* 99 (4): 774–806.

Haines, Michael R. 2001. "The Urban Mortality Transition in the United States, 1800–1940." National Bureau of Economic Research Historical Working Paper 134.

Harbaugh, William T., Arik Levinson, and David Molloy Wilson. 2002. "Reexamining the Empirical Evidence for an Environmental Kuznets Curve." *Review of Economics and Statistics* 84 (3): 541–51.

Harris, John R., and Michael P. Todaro. 1970. "Migration, Unemployment, and Development: A Two-Sector Analysis." *American Economic Review* 60 (1): 126–42.

He, Jie. 2006. "Pollution Haven Hypothesis and

Environmental Impacts of Foreign Direct Investment: The Case of Industrial Emission of Sulfur Dioxide (SO_2) In Chinese Provinces." *Ecological Economics* 60 (1): 228–45.

He, Jie. 2009. "China's Industrial SO_2 Emissions and Its Economic Determinants: EKC's Reduced vs. Structural Model and the Role of International Trade." *Environment and Development Economics* 14 (2): 227–62.

He, Kebin, Hong Huo, and Qiang Zhang. 2002. "Urban Air Pollution in China: Current Status, Characteristics, and Progress." *Annual Review of Energy and the Environment* 27: 397–431.

Heckman, James J. 2007. "The Economics, Technology, and Neuroscience of Human Capability Formation." *Proceedings of the National Academy of Sciences* 104 (33): 13250–55.

Henderson, J. Vernon. 1988. *Urban Development: Theory, Fact, and Illusion.* Oxford; New York; Toronto and Melbourne: Oxford University Press.

Henderson, J. Vernon. 1996. "Effects of Air Quality Regulation." *American Economic Review* 86 (4): 789–813.

Henderson, J. Vernon. 1997. "Medium Size Cities." *Regional Science and Urban Economics* 27 (6): 583–612.

Henderson, J. Vernon. 2009. "Urbanization in China: Policy Issues and Options." http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CDQQFjAB&url=http%3A%2F%2Fwww.econ.brown.edu%2Ffaculty%2Fhenderson%2FFinal%2520Report%2520format1109summary.doc&ei=y9kcUsDaIJWrsQTx8oDgCg&usg=AFQjCNE_4ITAeJsF8cW90W8s1WnOnRop6w&sig2=a_C4qqbhXDdoMjHJX5E5Ew&bvm=bv.51156542,d.cWc.

Hilton, F. G. Hank, and Arik Levinson. 1998. "Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions." *Journal of Environmental Economics and Management* 35 (2): 126–41.

Holmes, Thomas J. 1998. "The Effect of State Policies on the Location of Manufacturing: Evidence from State Borders." *Journal of Political Economy* 106 (4): 667–705.

Ingram, Gregory K., and Zhi Liu. 1999. "Determinants of Motorization and Road Provision." In *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer,* edited by Jose A. Gomez-Ibanez, William B. Tye, and Clifford Winston, 325–56. Washington, D.C.: Brookings Institution Press.

International Energy Agency. 2011. *Energy Prices and Taxes: Quarterly Statistics: Second Quarter 2011.* http://www.cne.es/cgi-bin/BRSCGI.exe?CMD=VEROBJ&MLKOB=578594431818.

Jaffe, Adam B, Steven R. Peterson, Paul R. Portney, and Robert Stavins. 1995. "Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?" *Journal of Economic Literature* 33 (1): 132–63.

Jin, Ginger Zhe, and Phillip Leslie. 2003. "The Effect of Information on Product Quality: Evidence from Restaurant Hygiene Grade Cards." *Quarterly Journal of Economics* 118 (2): 409–51.

Jin, Yanhong, Hua Wang, and David Wheeler. 2010. "Environmental Performance Rating and Disclosure: An Empirical Investigation of China's Green Watch Program." World Bank Policy Research Working Paper 5420.

Kahn, Matthew E. 1996. "New Evidence on Trends in Vehicle Emissions." *RAND Journal of Economics* 27 (1): 183–96.

Kahn, Matthew E. 1999. "The Silver Lining of Rust Belt Manufacturing Decline." *Journal of Urban Economics* 46 (3): 360–76.

Kahn, Matthew E. 2002. "Demographic Change and the Demand for Environmental Regulation." *Journal of Policy Analysis and Management* 21 (1): 45–62.

Kahn, Matthew E., and Erin T. Mansur. 2013. "Do Local Energy Prices and Regulation Affect the Geographic Concentration of Employment?" *Journal of Public Economics* 101: 105–14.

Kahn, Matthew E., and John G. Matsusaka. 1997. "Demand for Environmental Goods: Evidence from Voting Patterns on California Initiatives." *Journal of Law and Economics* 40 (1): 137–73.

Kahn, Matthew E., and Joel Schwartz. 2008. "Urban Air Pollution Progress Despite Sprawl: The 'Greening' of the Vehicle Fleet." *Journal of Urban Economics* 63 (3): 775–87.

Kenkel, Don, Dean R. Lillard, and Feng Liu. 2009. "An Analysis of Life-Course Smoking Behavior in China." *Health Economics* 18 (Special Issue 2): S147–45.

Knittel, Christopher R. 2011. "Automobiles on Steroids: Product Attribute Trade-Offs and Technological Progress in the Automobile Sector." *American Economic Review* 101 (7): 3368–99.

Landry, Pierre F. 2008. *Decentralized Authoritarianism in China: The Communist Party's Control of Local Elites in the Post-Mao Era.* Cambridge and New York: Cambridge University Press.

La Porta, Rafael, Florencio Lopez-de-Silanes, Andrei Shleifer, and Robert Vishny. 1999. "The Quality of Government." *Journal of Law, Economics, and Organization* 15 (1): 222–79.

Li, Hongbin, and Li-An Zhou. 2005. "Political Turnover and Economic Performance: The Incentive Role of Personnel Control in China." *Journal of Public Economics* 89 (9–10): 1743–62.

Li, Junfeng et al. 2012. *China Wind Power Outlook 2012* (In Chinese). http://www.gwec.net/wp-content/uploads/2012/11/China-Outlook-2012-EN.pdf..

Li, Wanxin, Jieyan Liu, and Duoduo Li. 2012. "Getting Their Voices Heard: Three Cases of Public Participation in Environmental Protection in China." *Journal of Environmental Management* 98: 65–72.

Liu, Antung A., and Junjie Zhang. 2011. "Fiscal Incentives and Infrastructure: The Case of Sewage Treatment in China." http://econ.ucsd.edu/~aaliu/pdfs/Fiscal_Incentives_and_Infrastructure.pdf.

Liu, Junguo, and Hong Yang. 2009. "China Fights against Statistical Corruption." *Science* 325 (5941): 675–76.

Loo, Becky P. Y., and Sin Yin Chow. 2006. "China's 1994 Tax-Sharing Reforms." *Asian Survey* 46 (2): 215–37.

Martinez-Bravo, Monica, Gerard Padró I Miquel, Nancy Qian, and Yang Yao. 2012. "The Effects of Democratization on Public Goods and Redistribution: Evidence from China." National Bureau of Economic Research Working Paper 18101.

McFadden, Daniel. 1976. "The Revealed Preferences of a Government Bureaucracy: Empirical Evidence." *Bell Journal of Economics* 7 (1): 55–72.

Mieszkowski, Peter, and Edwin S. Mills. 1993. "The Causes of Metropolitan Suburbanization." *Journal of Economic Perspectives* 7 (3): 135–47.

Mills, Edwin S. 1967. "An Aggregative Model of Resource Allocation in a Metropolitan Area." *American Economic Review* 57 (2): 197–210.

Mol, Arthur P. J. 2009. "Urban Environmental Governance Innovations in China." *Current Opinion in Environmental Sustainability* 1 (1): 96–100.

Moretti, Enrico. 2004. "Estimating the Social Return to Higher Education: Evidence from Longitudinal and Repeated Cross-Sectional Data." *Journal of Econometrics* 121 (1–2): 175–212.

Moretti, Enrico. 2012. *The New Geography of Jobs.* New York: Houghton Mifflin Harcourt.

Moretti, Enrico, and Matthew Neidell. 2011. "Pollution, Health, and Avoidance Behavior: Evidence from the Ports of Los Angeles." *Journal of Human Resources* 46 (1): 154–75.

Muller, Nicholas Z., Robert Mendelsohn, and William Nordhaus. 2011. "Environmental Accounting for Pollution in the United States Economy." *American Economic Review* 101 (5): 1649–75.

Mulligan, Casey B., Richard Gil, and Xavier Sala-i-Martin. 2004. "Do Democracies Have Different Public Policies than Nondemocracies?" *Journal of Economic Perspectives* 18 (1): 51–74.

Murphy, Kevin M., and Robert H. Topel. 2006. "The Value of Health and Longevity." *Journal of Political Economy* 114 (5): 871–904.

Muth, Richard F. 1969. *Cities and Housing.* Chicago: University of Chicago Press.

National Bureau of Statistics of China. 2012a. *China Statistical Abstract 2012*. Beijing: China Statistics Press.

National Bureau of Statistics of China. 2012b. *China Statistical Yearbook 2011* (In Chinese). Beijing: China Statistics Press.

National Development and Reform Commission. 2007. "Eleventh 'Five Year Plan' for the Development of the Coal Industry." (In Chinese). http://www.ndrc.gov.cn/fzgh/ghwb/115zxgh/P020070925583241015610.pdf.

National Development and Reform Commission of China, Department of Climate Change. 2010. "Appendix II—Nationally Appropriate Mitigation Actions of Developing Country Parties: China: Letter Including Autonomous Domestic Mitigation Actions, United Nations Framework Convention on Climate Change." http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5265.php.

Neidell, Matthew. 2009. "Information, Avoidance Behavior, and Health: The Effect of Ozone on Asthma Hospitalizations." *Journal of Human Resources* 44 (2): 450–78.

Netherlands Environmental Assessment Agency. 2012. "Trends in Global CO_2 Emissions: 2012 Report." http://www.pbl.nl/sites/default/files/cms/publicaties/PBL_2012_Trends_in_global_CO2_emissions_500114022.pdf.

Newell, Richard G. Adam B. Jaffe, and Robert N. Stavins. 1999. "The Induced Innovation Hypothesis and Energy-Saving Technological Change." *Quarterly Journal of Economics* 114 (3): 941–75.

Nordhaus, William D., and James Tobin. 1971. "Is Growth Obsolete?" Yale University Cowles Foundation Discussion Paper 319.

Olson, Mancur. 1965. *The Logic of Collective Action: Public Goods and the Theory of Groups.* Cambridge and London: Harvard University Press.

Organisation for Economic Co-operation and Development Working Group on Privatisation and Corporate Governance of State Owned Assets. 2009. "State Owned Enterprises in China: Reviewing the Evidence." OECD Occasional Paper. http://www.oecd.org/corporate/ca/corporategovernanceofstate-ownedenterprises/42095493.pdf.

Pargal, Sheoli, and David Wheeler. 1996. "Informal Regulation of Industrial Pollution in Developing Countries: Evidence from Indonesia." *Journal of Political Economy* 104 (6): 1314–27.

Parry, Ian W. H., and Kenneth A. Small. 2005. "Does Britain or the United States Have the Right Gasoline Tax?" *American Economic Review* 95 (4): 1276–89.

Pereira, Alexius A. 2004. "The Suzhou Industrial Park Experiment: The Case of China–Singapore Governmental Collaboration." *Journal of Contemporary China* 13 (38): 173–93.

Peterson, George E. 2006. "Land Leasing and Land Sale as an Infrastructure-Financing Option." World Bank Policy Research Working Paper 4043.

Pfaff, Alexander S. P. 1999. "What Drives Deforestation in the Brazilian Amazon? Evidence from Satellite and Socioeconomic Data." *Journal of Environmental Economics and Management* 37 (1): 26–43.

Ratcliffe, H. E., G. M. Swanson, and L. J. Fischer. 1996. "Human Exposure to Mercury: A Critical Assessment of the Evidence of Adverse Health Effects." *Journal of Toxicology and Environmental Health* 49 (3): 221–70.

Reyes, Jessica Wolpaw. 2008. "The Impact of Prenatal Lead Exposure on Infant Health." Unpublished.

Roback, Jennifer. 1982. "Wages, Rents, and the Quality of Life." *Journal of Political Economy* 90 (6): 1257–78.

Rosen, Sherwin. 1979. "Wages-Based Indexes of Urban Quality of Life." In *Current Issues in Urban Economics*, edited by P. Mieszkowski and M. Straszheim. Baltimore: Johns Hopkins University Press 74–104.

Rosen, Sherwin. 2002. "Markets and Diversity." *American Economic Review* 92 (1): 1–15.

Sawhney, Aparna, and Matthew E. Kahn. 2012.

"Understanding Cross-National Trends in High-Tech Renewable Power Equipment Exports to the United States." *Energy Policy* 46 (1): 308–18.

Selden, Thomas M., and Daqing Song. 1995. "Neoclassical Growth, the J Curve for Abatement, and the Inverted U Curve for Pollution." *Journal of Environmental Economics and Management* 29 (2): 162–68.

Schmalensee, Richard, Thomas M. Stoker, and Ruth A. Judson. 1998. "World Carbon Dioxide Emissions: 1950–2050." *Review of Economics and Statistics* 80 (1): 15–27.

Shapiro, Jesse M. 2006. "Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital." *Review of Economics and Statistics* 88 (2): 324–35.

Shen, Lei, Tao Dai, and Aaron James Gunson. 2009. "Small-Scale Mining in China: Assessing Recent Advances in the Policy and Regulatory Framework." *Resources Policy* 34 (3): 150–57.

Sieg, Holger, V. Kerry Smith, H. Spencer Banzhaf, and Randy Walsh. 2004. "Estimating the General Equilibrium Benefits of Large Changes in Spatially Delineated Public Goods." *International Economic Review* 45 (4): 1047–77.

Sigman, Hilary. 2002. "International Spillovers and Water Quality in Rivers: Do Countries Free Ride?" *American Economic Review* 92 (4): 1152–59.

Sinton, Jonathan E. 2001. "Accuracy and Reliability of China's Energy Statistics." *China Economic Review* 12 (4): 373–83.

Smith, Martin D., et al. 2010. "Sustainability and Global Seafood." *Science* 327 (5967): 784–86.

Song, W. W., K. B. He, and Y. Lei. 2012. "Black Carbon Emissions from On-Road Vehicles in China, 1990–2030." *Atmospheric Environment* 51: 320–28.

Stokey, Nancy L. 1998. "Are There Limits to Growth?" *International Economic Review* 39 (1): 1–31.

Tan, Xu, and Frank Wolak. 2009. "Does China Underprice Its Oil Consumption?" http://www.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/china_oil_pricing_020909.pdf.

Tang, Deliang, et al. 2008. "Effects of Prenatal Exposure to Coal-Burning Pollutants on Children's Development in China." *Environmental Health Perspectives* 116 (5): 674–79.

Tao, Ran, Fei Yuan, and Guangzhong Cao. 2007. "Regional Competition, Land Leasing and Local Fiscal Effect: Analysis Based on the Panel Data in Chinese Level Cities during 1999–2003 (In Chinese)." *Journal of World Economy* 10: 15–27.

Taylor, M. Scott. 2011. "Buffalo Hunt: International Trade and the Virtual Extinction of the North American Bison." *American Economic Review* 101 (7): 3162–95.

Tian, Li. 2008. "The 'Chengzhongcun' Land Market in China: Boon or Bane?—A Perspective on Property Rights." *International Journal of Urban and Regional Research* 32 (2): 282–304.

Tolley, George S. 1974. "The Welfare Economics of City Bigness." *Journal of Urban Economics* 1 (3): 324–45.

Van Rooij, Benjamin, and Carlos Wing-Hung Lo. 2010. "Fragile Convergence: Understanding Variation in the Enforcement of China's Industrial Pollution Law." *Law and Policy* 32 (1): 14–37.

Vennemo, Haakon, Kristin Aunan, Henrik Lindhjem, and Hans Martin Seip. 2009. "Environmental Pollution in China: Status and Trends." *Review of Environmental Economics and Policy* 3 (2): 209–30.

Wackernagel, Mathis, et al. 2002. "Tracking the Ecological Overshoot of the Human Economy." *Proceedings of the National Academy of Sciences* 99 (14): 9266–71.

Waldfogel, Joel. 2008. "The Median Voter and the Median Consumer: Local Private Goods and Population Composition." *Journal of Urban Economics* 63 (2): 567–82.

Wang, Alex L. Forthcoming. "The Search for Sustainable Legitimacy: Environmental Law and Bureaucracy in China." *Harvard Environmental Law Review*.

Wang, Hua, and Yanhong Jin. 2007. "Industrial Ownership and Environmental Performance: Evidence from China." *Environmental and Resource Economics* 36 (3): 255–73.

Wang, Wentao, Toby Primbs, Shu Tao, and Staci L. Massey Simonich. 2009. "Atmospheric Particulate Matter Pollution during the 2008 Beijing Olympics." *Environmental Science and Technology* 43 (16): 6440.

Witte, J. C., et al. 2009. "Satellite Observations of Changes in Air Quality during the 2008 Beijing Olympics and Paralympics." *Geophysical Research Letters* 36 (17): L17803.

Wolfram, Catherine, Orie Shelef, and Paul Gertler. 2012. "How Will Energy Demand Develop in the Developing World?" *Journal of Economic Perspectives* 26 (1): 119–38.

World Bank. 2007a. *Cost of Pollution in China: Economic Estimates of Physical Damages*. Washington, D.C.: World Bank.

World Bank. 2007b. *World Development Indicators 2007*. Washington, D.C.: World Bank.

Wu, Fulong. 2004. "Residential Relocation under Market-Oriented Redevelopment: The Process and Outcomes in Urban China." *Geoforum* 35 (4): 453–70.

Wu, Fulong. 2007. "Beyond Gradualism: China's Urban Revolution and Emerging Cities." In *China's Emerging Cities: The Making of New Urbanism*, edited by Fulong Wu, 3–25. New York: Routledge.

Wu, Jinan, and Liang Ma. 2009. "Government Performance and Promotion Mechanism: A Review (In Chinese)." *Journal of Public Administration* 2: 172–96.

Wu, Jing, Yongheng Deng, Jun Huang, Randall Morck, and Bernard Yeung. 2013. "Incentives and Outcomes: China's Environmental Policy." National Bureau of Economic Research Working Paper 18754.

Xu, Yuan, Robert H. Williams, and Robert H. Socolow. 2009. "China's Rapid Deployment of SO_2 Scrubbers." *Energy and Environmental Science* 2 (5): 459–65.

Yang, Ruijia, Wei Huang, Lishi Zhang, Miles Thomas, and Xiaofang Pei. 2009. "Milk Adulteration with

Melamine in China: Crisis and Response." *Quality Assurance and Safety of Crops and Foods* 1 (2): 111–16.

Zhang, Li, Simon X. B. Zhao, and J. P. Tian. 2003. "Self-Help in Housing and Chengzhongcun in China's Urbanization." *International Journal of Urban and Regional Research* 27 (4): 912–37.

Zhang, Qiang, et al. 2007. "No$_x$ Emission Trends for China, 1995–2004: The View from the Ground and the View from Space." *Journal of Geophysical Research: Atmospheres* 112: D22306: 1–18.

Zhang, Qingyu, Weili Tian, Yumei Wei, and Yingxu Chen. 2007. "External Costs from Electricity Generation of China Up to 2030 in Energy and Abatement Scenarios." *Energy Policy* 35 (8): 4295–4304.

Zheng, Mei, Lynn G. Salmon, James J. Schauer, Limin Zeng, C. S. Kiang, Yuanhang Zhang, and Glen R. Cass. 2005. "Seasonal Trends in PM$_{2.5}$ Source Contributions in Beijing, China." *Atmospheric Environment* 39 (22): 3967–76.

Zheng, Siqi, Jing Cao, Matthew E. Kahn, and Cong Sun. Forthcoming. "Real Estate Valuation and Cross-Boundary Air Pollution Externalities: Evidence from Chinese Cities." *Journal of Real Estate Finance and Economics*.

Zheng, Siqi, Yuming Fu, and Hongyu Liu. 2006. "Housing-Choice Hindrances and Urban Spatial Structure: Evidence from Matched Location and Location-Preference Data in Chinese Cities." *Journal of Urban Economics* 60 (3): 535–57.

Zheng, Siqi, Yuming Fu, and Hongyu Liu. 2009. "Demand for Urban Quality of Living in China: Evolution in Compensating Land-Rent and Wage-Rate Differentials." *Journal of Real Estate Finance and Economics* 38 (3): 194–213.

Zheng, Siqi, and Matthew E. Kahn. 2008. "Land and Residential Property Markets in a Booming Economy: New Evidence from Beijing." *Journal of Urban Economics* 63 (2): 743–57.

Zheng, Siqi, and Matthew E. Kahn. 2013. "Does Government Investment in Local Public Goods Spur Gentrification? Evidence from Beijing." *Real Estate Economics* 41 (1): 1–26.

Zheng, Siqi, Matthew E. Kahn, and Hongyu Liu. 2010. "Towards a System of Open Cities in China: Home Prices, FDI Flows and Air Quality in 35 Major Cities." *Regional Science and Urban Economics* 40 (1): 1–10.

Zheng, Siqi, Matthew E. Kahn, Weizeng Sun, and Danglun Luo. 2013. "Incentivizing China's Urban Mayors to Mitigate Pollution Externalities: The Role of the Central Government and Public Environmentalism." National Bureau of Economic Research Working Paper 18872.

Zheng, Siqi, Fenjie Long, C. Cindy Fan, and Yizhen Gu. 2009. "Urban Villages in China: A 2008 Survey of Migrant Settlements in Beijing." *Eurasian Geography and Economics* 50 (4): 425–46.

Zheng, Siqi, Rui Wang, Edward L. Glaeser, and Matthew E. Kahn. 2011. "The Greenness of China: Household Carbon Dioxide Emissions and Urban Development." *Journal of Economic Geography* 11 (5): 761–92.

Zhou, Li-an. 2007. "Governing China's Local Officials: An Analysis of Promotion Tournament Model." (In Chinese. With English summary.) *Jingyi Yanjiu/Economic Research Journal* 42 (7): 36–50.

Zhou, Xueguang. 2001. "Political Dynamics and Bureaucratic Career Patterns in the People's Republic of China, 1949–1994." *Comparative Political Studies* 34 (9): 1036–62.

Zhou, Ye'an, and Quan Zhang. 2008. "Financial Decentralization, Economic Growth and Fluctuations." (In Chinese. With English summary.) *Management World* 3: 6–15.

Zhou, Ying, Jonathan I. Levy, John S. Evans, and James K. Hammitt. 2006. "The Influence of Geographic Location on Population Exposure to Emissions from Power Plants throughout China." *Environmental International* 32 (3): 365–73.