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Does Pollution Hinder Urban Competitiveness?

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Abstract

This paper surveys the recent literature exploring the causes of urban pollution in the developing world and the implications of such pollution for a city's competitiveness. Within a system of cities, cities compete for jobs and people. Those cities that specialize in heavy industrial activity will gain from a manufacturing boom but are more likely to be polluted than a city that specializes in the service economy and one that makes investments in regulations to reduce the social costs of power generation, transportation, and household services. The paper explores three main questions. First, why does pollution inhibit urban competitiveness? Second, why is this effect likely to grow in importance over time? Third, why have cities been slow to adopt cost-effective regulatory strategies? .

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Does Pollution Hinder Urban Competitiveness?[1]

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JEL: R11, Q52, Q53

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Urbanization contributes to per-capita income growth through facilitating trade and learning. Within a developing nation, cities compete against each other to attract people and jobs. These cities form a system of cities.[2] Some cities have a competitive edge because their geographic location offers a productivity and amenity advantage. Capital cities feature larger populations as such areas command greater political resources.[3] A city that experiences population growth and an influx of capital while facilitating young people's human capital acquisition is a **competitive city**.

There are several policy levers for helping a city to become more competitive as it attracts domestic workers and foreign direct investment, and skilled international migrants. The 2015 World Bank report "Competitive cities for jobs and growth: What, who, and how" emphasized that competitive cities foster rapid economic growth through interventions that enhance institutions and regulation, infrastructure and land, skills and innovation and enterprise finance.

This survey paper extends the competitive cities research agenda by focusing on the role of urban quality of life in the developing world and in particular on the role that clean air and water and local greenness play in enhancing a city's competitiveness. We examine the role of regulation, and infrastructure as determinants of urban quality of life as they improve an area's environmental quality.

All else equal, those areas that feature lower air and water pollution levels and more local beauty have a competitive advantage in attracting people and jobs. By enhancing urban quality of life, city leaders can directly enhance a city's attractiveness to skilled people and foreign capital and can contribute to facilitating skill formation of local youth. Higher quality of life also increases the supply of enterprise finance due to the geographic location of where venture capital is situated in a nation.

The "economic returns" to quality of life are likely to grow over time in those developing nations featuring rising educational attainment.[4] Institutions and regulations play a key role in

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[2] Henderson JV, Ioannides YM. (1981).
[3] Ades AF, Glaeser EL. (1995).
[4] Costa DL, Kahn ME. (2004).

determining whether externalities are internalized and at what cost to society. Infrastructure and land policy together determine whether a city can deliver clean water and garbage disposal as it grows. A city's skill level can rise either because it attracts the skilled to move there or because it invests in its educational system so that it educates the new generation and these young people choose to remain in the city. Low pollution levels contribute to skill formation[5] and a child's development.[6] Such urban greenness helps a city attract foreign migrants to live and work there.

The 2015 World Bank report also emphasized enterprise finance as a key element to strengthen city competitiveness. Research from the United States has documented that venture capitalists invest disproportionately in local ventures.[7] This suggests that if the high skilled are attracted to high quality of life areas, then these areas will have greater access to financing.

This survey paper argues that cities with a better quality of life as measured by climate, beauty and the absence of pollution become more competitive over time. Our core logic is based on the claim that sustainable economic growth is tied to rising levels of human capital. This in turn raises the question of how a city builds up its human capital stock. It can either attract the skilled to migrate in or it can "home grow" such talent through local public goods and environmental conditions that facilitate learning and health for young people. If urban "greenness" contributes to quality of life and this attracts the skilled and promotes skill formation, then the green agenda dovetails with the growth agenda.

Our analysis of the causal effects of "greenness" on urban economic growth turns around the classic Environmental Kuznets Curve (EKC) logic (Grossman and Krueger 1992). The goal of the original EKC research was to measure how much does pollution increase as a poor nation develops and at what "turning point" does subsequent economic growth actually contribute to environmental progress. World Bank research such as Dasgupta et. al. (2002) has played a key role

[5] Zhang, Xin; Chen, Xi; and Zhang, Xiaobo. (2018).
[6] Buka I, Koranteng S, Osornio-Vargas AR. (2006).
[7] Coval JD, Moskowitz TJ. The geography of investment: Informed trading and asset prices. Journal of political Economy. 2001 Aug;109(4):811-41.

in highlighting that the EKC can shift over time due to technological change and a rising awareness of the health and quality of life costs of being exposed to pollution.[8]

While reducing pollution improves local quality of life and this has clear benefits, reducing pollution also imposes cost. If the pollution reduction is achieved because of substitution from coal to cleaner fuels, then coal miners will lose work. If the pollution reduction is achieved because of the enforcement of regulations, then the marginal cost of production will increase, and this will lead to higher consumer prices, lower returns on capital and a reduced demand for workers in that industry. These examples highlight that the economic incidence of pollution reduction must be explored to inform the ex-ante analysis of whether a given policy will achieve both efficiency and equity goals.

This paper surveys what key lessons emerge from ongoing empirical research on the links between pollution and urban competitiveness. With an understanding of these effects, local governments can make informed decisions given the net benefits and consequences of implementing new regulations. Developing countries face the greatest opportunities from ongoing urbanization and their residents are exposed to the highest levels of pollution and hence are the focus of our discussion.

Urban Growth and Pollution Dynamics

Each nation features many cities (the system of cities) for firms and workers to choose from (Helsley and Strange 1990, Henderson 1974). These cities differ with respect to attributes such as climate and coastal beauty and environmental quality (Kahn and Walsh 2015).

Cities of the same population size can experience very different environmental outcomes depending on the city's income, industrial composition and investments in energy sources. A city's pollution level is determined by the economic activity that takes place within its borders and by any cross-border spillovers, and can be influenced by regulations, policies, and other national and local decisions. In Turkey, for example the introduction of natural gas pipelines has significantly

[8] Dasgupta S, Laplante B, Wang H, Wheeler D. (2002).

reduced local air pollution and improved quality of life and reduced infant mortality.[9] Pollution is produced by several different sectors in an urban economy. For example, power generation can be a major polluter especially when coal is the main energy source for power generation. The transportation sector can also be a major creator of local air pollution especially when the vehicle stock features older vehicles using low quality fuels.[10] Industry often contributes greatly both air and water pollution. Further, households can also contribute to local air and water pollution through choices such as how they choose to heat their homes or cook, or how they dispose of their sewage and garbage.[11] But, not all pollution is produced locally. As shown by the Asian Brown Cloud, smoke from Indonesia can drift over to affect quality of life in Singapore.[12]

This discussion highlights that the sheer scale of economic activity in a city is a correlate of urban pollution. It also points at a two-way causal relationship between urban growth and pollution. As developing nation cities grow, pollution is likely to rise due to the scale effects of population, industrialization and power generation. This was the original EKC logic. At the same time, a U.S based literature has argued that urban levels of human capital are a crucial correlate of economic and population growth.

Empirical growth studies have examined the correlates of urban economic growth for different geographic units of analysis (Baumol, 1986; De Long, 1988; Barro, 1991) and U.S. states (Barro, Sala-i-Martin and Blanchard, 1991; Blanchard and Katz, 1992), Glaeser et. al (1995) have focused on city growth. Assuming free migration across cities, they use population growth as a measure of city growth and estimate an equation of the form:

$$\log\left(\frac{L_{i,t+1}}{L_{i,t}}\right) = \beta X'_{i,t} + \chi_{i,t+1} \quad \textbf{(1)}$$

[9] Cesur R, Tekin E, Ulker (2016).
[10] Davis LW, Kahn ME. (2010).
[11] Pfaff AS, Chaudhuri S, Nye HL. (2004).
[12] Auffhammer M, Ramanathan V, Vincent JR. (2006).

where $L_{i,t}$ denotes population of city i at time t, $X'_{i,t}$ is a set of characteristics of the city that affects city productivity and quality of life, β is the corresponding estimated coefficient, and $\chi_{i,t+1}$ is the error term, uncorrelated with urban characteristics.

A robust empirical finding is that a city population's initial education level is a key predictor of future growth (Glaeser et.al. 1995). Human capital is both a correlate of population growth and local wages. Rauch (1993) was the first to study how differences in human capital across cities contribute to growth. He estimates hedonic wage and rent equations using individual, housing, and city characteristics. He uses average levels of education and work experience as a proxy for the level of human capital and estimates that a one-year increase in city level education increases wages by 2.8%.

Cities with higher overall levels of human capital tend to grow faster. Glaeser et al. (1992) test Jacobs (1969) and Porter's (1990) economic growth theories and find that knowledge spillovers that occur between industries contribute to city and regional growth. Moretti (2002) finds that manufacturing productivity increases more rapidly in cities where the share of college graduates is higher. He estimates that human capital spillovers increase plant output by 0.1% per year (during 1980s). Moretti (2004) reviews the models and empirical approach for measuring productivity spillovers.

Human capital is not randomly assigned in cities. Cities with higher productivity and better amenities and strong local universities attract more productive workers. If human capital causes growth and if skilled people seek out urban amenities, then a city can enhance its competitiveness by boosting and preserving its amenities. The challenge here is the jump from observing the correlation to inferring causality.

Moretti (2004) and more recently Glaeser and Lu (2018) summarize the econometric challenges associated with modeling a city's human capital stock and explicitly addressing endogeneity concerns. They discuss empirical strategies to overcome it. Since urban researchers cannot run a field experiment in which a city's human capital level is determined by random assignment, the next best methodology relies on finding an instrumental variable that is correlated with a city's human capital stock but can be defended as not being correlated with the error term in the outcome equation. Moretti (2004) and Glaeser and Lu (2018) use historical information on the location of major universities and in the case of China use information on the decentralization of universities (imposed by the central government) as instrumental variables.

Pollution as a Determinant of Urban Competitiveness

The previous section argued that human capital is a key correlate of urban growth. This section argues that pollution is a significant disamenity that repels high human capital people. This creates an incentive for cities to pursue strategies to reduce their pollution. Economic research on the demand for "green cities" uses revealed preference methods to measure what is the rental premium for living in a city or neighborhood with better environmental conditions, and hence higher quality of Researchers have also estimated the direct morbidity and mortality risk associated with living in a highly polluted area.[13] In recent years, such disamenity studies have used data from China (see Zheng and Kahn 2017), and India (see Gupta and Spears 2017). As the urban population grows richer and more educated the relative importance of pollution as a disamenity is likely to rise (Selden and Song 1995; Costa and Kahn, 2004; and Hammitt and Robinson, 2011).

Recent research using city-level panel data explores how a city's industrial structure and pollution levels evolve over time. Beach and Hanlon (2016) study pollution and industrial agglomeration across British cities in the 19th century. At that time, British cities differed with respect to their industrial structure. Some cities specialized in textiles while other specialized in steel production. These industries differed with respect to their energy intensity (energy consumption per unit of output). Industries such as steel are much more energy intensive than say, textiles. Given that coal was the nation's main source of energy and coal is highly polluting, those cities that specialized in dirty industries experienced a sharp increase in pollution when dirty industries boom. The authors document that as England became an exporting powerhouse, its cities that specialized in dirty industries scaled up their production and became polluted. As coal

[13] See Chen, Olivia, and Zhang (2017).

consumption increased in the booming energy intensive industries, other cleaner industries moved away from these cities.

The basic theory of compensating differentials predicts that firms must pay workers "combat pay" to remain in low amenity jobs (Rosen 2002). As pollution rose in cities such as Sheffield in Northeast England, clean industries left the city to move to cleaner cities to avoid paying this combat pay. This net dynamic led the polluting cities to experience an industrial composition shift so that their industrial structure became highly concentrated in highly polluting industries. While Glaeser et. al. (1992) find evidence supporting Jane Jacobs' theory that cities featuring more diverse industrial structures grow faster, Hanlon's research presents a dynamic equilibrium such that cities that specialize in energy intensive industries (and hence the dirty cities) become even more specialized over time. Such specialized cities (think of Detroit or Pittsburgh) become more exposed to external shocks because the local economy is not diversified.

Beach and Hanlon estimate the effect that the use of coal has on quality of life and urban productivity. They find that rising pollution caused a decrease in local productivity. This case study demonstrates that pollution results as a consequence of urban growth, when the growth is caused by increased demand for urban output that happens to be highly energy intensive. Such pollution growth affects the growth of other industries. Such industry dynamics highlights that industrial growth is both a cause of pollution and an effect of such emerging pollution.

The UK 19th century case demonstrates that a growing city whose growth is concentrated in energy intensive industries is likely to experience a rising pollution level both due to booming factories and nearby fossil fuel power plants generating the power that is used by the local industries. This process yields higher local ambient pollution levels. These pollution levels are further exacerbated if well paid industrial workers use their pay to buy private vehicles that contribute to transport and household emissions.

Unlike in England in the late 19th century, technological progress in environmental engineering opens up the possibility of reducing emissions per unit of output through pollution control devices being adopted. Unlike in the past, cities have access to a larger menu of energy sources (such as substituting from coal to natural gas). This energy ladder raises the possibility of further reducing the pollution cost per unit of industrial output. Of course, the willingness to use "green power" rather than coal hinges on the cost of adopting green power.[14] While dirty fuels are cheaper than "green power", this differential narrows over time due to technological progress and learning by doing effects. Dasgupta et. al. (2002) argue that the Environmental Kuznets Curve shifts down and in over time. This reduction in the cost of green power provides one micro-foundation for this claim.

The effects of pollution on economic growth can be estimated following a simple model of the form:

$$Y_i = \alpha + \delta P_i + \beta X_i + \epsilon_i \quad \textbf{(2)}$$

where Y_i is a measure of city *i* growth, P_i is a measure of pollution in city *i* (e.g. particulate matter), and X_i is a vector of control variables. The parameter of interest is δ. Estimating δ using standard OLS may yield a biased estimate because growth may also affect pollution. The negative effects of pollution are likely to be even larger in a city specialized in human capital. In equation (2), the unit of analysis is a city. This aggregate relationship captures that individuals and firms choose which city to locate in. All else equal, if pollution is higher in a specific city this will reduce the likelihood that people and jobs locate there if people's well-being and firm-level profitability is threatened by pollution. This equation (2), however, does not capture the notion of a cross-elasticity. If a rival city's pollution increases this will benefit the other city as economic activity (especially the skilled) will migrate to the cleaner place.

In estimating equation (2), pollution could be correlated with the unobserved determinants of urban growth. Hence, instrumenting for air pollution requires finding a city/year level variable that is correlated with the city's ambient pollution level but uncorrelated with the unobserved determinants of the outcome variable. Bayer et al. (2009) use air pollution originated at distant sources as an instrument for local pollution. They model the household location decision and estimate willingness to pay for a one-unit reduction in particulate matter concentration. Their study also confirms the importance of instrumenting for local air pollution. Zheng et al. (2014) use geographic variables to instrument for air pollution and estimate real estate prices in China. They

[14] Wolfram C, Shelef O, Gertler P. (2012).

find that the use of cross-boundary spillovers overcomes some of the problems that previous OLS estimations had. A recent study from Birjandi-Feriz and Yousefi (working paper, 2017) studies the effects of a random year-to-year dust exposure (from dust storms) on manufacturing firm productivity in the Islamic Republic of Iran.

While these studies focus on air pollution, similar issues arise with downstream water pollution. Sigman (2002) and Kahn, Li and Zhao (2015) highlight pollution is produced not as a byproduct of a city's economic activity but rather due to cross-boundary spillovers. Such spillovers cross political borders such as nations and thus politicians do not internalize these social costs. Such studies stress the role of regulation and compliance mechanisms to minimize spillovers from one area or administrative unit to the other. For example, the effects of upstream pollution in rivers where the negative effects of pollution are suffered by a large pool of downstream neighbors. Sigman finds evidence that international spillovers affect water quality, and that countries in fact free ride on controlling pollution levels on international waters. International rivers outside regulated countries show higher levels of pollution upstream, compared to domestic rivers. This spillovers research suggests that a city's geographic location (whether it is downstream along a river and located close to a national boundary) can be used as an instrumental variable for explaining high levels of local water pollution.

Estimates of relationships such as equation (2) using OLS raise concerns about omitted variables bias. Recognizing this challenge, researchers have sought out "natural experiment" strategies such that there is an exogenous change in pollution due to national government policy. Two recent examples come from energy policy with one from Turkey and one from China. Cesur, Tekin and Ulker (2017) study the case of Turkey's investment in natural gas. In Turkey, the government has invested in a spatial natural gas pipeline expansion. As power plants substituted to natural gas, this move up the energy ladder in areas that received an early upgrade and provides the researcher with an exogenous source of pollution variation. The authors document the reduction in infant mortality in areas of the nation that were treated with the cleaner energy source. The Turkey case suggests that the world-wide rollout of natural gas could have significant benefits on local air pollution. As China increases its imports of natural gas, similar gains could be observed.

In the case of China, a long standing policy offered residents of cities north of the Huaii River free winter heating. Given that this heating was generated by burning coal, this policy greatly contributed to local pollution levels. Chen et. al. (2013) use this sharp spatial discontinuity in this policy as an instrumental variable. This approach allows them to generate new estimates of the mortality costs of pollution. While they are not directly measuring the growth effects of pollution, their work does offer a direct indicator of the quality of life costs of excess pollution generated as a byproduct of a well intended policy (offering free heat in very cold winter cities).

The Economic Returns to a Location's Beauty

The theory of compensating differentials argues that local wages and rents adjust to reflect a city's fundamentals (Liu (1976) and Rosen (1979)). Roback (1982) uses a general equilibrium model that includes both labor and land markets to determine the value of city amenities. A city with low quality of life will feature low rents and high wages to compensate people for living there. Facing this spatial wage and real estate price gradient, different people and industries will choose where to locate. High tech firms will seek to locate where there is an abundant local pool of skilled workers. If skilled workers cluster in high amenity cities featuring higher rents, then such firms are more likely to locate there. Endogenous amenities such as good restaurants and retail cluster nearby and the consumer city forms (Glaeser, Kolko and Saiz 2001; Waldfogel, 2008; and Zheng, Sun, Wu, and Kahn, 2017).

In the developing world, cities whose leaders seek to move up the quality ladder to become a "green city" must evaluate what is holding back the city and what types of industries and firms would move to the city if the city improved its environmental performance. If a city moves up the rankings, it will experience rising real estate prices and its firms will be able to attract workers without paying a wage premium. However, some of these standard consequences may be affected by market rigidities that can create a different set of outcomes. For example, a lack of flexible labor markets that prevents workers to move to less polluted cities can result in more workers exposed to pollution and more firms needing to pay a wage premium.

Beautiful cities can take advantage of their innate amenities and use tourism to boost city growth and development, particularly in developing countries. One of the benefits that tourism specialization provides is that, by being labor intensive, it helps these economies to reduce unemployment. This in turn can be the basis for long-term growth and development.

Research has found a positive correlation between tourism specialization and growth. Some studies use country-level panel data and focus on time-series variation (Sequeira and Macas Nunes 2008). Others like Arezki et al. (2012) concentrate on long-term growth and find that an increase in tourism of one sample standard deviation increases GDP per capita by 0.5 percentage points per year.

Recent work by the World Bank (Licciardi and Amirtahmasebi, 2012) highlights the link between cultural heritage and sustainable development, by recognizing the potential for tourism that these places have. This work not only stresses how these well positioned cities that are specializing in tourism activities find their path to economic growth (Arezki et al. 2012) but also how designation of heritage sites affects property values. For example, Lazrak et al.'s (2011) work focuses on the economic valuation of cultural heritage, finding that houses located in historical areas are worth approximately between 23% and 26% more than houses located outside those areas. Furthermore, dwellings with a listed heritage status gain a direct value premium ranging from 19.5% to almost 27%. Hence, harnessing a city's beauty can boost economic growth through tourism and a flourishing real estate market.

Faber and Gaubert (2016) use microdata from Mexico to study the long-run consequences and channels through which tourism contributes to growth in developing countries. Using measures of attractiveness of beaches, they construct a set of instrumental variables to estimate the effect of local tourism on local growth. They find that a 10 percent increase in local tourism revenue results in an increase in municipality employment and GDP in 2.8% and 4.3% respectively, for Mexico's cities. This growth is partly driven by cross-sector and within-sector spillovers on manufacturing industries. These findings support the claim that tourism is a good tool to incentivize growth in developing nations.

Nonetheless, Arezki et al. (2012) also raise the point that tourism as a sole strategy is not enough to sustain growth over time. Complementary development policies and investments are needed to turn tourism into a growth strategy. For example, tourism in the city of Livingston in

Zambia, which boasts Victoria Falls (UNESCO World Heritage Site) is complemented by an export oriented economy focused also on copper, agribusiness, and gemstone production. Another example is Sousse, Tunisia, where the Medina of Sousse is also a UNESCO World Heritage Site. Even though the main activity is tourism, with all-season resorts, the city is also known for its olive oil production.

Examples of cities with unique characteristics and outstanding beauty are not rare in the developing world. There is Rabat, in Morocco where the modern world and ancient history are brought together and the Medina of Rabat, a World Heritage site attracted a record of 10.4 million visitors in 2016. Natural and historical beauty are also complemented with an important textile industry and leather handicrafts. Or Malindi, located at the mouth of Galana River, on the Indian Ocean coast, in the South of Kenya, were the Gedi Ruins can be found; a city of 207,253 inhabitants (2009 Census) surrounded by the Watamu and Malindi Marina National Parks, is also house to classic examples of Swahili architecture. Malindi, a hidden gem of Kenya, has some nascent industry of cotton seed oil.

The natural beauty of such cities creates a complementarity between natural capital and proximate physical capital such as hotels and restaurants. These profit seekers become a vested interest group with an incentive to preserve the beauty of the area in order to engage in product differentiation. They can charge a higher price markup if the area is unique.

Declining transportation costs (through cheaper air travel) in the developing world increase the extent of the market and create incentives for beautiful cities to invest and maintain their beauty. Cities such as New York City gain a large share of their income from domestic and international tourism. Over the last 15 years, international connectivity has increased dramatically for developing countries. For example, between 2003 and 2013, Asia-pacific region and Africa have increased the number of international routes by 61% and 32% respectively, while the Middle East region has experienced the largest growth in direct and connecting passenger traffic (almost

60% in 2013).[15] Better roads also allow local tourists to travel within countries. Kenya has almost tripled the total number of kilometers in roads between 2008 and 2013.

Beautiful and touristic cities attract investments. Zheng and Kahn (2013) highlight that complementarity, such that the private sector invests more in areas where public goods are improved. They focus on the 2008 Beijing Olympics. Where Beijing invested in green space and improved public transit infrastructure, the private sector subsequently invested in new, higher quality housing and new restaurants and shopping opportunities.

The likely mechanism through which the complementarity between private and public investment takes place is related to time allocation. When an urban area is more pleasant, people want to spend more time there. Anticipating this willingness to pay more money and time in cities, retailers and developers invest on private capital to complement the natural beauty of such cities.

Firm Productivity and Pollution Exposure in the Developing World

Polluted cities may feature less productive firms both due to a selection effect and a treatment effect. The best minds may refuse to live in such polluted cities (this is the selection effect). Conditional on locating in a city, firms may be less productive in a high polluted environment. Pollution exposure lowers a worker's productivity (Kampa and Castanas 2008). Air pollution can cause respiratory and heart diseases, increasing mortality especially for vulnerable groups. Graff-Zivin and Neidell (2013) review these findings.

The fact that cities attract better workers has been well studied. Combes, Duranton, and Gobillon (2008) find empirical evidence of spatial sorting by skills for French workers. Behrens, Duranton, and Robert-Nicoud (2014) develop a model showing that ex-ante sorting along talent, combined with other factors, contributes to concentration of workers in larger cities. The role that pollution plays in affecting this sorting in the developing world has been under-studied.

Pollution can affect productivity through different channels. First, it can have a direct effect on lowering a worker's ability to function and to think. Second, if the pollution triggers new

[15] Morphet, H and Bottini, C, "Air connectivity: Why it matters and how to support growth". Connectivity and Growth. Directions of travel for airport investments. PWC, November 2014, www.pwc.com/capitalprojectsandinfrastructure.

environmental regulations to be adopted then these regulations may require certain capital investments that contribute to lowering the firm's overall productivity.

Productivity empirical studies estimate a model of the form:

$$y_{it} = \beta\ PM_t + X_t'\gamma + \alpha_i + \delta_t + \epsilon_{it} \quad \textbf{(3)}$$

where y_{it} is a measure of productivity such as hourly wage or quantities produced per unit of time, PM_t measures pollution (fine or coarse particulate matter, ozone concentration), and β is the parameter of interest. A vector of control variables X_t' frequently includes climate conditions that can exacerbate the effects of pollution exposure or affect its dispersion. The regressions also often include individual, time of other types of fixed effects.

Crocker and Horst (1981) study the effect of ozone and temperature changes on productivity of 17 citrus harvesters in Southern California. Graff-Zivin and Neidell (2012) assess the impact of pollution on agriculture workers. They use a panel data set with daily worker productivity data, and daily ozone levels to measure the negative effects of environmental conditions on worker productivity. They emphasize the endogeneity problem that arises because of sorting (more productive workers moving to less polluted areas) and exposure behavior (workers avoiding outdoor working tasks when pollution is particularly high). To overcome these issues, they use an individual level panel data set with daily worker productivity from a large farm that pays through piece-rate contracts. Because of the incentives of these contracts, they can use this measure of productivity as a proxy for productivity. They also have data on the decision to work and number of hours worked, which helps them rule out avoidance behavior.

Other studies have used panel data to estimate the effects of pollution on worker productivity. Chang et al. (2014) study the effects of particulate matter in the productivity of pear packers, controlling for weather conditions such as temperature, wind speed, rain, solar radiation. Adhvaryu et al. (2014) explore the effects of fine and coarse particulate matter on the garment industry in India, including also how certain supervisor characteristics, particularly experience and relatability, impact the results. Chang et al. (2016) perform a similar analysis for call centers in China, controlling also for changes in temperature. Each of these studies documents negative effects of pollution. The effect of pollution may interact with the heat to further cause productivity losses.

Air conditioning and air purifiers are costly pieces of capital to install and to operate but highly humid places such as Singapore have shown that they can continue to thrive in the heat. Graff-Zivin and Kahn (2016) argue that the most productive firms will be the most likely to adopt these technologies in order to shield their workers from adverse climate conditions.

If the most productive workers work for the most productive firms, then such adaptation strategies (including air filters and air conditioning) will mean that wage inequality under-estimates quality of life inequality because the highest paid workers will have the best workplace conditions.

Given that air pollution has causal effects on an individual's health, it is no surprise that labor supply is sensitive to pollution. Ostro (1983) studies the effect of pollution (particulates and sulfates) on work lost days and restricted activity days. Hausman et al. (1984) estimate a Poisson specification to evaluate the relationship between pollution and the amount of work days lost.

In developing countries, a few studies focus on the effects of pollution on labor supply. Carson et al. (2011) study the effect of arsenic contaminated water in Bangladesh. They find that household labor supply is 8% smaller due to arsenic exposure. They also look at the distribution of worked hours within households, finding that tasks are reallocated between male and female members to reduce the risks of exposure. Hanna and Oliva (2015) estimate the effect of pollution on labor supply by looking at the change in sulfur dioxide concentration after the closure of a large refinery in Mexico City. They find that the decline in pollution of 19.7% increases the amount of hours worked per week by 3.5% (1.3 hours). Aragón et al. (2016) focus on the effect of particulate matter ($PM_{2.5}$) on labor supply in Peru, showing that the negative effects of pollution are concentrated on households with susceptible dependents.

In closing this section, we note that urban research on agglomeration has emphasized the productivity advantages of industries locating close to each other. Hence, the attractiveness of a city and the value a firm assigns to its quality of life may also come through co-agglomeration benefits. For example, if two industries trade with each other or learn from each other then it is valuable for them to be close to each other. If an important co-agglomeration industry seeks a clean city, does it attract other firms that do not value clean air but seek to be close to it due to ideas and transportation costs for inputs and output? Conversely if a polluting industry has strong co-agglomeration, does a city remain competitive because of the agglomeration effects? Ellison, Glaeser and Kerr (2010) use US manufacturing data to test Marshall's theories of industrial agglomeration. They find that all three forces (goods, labor, and ideas) are similar in influencing co-agglomeration patterns, with input-output flows being slightly greater. However, to date, the links between such co-agglomeration benefits and pollution have not been explored.

Human Capital Development and Pollution

Environmental research documents the negative health and quality of life effects of pollution exposure provides an additional incentive for more developing countries' cities to invest in the "green economy".

In a high pollution environment, the human capital acquisition process will be affected. Greenstone and Hanna (2014) survey this work in the developing world. Several of Janet Currie's studies (see Currie and Vogl, 2013, Currie et al. 2013, Currie et al. 2014) document the links between early life exposure to pollution and later life negative outcomes. This work is related to James Heckman's work on skill formation and dynamic complementarities.[16] If a child is sickly because of pollution exposure, this child learns less in school and has trouble achieving her full potential. In this sense, local pollution affects human capital accumulation and affects later life success in labor markets.

Beach and Hanlon (2016) look at the effects of pollution on mortality in 19th century England. Beach and Hanlon (2016) use local industrial coal use levels and estimate the effects on infant mortality. They distinguish between upwind and downwind districts, and control for mortality due to causes related to poverty, poor sanitation and crowded living conditions. They find that one standard deviation increase in coal use raises infant mortality by 6.7% to 8%. Hanlon and Tian (2015) extend that work by comparing pollution effects on mortality in historical England

[16] Heckman JJ. (2006).

versus Chinese cities in 2000. They find that although effects are less pronounced in modern economies, there are still adverse effects of pollution on mortality in rapidly industrialized countries.

Research on the Costs of Reducing Developing Countries' Urban Pollution

A city that actively seeks to increase its competitiveness through reducing its pollution will incur costs. These costs hinge on what sector of the economy is the major source of the pollution externality. Suppose that coal fired electric power is the major cause of a city's pollution. The economic cost of a "green" power sector transition hinges on how costly it is to move up the energy ladder to using natural gas and renewable energy to generate power. If electricity prices are now higher because of this transition, then the lost profits and consumer surplus associated with facing higher prices must be counted as part of the costs. Suppose that heavy industry is the major cause of a city's pollution. If the city reduces pollution by enforcing new regulations, then the costs of this regulation will be borne by consumers who will now face higher product prices, workers who may now have fewer job opportunities and the owners of the firm who now earn lower profit. Suppose that the transportation sector is the cause of the city's pollution. If the city regulates gasoline and vehicle emissions technology, then vehicle owners will now face higher prices to buy vehicles and to operate them.

These three examples highlight key cost parameters in determining who bears the costs of enhancing a city's competitiveness through pursuing pollution reduction. In each of these cases, we have assumed that the bulk of the pollution is produced locally.

This discussion highlights that the extent to which industrial workers, electricity consumers, and vehicle drivers bear the brunt of regulatory costs hinges on many economic parameters. Elected officials are likely to be aware of how their constituents will be affected by increases in regulation. If they anticipate that the costs of certain policy changes exceed the benefits for their key constituents, then these officials will be less likely to support them (Eyer and Kahn 2017).

For example, consider a case in which incumbent industry such as cement makers cannot cheaply adapt to regulations intended to reduce local air pollution. Even if new entrants could more cheaply adapt, local officials would be less likely to enact such regulation if this industry is paying bribes or providing key campaign contributions (Dasgupta, Hettige, Wheeler 2000).

Urban officials in the developing world will be wise to anticipate the unintended consequences of introducing environmental regulations. Studies have documented that new vehicle regulation encourages vehicle owners to keep their grandfathered vehicles longer (Gruenspecht 1981, Stavins 2007). New power plant regulation encourages managers of existing power plants to not phase them out so they can avoid the new capital tax (Nelson, Tietenberg, and Donihue 1993). In the developing world, formal firm regulation is likely to increase the substitution of firms into the unregulated informal sector (Kahn and Pfaff 2000).

Regarding the instruments that could be implemented, developing countries also face particular challenges. Market based instruments, as well as command and control measures need to be supported by a strong institutional system that assists in their implementation. The fragility of national and regional institutions, and the weak integration between them in these countries is often a concern. Motta et al. (1999) focus on 11 Latin American and Caribbean countries and find that market based instruments that introduce gradual and flexible reforms are more likely to succeed because these reforms can accompany a changing institutional framework. They also emphasize that the collected revenue from these instruments needs to be channeled to local authorities to help them support building institutional capacity. This is an important point because even though most of the instruments are shaped at the national level, the direct implementation often falls in the hands of local institutions. Successful implementation will have a direct impact on cities' quality of life and will improve their competitiveness, offering additional incentives to city leaders to adopt and enforce these policies.

Research set in the United States has studied how manufacturing firms respond to energy prices and environmental regulation (Gray and Shadbegian 2003). U.S. Clean Air regulation assigns each county in the nation to low regulation (attainment status) or high regulation (non-attainment status) in each year for six measures of ambient air pollution. This regulatory categorization allows researchers to partition geographic areas into those that do and do not face high regulation. Research by Greenstone (2002) has documented that manufacturing clusters in areas with less environmental regulation. Kahn and Mansur (2013) build on this literature. They model manufacturing industries such as steel and apparel as differing on three dimensions. Some industries are energy intensive while others are labor intensive and some are pollution intensive. U.S. counties differ on at least three dimensions. Such geographic areas are pro-labor unions, others have stringent environmental regulation and others have high electricity prices. Kahn and Mansur (2013) compare the spatial clustering patterns of 20 different industries in the U.S. by studying county border pairs. Such county border pairs are physically close to each other, but they can differ with respect to the energy prices, and labor and environmental regulation. They find that pollution intensive industries locate on the border where environmental regulations are more lax (the pollution havens effect) and that energy intensive industries locate on the side of the border where electricity is cheaper. Government policy then can reduce pollution by encouraging the adoption of pollution abatement equipment or by deflecting polluting activity to less regulated areas. In the case of developing nations, the standard claim has been to posit the pollution haven hypothesis such that poor nations limit their environmental regulations in order to attract footloose polluting factories (Birdsall and Wheeler, 1993, Eskeland and Harrison, 2003, Cole, 2004).

In the developing world, electricity shortages limit industrial output (Fisher-Vanden, Mansur and Wang 2015, Allcott, Collard-Wexler, O-Connell 2016). While coal is dirty, it is a reliable electricity source that generates power with less variability than wind or solar power. In developing nations that price electricity artificially low and seek to generate a growing share of their power from renewables, systemwide blackouts will become more likely. This example highlights how the interaction of government policies, in this case energy pricing and renewables policy, affects the competitiveness of specific industries.

Up until this point, we have focused on how industry is affected by policy. The residential and transportation sectors are also affected by regulations. A U.S. housing literature has documented the costs and the economic incidence of “green city” housing regulation. Many beautiful cities such as Portland and London have growth boundaries and zoning codes that set aside land for public parks and limits the heights of buildings. While these restrictions enhance the city’s beauty, these supply side policies limit new construction and encourage suburban sprawl (as housing is built there) and raise urban housing prices so that incumbent owners gain but young poorer people are priced out of the market (Glaeser and Gyourko, 2003, Glaeser and Ward, 2009, Glaeser, Gyourko, and Saks, 2005, Brueckner and Sridhar, 2012 in India, Brueckner et al. 2016 in China).

The challenge in estimating these zoning costs is the construction of a counter-factual. If land use regulations enhance overall urban environmental quality then they offer benefits, but what are the costs? How much cheaper would quality adjusted housing be in a regulated city if the city faced less regulation? This housing cost premium is another cost of using regulation to increase a city's "greenness". There is a fundamental missing data challenge here. No city has a "twin," so it is very difficult to estimate the housing market costs and the distributional effects (as incumbent land owners gain) from stringent land use zoning regulations.

Regulatory Cost Dynamics

Continuing innovation and experimentation by for-profit firms creates the possibility that the costs of environmental regulation decline over time. With rising stocks of global human capital, innovators (think of Elon Musk) continue to patent new ideas and these green innovations lower the cost of pursuing the green economy. Paul Romer has emphasized the importance of human capital in the innovation process (Romer, 1990). His work suggests that technology and rules are important components of globalization that contribute to poverty reduction and economic growth. Because endogenous innovation has the potential of lowering the costs of compliance with existing regulations (Romer, 2010), they can create a virtuous cycle that has the potential of improving quality of life and through that contributing with city competitiveness. This beneficial role of globalization is a key theme that merits additional research. Developing countries that are open to trade will more quickly be able to access cutting edge technology that can help to decouple pollution from economic activity. Such innovation helps to shift in and down the environmental Kuznets curve relationship (Dasgupta et. al. 2002).

If this optimistic hypothesis is correct, then the competitiveness agenda for urban leaders in developing countries will become cheaper for them to embrace. If at the same time, their citizens are growing richer and demand investments in improved quality of life, then this creates the possibility of more leaders being willing to enact best practices in the green space.

The "Porter Hypothesis" goes a step further here. Michael Porter has argued that environmental regulation can lower a firm's cost of doing business by enhancing its competitiveness (Porter 1991; Porter and van der Linde 1995; Ambec et al. 2013). This argument is known now as the Porter Hypothesis, with a *weak* version where regulation encourages innovation, and a *strong* version where innovation more than offsets the costs of regulations.

Empirically, the Porter Hypothesis have been studied by many authors. Ambec et al. (2013) review this literature and when focusing on the strong version, they distinguish between firm-level and country-level competitiveness.

In the developing world, weak enforcement of regulation suggests that we have not had credible tests of the Porter Hypothesis. Murty and Kumar (2003), who find arguments to support the Porter Hypothesis for manufacturing firms in India, and Zhang, Bu, and Yang (2014), who find that environmental regulations could improve productivity in Chinese cities, but effects are different depending on firm size, location and industrial sector.

Open Questions about the Connection between City Competitiveness and Pollution

There are many open research questions at the intersection of urban competitiveness and a developing country city's environmental performance. First and foremost, if a city's competitiveness could be enhanced by reducing local pollution exposure, why is it that the city has not already addressed the issue? If local officials are unaware of the firm level productivity and the household level benefits of pollution progress, then further empirical work that estimates such costs and benefits can help inform decision making.

As a city's population grows richer and more educated, it is likely that their overall environmentalism will rise and they will be willing to pay more for environmental protection. As the value of a statistical life increases with economic development (see Costa and Kahn, 2004), then the value of reducing pollution rises (see Selden and Song 1995). Whether there are significant differences across nations with respect to the impact of economic development on the desire for environmental protection is an important question (Israel and Levinson, 2004).

As we discussed above, a key issue in the developing world relates to how "footloose" are dirty and clean firms in response to both environmental progress and to changes in environmental regulations? As one geographic area increases its environmental regulation, what jobs are likely to leave or not grow as quickly? What jobs will be attracted to the area? Firms reveal that regulations are costly if they leave the area. To answer this question empirically requires firm level panel data such that a researcher can observe the birth and deaths of firms and know their industry, pricing, and inputs used. Ideally, such data would resemble the U.S. Longitudinal Research Data on manufacturing. If a matched worker/firm panel data set could be created for different cities in the developing world, then researchers would have an excellent laboratory to study how productivity, worker turnover and wages evolve as local pollution and climate conditions change.

From a city's perspective, the urban leaders will be slow to embrace the green agenda if it threatens to raise costs for their key constituents. As discussed in an earlier section, energy intensive industries and older incumbent dirty firms may resist new environmental regulations that would raise their cost of production and lower their profits. If such firms are politically influential then local leaders may not be willing to embrace the green agenda because of such interest group pressure. Future research could investigate this by tracing out social networks between firm leaders and urban leaders. Such a research design has been used in papers studying China's spatial investments.

In the developing world, some cities may be slow to embrace the green agenda because they are liquidity constrained and cannot raise the necessary funds to finance a credible regulatory agency. Standard compensating differentials logic predicts that local land prices would be higher if pollution could be cost effectively reduced. If the city has a property tax system, this would generate a flow of income that could be earmarked to delivering environmental protection. If cities need to raise funds to pay for public goods that provide environmental protection, how should they do this? Cutler and Miller (2006) discuss the role that municipal bond markets played in the United States in early 20th century as major cities mitigated their water pollution problems. Cities issued municipal bonds and used the proceeds to finance costly water projects. This raises issues of which cities in the developing world have the capacity to credibly collect property taxes and have the computer systems and the institutions to enact such a system with minimal corruption and under-payment. If property taxes are collected, would this lead to a rise of the informal economy as urban residents seek to hide from the authorities?

Many developing countries' cities feature significant slum populations. As the slum population density increases, how does the scale of this low-income activity affect local water pollution (due to the lack of formal sanitation access) and local air pollution (due to the burning of low-quality cheap fuels)? Research from Brazil documents that many of its mayors actively seek to discourage poor people from moving to their cities by not connecting their housing to the water grid (Feler and Henderson 2011). Whether mayors have sufficient incentives to invest ex-ante in infrastructure to limit disease contagion and pollution associated with slum growth remains an open question (Ashraf et. al. 2017).

Conclusion

Pollution exposure hinders urban competitiveness when it slows down human capital attainment and discourages skilled individuals from moving to an area. Pollution raises quality of life inequality when high-skilled workers work for firms that invest in worker protection. In contrast, less educated workers work outside or work in the informal sector or work for firms that do not invest to protect their workers.

In the mid-1990s, adherents of the Environmental Kuznets Curve hypothesis would posit that poor nations would inevitably experience rising pollution as a byproduct of economic development. Such nations would gladly sacrifice environmental quality as they ramped up their industrial production, burned fossil fuels such as coal to generate the electricity needed to fuel industry and the rising demand of the household sector. As the middle class grew richer in these nations, they substituted to private vehicle use and this in turn increased local air pollution.

While this supply side explanation of the rise in pollution production certainly has some empirical support, it ignores the demand side and the rise of induced innovation. Given that health capital and human capital are the major engines of modern urban economic growth, it is a short-sided growth strategy to build up the local economy through a heavy industry based economic development plan.

Undesirable cities will feature lower rents and higher wages to compensate workers as “combat pay”. If an individual city becomes more desirable (due to shifting industrial composition, an energy transition to cleaner fuels, and effective regulation), then rents will rise and the city will pay smaller wage premiums for the same quality workers. Under this logic, land owners in the city will be the major winner. But, if enough cities within the system of cities experience such upgrades then a general equilibrium effect will be induced such that the general well-being of the entire population increases. Effectively, the aggregate supply curve of “amenities” would be shifting out and this lowers the price that people implicitly pay for non-market goods (Roback 1982). Incorporating non-market goods into national accounts of well-being is a crucial task for judging living standards for a nation over time and comparing living standards across nations at a point in time (Jones and Klenow 2016).

This survey paper has stressed that more cities in the developing world will soon view environmental protection as a competitiveness strategy. As human capital attainment rises in these nations, more of the most productive firms will be footloose skilled firms. If the city specializes in high skill or tourism, then pollution is highly detrimental to competitiveness.

Capital cities may be an exception. In the developing world, especially in South America, the major capital city has a much larger share of the nation’s population and there are relatively few cities for people to choose between (Ades and Glaeser 1995). Urban economists have emphasized the importance of Tiebout “voting with your feet” as a disciplining device that provides local mayors with stronger incentives to deliver better service performance. Major capital cities such as Beijing and New Delhi have very high levels of air pollution. Such capital cities, due to their political importance, will continue to attract firms and workers even if the city suffers from congestion and pollution.

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