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Pollution and City Competitiveness

A Descriptive Analysis

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Abstract

As cities grow, the negative effects of congestion start to play their part, often affecting the cities' ability to become and remain competitive. Although many studies have focused on these negative effects, the links between pollution and city competitiveness are less explored. This paper focuses on this relationship, particularly the links between air pollution and city growth, and how it correlates with city competitiveness. Although high-income cities are usually better at managing pollution, the paper finds successful examples of fast-growing, lower-income cities that are able to tackle this issue. The evidence shows that cities can be competitive and still manage pollution, as long as they have a proactive attitude and focus on developing a green agenda to support this journey.

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Pollution and City Competitiveness: a Descriptive Analysis[1]

Nancy Lozano-Gracia and Maria E. Soppelsa

JEL: Q53, R11, O44

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Introduction

The contribution of cities to economic growth is now well accepted both in the economics and public policy literature. Estimates suggest that they contribute as much as 80 percent to the global GDP. By providing a spatial environment where firms and people meet, cities facilitate trade and interactions, help connect different stages of production, and take advantage of economies of scale. The agglomeration processes that cities bring are crucial for development, pushing countries to grow faster (Duranton, 2008, Glaeser, 2014, Duranton, 2015). Cities that succeed at attracting new firms, workers, and investment are often identified as competitive cities. They often perform above their national average, generate jobs, and increase income levels to their citizens (World Bank, 2016).

Fast growing cities are often subject to congestion effects that can hinder their ability to become competitive. Congestion effects of growing cities are well documented and include things such as traffic congestion, crime, and pollution. These are what Ed Glaeser has called the "demons of density" (Glaeser, 2012). While a lot has been said about the links between productivity and traffic congestion (Ciccone & Hall, 1993; Graham, 2007), the links between pollution and city competitiveness have been less explored (Tolley 1974, Glaeser 1998).

Large population numbers pose increased pressures on local environments and when not well managed can lead to pollution that may affect livability and in turn, productivity in a city. Among the different types of environmental challenges that can stem as a result of the increased densities found in cities, air pollution poses serious challenges, given the difficulties in regulating emissions and the fact that this externality transcends the geographic limits of the city, making it very difficult to assign costs (and benefits) related to it. Consequently, many growing cities, particularly in developing countries, pay little or no attention to how to manage air pollution, ignoring the impacts that this may have not only on the health and livability of its citizens, but also on the productivity of firms and workers, and ultimately, the competitiveness of their city.

In a recent report, the World Bank has laid out a clear definition of what is a competitive city[2]: a city that is growing fast, generating jobs, and increasing the level of income for its inhabitants. This work provides a framework for thinking about building competitiveness in a city, through strong institutions, efforts to provide good infrastructure and well-functioning land markets, foster skill and innovation, and providing the needed enterprise support and finance for the local economy to thrive. This framework, however,

[2] World Bank, 2016.

does not provide an assessment or analysis on how pollution overall, and in particular, air pollution, affects competitiveness and what could be policies and actions that could allow city leaders to manage the negative effects of pollution while still fostering increases in cities' competitiveness.

In this work, we aim at taking a first step toward expanding the Competitive Cities framework to include considerations on pollution, by providing an exploratory analysis that brings together indicators of city competitiveness and air pollution, and through that elicit patterns that can help in providing a first step toward understanding the links between these two key issues.

We focus on a descriptive analysis for two main reasons. First, this type of analysis can provide some useful insights on the main characteristics that make a city competitive and how these characteristics relate to pollution. It can help understand the path that cities may take to achieve growth and how pollution can be a consequence and a cause in this journey to achieve competitiveness. In that sense, it can shed some light on the challenges a competitive city may face and how it can overcome them. Second, building on the argument that pollution interacts with city competitiveness, as both a consequence of growth and a cause affecting the city's ability to become more competitive, a descriptive analysis can help to understand the stylized facts behind this relationship and conceptualize this interaction.

The paper is structured as follows. The next section briefly describes the data. Section three focuses on summarizing the Competitive Cities framework laid out in the World Bank Report (2016) and moves to focus on air pollution. It pinpoints to the most polluted cities across regions and how that characteristic relates to development and income levels. Section four looks more in detail at the interaction between pollution and competitiveness, paying attention to which types of cities are experiencing the challenge of fast grow and pollution, particularly in developing regions, and lays out a typology of cities bringing together the concepts of competitiveness and pollution.

Description of the Data

For this analysis we combine three data sets. First, we use the same data set used by the Competitive Cities report (World Bank, 2016) which includes city-level data from the Oxford Economics Dataset.[3] Oxford Economics Dataset is a global administrative data set that provides economic indicators and

[3] We would like to thank the Competitive Cities Team for cleaning and preparing the Oxford Economics data set.

performance for 775 cities, from 2000 to 2015. It includes capital cities and cities with at least 400,000 inhabitants. located in 140 countries across all regions and all income levels.[4]

Second, we combine Oxford Economics Dataset with city centroids data from the Global Rural-Urban Mapping Project data set (GRUMP) to geo-reference the cities. Since we did not have the associated geographic limits for each of the cities in the original Oxford Economics Dataset, we chose to match each city with the corresponding city centroid to avoid using arbitrary limits. Since there was no common identification for the cities in both data sets, we use the name of the city (and country) for matching purposes. Because of this limitation, not all cities were perfectly matched. After manually fixing more than 200 city names to improve the matching, we end up with 769 geo-referenced cities, distributed by region as follows: 27.5% in East Asia Pacific, 22.5% in OECD countries, 12.5% in Latin America, 11.5% in South Asia, 9.5% in Sub-Saharan Africa, 9% in Europe and Central Asia, and 6.5% in Middle East and North Africa. The six cities in the Oxford Dataset that we were unable to match are: Baixada Santista and Norte Catarinense (Brazil), Erdos (China), Male (Maldives), Marseille (France), and Podgorica (Montenegro).

Third, we combine the city-level data with PM 2.5 surface data estimated by van Donkelaar et al. (2016). They combine Aerosol Optical Depth (AOD) data from MODIS satellite (NASA), MISR, and SeaWIFS Instruments with the GEOS-Chem Chemical transport model to obtain surface-level measures of PM 2.5.[5] Their resulting data set is a global raster with a resolution of 0.1 degrees x 0.1 degrees, containing the annual mean estimated surface level of PM 2.5, for the years 1998 to 2015. For each year and geo-referenced city, we extract the annual mean level of PM 2.5, using a 10 km buffer around the city centroids.

[4] As mentioned in the World Bank Report (2016), income levels are defined by the World Bank Group's per capita GDP cut-off lines as of 2012: low income (below $1,035), lower-middle income ($1,036-$4,085), upper-middle income ($4,086-$12,615), and high income (above $12,616).

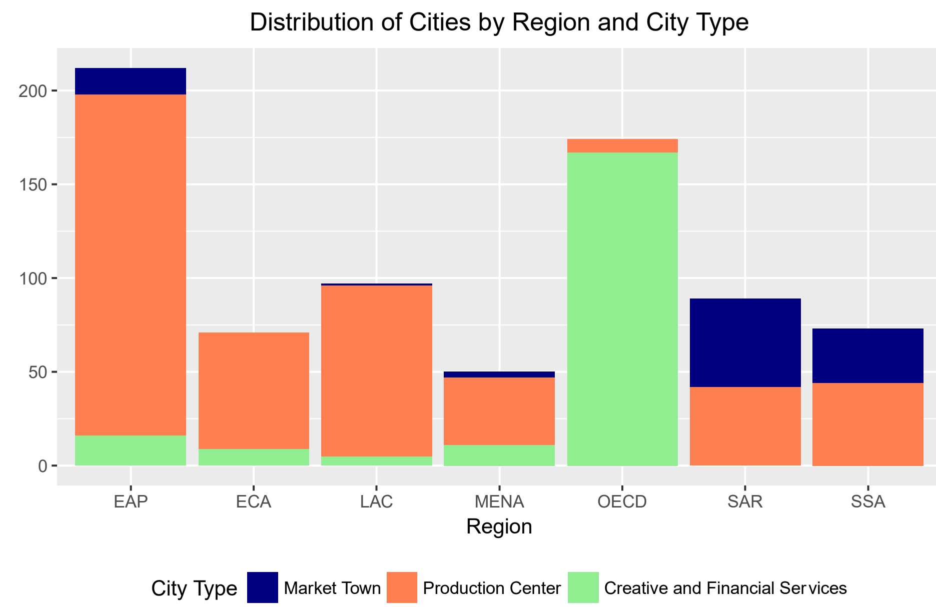
[5] As mentioned before, because fine particles can have long lasting effects on human health, we focus our analysis on the smallest of these particles, those with diameter less than 25 microns (PM 2.5). These particles can be measured with two different methods. The first method has been widely used and consists of placing ground-level monitors, that can measure concentration levels on the earth surface. These monitors are fairly precise but can be costly to install and maintain, involving sophisticated equipment, and requiring technical knowhow. This results in many countries having only one monitor, limiting the possibility to perform a city-level analysis. The second method involves satellite-driven technologies that can measure concentration levels in the atmosphere and, with the help of ground-level measures, reasonably estimate ground-level pollution. This method provides a global coverage of concentration levels, which makes it particularly useful for our study at the city level.

While the data cover the years 2000 to 2015, we focus on the most recent 10-year period, between 2006 and 2015. Years prior to 2006 show several missing values for two of our variables of interest. Approximately 25% and 30% of city GDP per capita growth rate and city employment growth rate values, respectively, are missing for the year 2001. These percentages decrease for the subsequent years with only two missing observations for each variable for the year 2006. The period we chose has then the double advantage of being the most recent and complete.

Using the information in the data set, and following the classification provided in World Bank Report (2016), cities can be classified in three broad categories depending on their mix of economic sectors: Market towns, Production Centers, and Creative and Financial Services. Market towns are cities with a GDP per capita below $2,500 and where consumer services account for a large proportion of the economy; Production Centers include cities with a GDP per capita between $2,500 and $20,000 with their economy mostly focused on manufacturing, construction, and mining industries; and Creative and Financial Services refer to cities with a GDP per capita above $20,000 where high-end services account for an increasing share of their economies.

This distinction of cities by major economic activity can help us understand how different the challenges could be for different types of cities. Figure 1 shows the distribution of these different types of cities by region. Blue represents Market Town cities, Orange corresponds to Production Centers, and Creative and Financial Services are shown in green. It is clear from this figure that the distribution of city types varies widely across regions. On one extreme, in South Asia and Sub-Saharan Africa, cities are either Market Towns (blue) or Production Centers (orange). These cities are often starting their industrialization process, attracting population, and growing fast. They often struggle with the natural consequences of fast growth, such as how to accommodate a growing population or how to manage increasing pollution levels. In these regions we can expect to find cities that are facing high pollution levels coming from early industrialization and poor living conditions. On the other extreme, we find that most cities in OECD countries fall in the Creative and Financial Services category (green), and there are no Market Town cities. Creative and Financial Services cities face different challenges, such as increasing housing prices in downtown or improving public transportation systems. We expect for these cities to show lower levels of pollution which is usually the case for more developed countries that have succeeded at managing pollution levels without affecting growth. In the rest of the regions, the majority of the cities are Production Centers (orange) with likely a variety of pollution levels, mostly associated with different types of industrial activity and the city level of development.

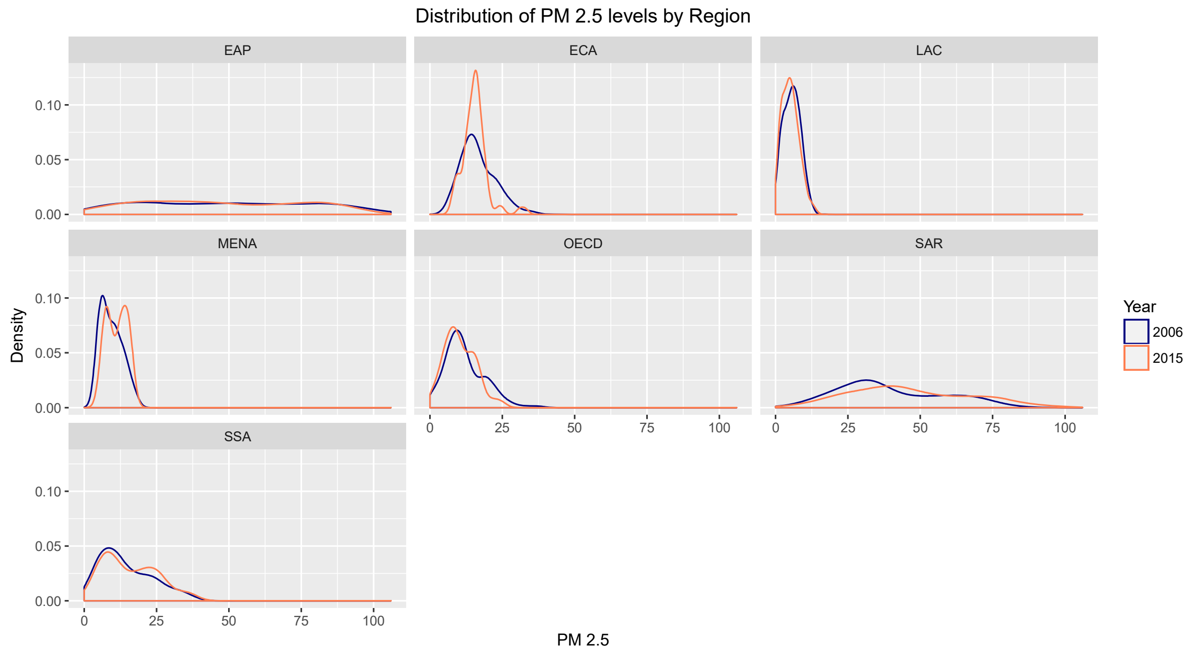
Figure 1: Market Towns, Production Centers, and Creative and Financial Services



Looking at the distribution of PM 2.5, we find that pollution varies widely across regions. Figure 2 depicts the distribution of pollution for each region and at two points in time, 2006 and 2015 (initial and end points of our period of analysis). Each of the graphs in the figure corresponds to one region. In each graph, we show in orange the distribution corresponding to the year 2006, and in blue the one corresponding to 2015.

The first thing to notice is that the distribution in some regions spans throughout the whole range of pollution (for example in East Asia Pacific), while pollution in other regions is concentrated around certain levels (for example, in Latin America maximum levels of pollution reach approximately 13). This is interesting because regions have certain development patterns that can be associated with pollution levels. This then motivates our next analysis: is there a relationship between city pollution and development or income levels?

Figure 2: Distribution of PM 2.5 annual means by region



Second, we compare the distribution for each region between 2006 and 2015. We find all three different possibilities. First, the distribution between 2006 and 2015 shows little or no change. This is the case for example in East Asia Pacific. Second, the distribution of pollution in 2015 has shifted to the left or more concentrated in lower values, showing an improvement in pollution levels. This is true in Latin America (slight shift to the left) and Europe and Central Asia (concentrated in lower values) regions. Third, the distribution in 2015 has shifted to the right or has become flatter, showing that pollution conditions have worsened in that region. Examples of this are Middle East and North Africa (shift to the right), South Asia (flatter), and Sub-Saharan Africa (slight shift to the right). A first approach to identify which regions have worsened their pollution distribution is useful to guide the analysis and help focus on recognizing interesting city examples in those regions.

Competitive Cities and Pollution

Cities that are developing fast are often identified as competitive cities. Recent work in the World Bank (Competitive Cities for Jobs and Growth, 2016) defines competitive cities as those that “successfully facilitates their firms and industries to create jobs, raise productivity and increase the incomes of citizens over time”. These cities are growing at a faster pace than their nations, attracting foreign direct investment, and constituting engines that push national growth. They often face challenges that are a direct consequence of this rapid growth, such as congestion and pollution management. How they will manage those challenges has a direct impact on their ability to keep growing and remain competitive.

In order to identify which cities fall in this category of competitive cities, we follow the characterization presented in the World Bank Report (2016) and take a look at how cities perform in three key variables: GDP growth, job creation, and productivity. These key variables show how cities are performing and are good measures to pinpoint competitive cities for the following reasons. Cities with a higher GDP growth rate are usually better positioned to attract firms and foreign direct investment. They are often full of potential opportunities for their habitants, also attracting more people. An increasing demand for jobs clearly plays a central role in attracting workers and contributes to maintain city development, while an increasing productivity helps attract qualified workers by offering better compensation.

More specifically, we look at the difference between city and national values for GDP growth, job creation, and productivity. We take a city's GDP per capita growth and for each year, subtract the national GDP per capita growth to get how much the city is growing with respect to the national values. We follow the same logic to calculate job creation and productivity relative indicators. For job creation, we use city and national yearly employment growth rates. To measure productivity, we use city and national gross value added per worker, per year.

By focusing on these three variables, and how they compare to the national indicators, we can identify cities that are performing above average. This analysis can shed light on what makes such cities that are "above the norm" different from others. It can also define typologies of cities that can help identify possible paths that new growing cities may follow in the future. This descriptive analysis will stop short from identifying any causal relations. Even though this exercise will not be able to answer causality questions, looking at correlations and city typologies can still be informative and a good starting point to understand city performance, challenges, and future problems that may come as a consequence of rapid growth.

We then move forward and compare cities' performance for the whole period of analysis, between 2006 and 2015. We construct a yearly average by city for each of the three variables, and use this annual average to identify which cities are outperforming their nation, on average, throughout this period. Because we are using an annual average for a considerably long period of 10 years, we may be smoothing out the growth of some cities if they experience higher rates in the last five years for example. Although this can underestimate these cities' performance and fail to identify them as competitive, we think that analyzing these variables for a longer period has the advantage of recognizing those cities that have been able to remain competitive for a sustained period of time. We then look at cities' performance on each of these variables separately.

We then construct a ranking of cities that are outperforming their nation in each of the variables under analysis, i.e., the differences between city and national per capita GDP growth, employment growth, and productivity growth. Looking at the top 10 cities that are outperforming their nation in terms of GDP growth rates, nine of those 10 cities are located in China. This comes as no surprise considering the incredible growth that the country has experienced in the last decades and that cities are the key actors pushing that economic growth. These Chinese cities are growing at an average annual rate above 10%. Similarly, in terms of employment growth rate and productivity, five of the top 10 cities in each category are also Chinese cities.

Despite the large number of Chinese cities among top performers, after leaving them aside, examples of competitive cities can be found all over the world with some interesting patterns emerging. Almost all top 10 cities outperforming their nations in terms of employment growth are located in low and lower-middle income countries. For example, Lusaka, Zambia is generating an average of almost 9 percentage points more jobs per year than the national average. Six of the 10 top cities outperforming in terms of GDP growth are also located in low and lower-middle income countries. For example, Abeokuta (Nigeria) and Kigali (Rwanda) have been experiencing an annual average GDP growth between 3 and 4 percentage points above their national average. The situation is quite different for cities with increasing rates of productivity, with half of them located in upper-middle or high-income countries. The city with the highest productivity growth rate is Makhachkala (Russian Federation), which has outperformed the nation by 3.3 percentage points. The list of the top 10 cities outperforming their national average in each of the three categories is shown in Table 1.

Table 1: Top Ten Cities outperforming the National Average in terms of GDP per capita, Employment, and Productivity Growth

Top Ten Cities - GDP Growth					
City	**Country**	**Country Income Group**	**GDP Dif**	**Employment Dif**	**GVA Dif**
Makhachkala	**Russia**	**Upper middle income**	**0.0443**	**0.0232**	**0.0331**
Sharjah	**UAE**	**High income: nonOECD**	**0.0411**	**-0.0102**	**0.0283**
Abeokuta	Nigeria	Lower middle income	0.0386	0.0141	0.0108
Benin City	Nigeria	Lower middle income	0.0319	0.0275	0.0057
Ibadan	Nigeria	Lower middle income	0.0311	0.0196	0.0072
Kigali	**Rwanda**	**Low income**	**0.0305**	**0.0591**	**0.0102**
San Jose-Sunnyvale-Santa Clara, CA	**United States**	**High income: OECD**	**0.0299**	**0.0117**	**0.0263**
Penza	Russia	Upper middle income	0.0297	0.0002	0.0239
Ogbomosho	Nigeria	Lower middle income	0.0296	0.0409	0.0069
Onitsha	**Nigeria**	**Lower middle income**	**0.0294**	**0.0450**	**0.0052**

Top Ten Cities - Employment Growth					
City	**Country**	**Country Income Group**	**GDP Dif**	**Employment Dif**	**GVA Dif**
Nay Pyi Taw	Myanmar	Low income	-0.1636	0.4083	-0.0840
Lusaka	Zambia	Lower middle income	-0.0022	0.0885	-0.0580
Ouagadougou	Burkina Faso	Low income	-0.0050	0.0810	-0.0422
Kigali	**Rwanda**	**Low income**	**0.0305**	**0.0591**	**0.0102**
Pondicherry	India	Lower middle income	0.0062	0.0554	-0.0319
Abuja	Nigeria	Lower middle income	0.0149	0.0533	-0.0036
Kabul	Afghanistan	Low income	0.0190	0.0500	-0.0310
Lilongwe	Malawi	Low income	-0.0020	0.0496	-0.0258
Bujumbura	Burundi	Low income	0.0075	0.0471	-0.0208
Onitsha	**Nigeria**	**Lower middle income**	**0.0294**	**0.0450**	**0.0052**

Note: Cities that are in the top ten ranking outperforming their national average in more than one category are highlighted as follows:

- Orange and green for those that outperform in GDP per capita en Employment growth,
- Orange and blue for those that outperform in GDP per capita and Productivity growth,
- None of the cities outperform in both Employment and Productivity growth.

It is also evident from this table that cities often do not perform well in all three variables. Nonetheless, some examples for cities that outperform their nation in GDP and another category can be pointed out.

To make it clearer, we highlighted these cities showing the two outperforming categories they share in different colors. We use orange and green to denote those cities that outperform their national average in terms of GDP and employment growth, and orange and blue to distinguish cities that outperform their national average in terms of GDP and productivity growth. From these top 10 cities, none of them outperforms their national average in terms of employment and productivity growth at the same time.

Looking into the particular categories, Onitsha and Kigali are two examples of cities that manage to grow fast and create jobs in the process (highlighted in orange and green). With a GDP growth rate above 3 percentage points compared to their nations, these cities generate jobs at a rate of 4.5% and 6% above their national average rate, respectively. They are located in countries experiencing different degrees of urbanization and development. Nigeria is a lower-middle country with almost half of its total population being urban (as of 2015). Rwanda is a low-income country with approximately 28% of urban population (as of 2015). This shows, once again, that becoming a competitive city does not depend solely on the national context but also on the path cities choose to follow. It is also worth notice that these two cities, although not ranked as top 10 in terms of productivity growth, still show an average GVA growth above their national average.[6]

On the other hand, examples of cities with a high rate of GDP growth and productivity are easier to find in more developed countries, as it is the case of Makhachkala (Russia), Sharjah (United Arab Emirates), and San Jose (California, USA), highlighted in orange and blue. Makhachkala and San Jose not only experience a high rate of GDP growth (an annual average of 7% and 3.5% respectively) but have also increased their productivity in almost 4 and 3 percentage points with respect to the national average. They are located in highly urbanized countries,[7] and both also show employment growth levels above their national average (although not high enough to be included in the top 10 cities in terms of employment growth). The case of Sharjah is different, since the high averages of GDP per capita and productivity growth are influenced by considerably high growth rates in 2006 and 2008. The city shows low (and even negative) growth rates for the rest of the years.

But cities that grow fast -and hence can be classified as competitive, are often also riddled by the challenges brought by environmental pollution. Pollution is a natural byproduct of economic development

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[6] Note that all the top 10 cities in terms of employment growth show an average productivity growth rate below their national average (negative productivity growth rate in Table 1: Top Ten Cities – Employment Growth).

[7] As of 2015, 74% of the Russian population and 80% of the U.S. population are urban.

and growth. Industrialization, growing populations, and the use of motorized vehicles in cities contribute to increase the levels of pollution. Cities are hence faced with a two-pronged challenge. On the one hand, they want to attract industries and firms that can help their city grow and develop. On the other hand, the agglomeration of certain types of industries can increase air and water pollution, and the concentration of people in cities is often met with increased used of motorized transport, both key sources of air pollution. Ensuring the benefits of economic growth outweigh their costs, including air pollution, is often the main concern of city leaders.

Although all types of pollution are important and need attention, in this paper we focus on air pollution for its critical impact on health and economics. Air pollution is the fourth leading cause of death worldwide. In 2012, the WHO estimated that approximately 7 million people died prematurely due to air pollution. This means that air pollution is responsible for 1 in 10 deaths worldwide, killing more people than AIDS, Tuberculosis, and Malaria combined. From all the different pollutants that contribute to contaminated air, particulate matter affects more people than any other pollutant. Particulate matter "…consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. The most health-damaging particles are those with a diameter of 10 microns or less, which can penetrate and lodge deep inside the lungs".[8] The WHO estimates that 87% of the premature deaths due to air pollution occur in low and middle-income countries, particularly in Western-Pacific and South East Asia regions. [9] Because outdoor air pollution is not influenced by individual behavior, the role of the national and local government is key.

Pollution and the Relationship with City Competitiveness

We have identified some of the characteristics that make a city competitive. Fast growing cities that are outperforming their nations, with the ability to create jobs, increase productivity, and attract foreign direct investment fall in this category. We have also described pollution management as one of the challenges these cities face in their journey to become competitive, and briefly mentioned how pollution

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[8] "Ambient (outdoor) air quality and health". WHO Fact sheet. September 2016. www.who.int.

[9] According to World Health Organization global update 2005, air pollution guidelines are the following:

- PM 2.5: 10 $\mu g/m^3$ annual mean; 25 $\mu g/m^3$ 24-hour mean
- PM 10: 20 $\mu g/m^3$ annual mean; 50 $\mu g/m^3$ 24-hour mean
- Ozone: 100 $\mu g/m^3$ 8-hour mean
- NO_2: 40 $\mu g/m^3$ annual mean; 200 $\mu g/m^3$ 1-hour mean
- SO_2: 20 $\mu g/m^3$ 24-hour mean; 500 $\mu g/m^3$ 10-minute mean.

and growth could be related. We now try to look deeper into this relationship between pollution and city competitiveness.

Combining the two sets of data provides new interesting evidence. In 2015, 65% of the cities show an annual mean concentration of PM 2.5 that is above the level considered acceptable by the WHO (10 $\mu g/m^3$). From these cities, almost 30% are located in China, 15% in India, and only less than 1% in Latin America. What is most interesting is that all 151 Chinese cities, all 72 Indian cities, and only 4 of 97 LAC cities (4%) fall in this category (PM 2.5 annual mean above 10 $\mu g/m^3$). After ranking these cities from highest to lowest in terms of PM 2.5 level, 18 of the 20 most polluted cities are Chinese cities. The only two exceptions are, as expected, in India: Patna and Gorakhpur. Actually, the city of Patna shows the highest level of PM 2.5, with an annual mean of 95.75 $\mu g/m^3$. Gorakhpur ranks sixth with an annual mean of 91.5 $\mu g/m^3$. The rest of the cities in the ranking (the 18 Chinese cities), show PM 2.5 concentration levels above 85 $\mu g/m^3$. The fact that the 20 most polluted cities are in China or India is not surprising considering that we have already pointed out how the distribution of pollution levels varies across regions, with some regions experiencing low levels, while other showing all cities above the WHO safe threshold.

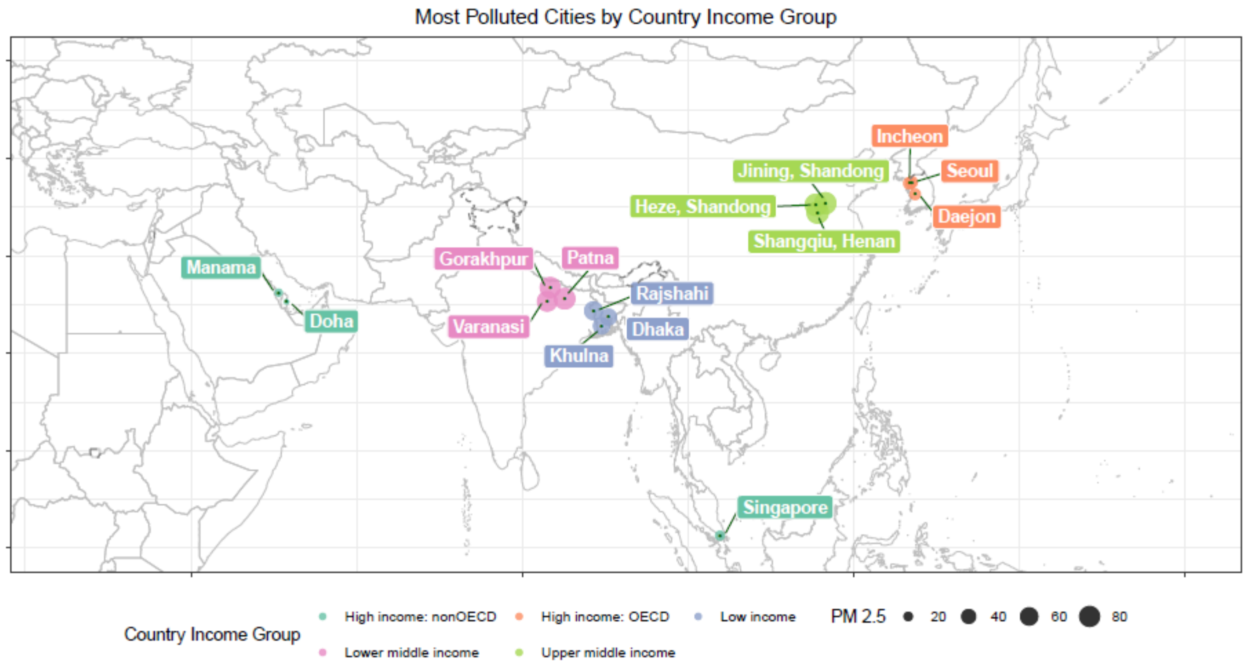
A first look back at the top 20 most polluted cities shows an interesting fact: all of these 20 cities are also growing faster than their corresponding nations - China and India (Table 2). Between 2006 and 2015, China grew at an annual average rate of 9%, while India grew at a 5.7% rate. Despite these high growth rates, the 20 cities were able to outperform their nations while experiencing the highest levels of air pollution. For example, during this period, the average growth rate for half of the Chinese cities was 3 percentage points above China's average growth. While pollution is a by-product of such rapid economic development, the question remains on whether such cities may reach a point where the negative externalities brought by such rapid growth -including air pollution, may outstrip the benefits of growth.

Table 2: Top Twenty Most Polluted Cities, and their performance in terms of GDP, Employment, and Productivity growth, compared to national averages.

City	Country	Region	PM25	City-Nat GDP per capita growth	City-Nat Employment growth	City-Nat GVA growth
Patna	India	SAR	95.8	0.002	-0.016	0.026
Taizhou, Jiangsu	China	EAP	93.8	0.018	0.017	0.000
Heze, Shandong	China	EAP	93.7	0.023	0.027	-0.007
Yangzhou, Jiangsu	China	EAP	93.0	0.015	0.012	0.003
Changzhou, Jiangsu	China	EAP	92.7	0.016	0.011	0.004
Gorakhpur	India	SAR	91.5	0.008	0.016	-0.010
Huaian, Jiangsu	China	EAP	91.0	0.029	0.027	0.002
Jining, Shandong	China	EAP	91.0	0.012	0.016	-0.006
Shangqiu, Henan	China	EAP	91.0	0.026	0.015	0.002
Yancheng, Jiangsu	China	EAP	90.7	0.018	0.020	-0.004
Liaocheng, Shandong	China	EAP	90.5	0.014	0.020	-0.009
Fuyang, Anhui	China	EAP	90.3	0.011	0.016	-0.010
Bozhou, Anhui	China	EAP	89.7	0.011	0.024	-0.016
Nanjing, Jiangsu	China	EAP	89.5	0.013	0.021	-0.008
Wuxi, Jiangsu	China	EAP	89.0	0.011	0.010	0.000
Xuzhou, Jiangsu	China	EAP	88.7	0.017	0.012	0.003
Zhenjiang, Jiangsu	China	EAP	88.3	0.015	0.017	-0.003
Suqian, Jiangsu	China	EAP	87.5	0.025	0.023	0.001
Nantong, Jiangsu	China	EAP	87.0	0.017	0.025	-0.008
Zhoukou, Henan	China	EAP	86.7	0.016	-0.004	0.010

We now look at each country income group and identify the three most polluted cities. Each group is shown in a different color and the size of the dot surrounding the city indicates the level of pollution. The first thing we notice is that all these cities show an annual mean concentration of PM 2.5 that is above what is considered safe by the WHO (10 $\mu g/m^3$), even in developed countries. However, these levels vary widely from one income group to another (see Map 1).

Map 1: The three most polluted cities, by country income group



It is interesting to notice that concentration levels of PM 2.5 can reach different maximums depending on the country income group the city belongs to. As expected, cities in high income countries, both OECD (orange) and non-OECD (dark green) show the lowest levels of pollution. These cities reach a maximum annual average of almost 30 and 21 $\mu g/m^3$ for each group respectively. Even though these levels are still considered unsafe, they are relatively low compared to what cities in upper-middle (light green) and lower-middle (pink) income countries face. These cities have an annual average PM 2.5 concentration that is far beyond safe levels, with maximums around 94 and 85 $\mu g/m^3$ respectively. Most polluted upper-middle income cities are located in China, while those in lower-middle income countries are located in India. These two countries are developing fast, which a priori supports the claim of a positive relationship between high levels of pollution and growth. In low income countries (blue), the three most polluted cities show PM 2.5 levels that range between 51 and almost 64 $\mu g/m^3$, which indicates pollution levels are rising fast for cities that are starting to grow faster.

An Environmental Kuznets Curve at the City Level

In thinking about how pollution levels correlate with development, we go back and look at the relationship between pollution and growth known as the Environmental Kuznets Curve (EKC). This concept was first introduced by Grossman and Krueger (1991) although the name was coined by Panayotou (1993) due to its resemblance with the inverted U-shape relationship between per capita income and income inequality found by Kuznets (1955). Grossman and Krueger (1991) find that concentration of sulfur dioxide and dark matter increases with GDP growth for low income countries and decreases with GDP growth for higher income countries. They focus on the effects that trade liberalization could have on the environment and use a cross-section of urban area pollution and country per capita GDP. Shafik and Bandyopadhyay (1992) find similar results while focusing on the decision nations make to offset the negative environmental effects associated with growth and how that decision may be affected by the lack of incentives (for example, when the burden of pollution is experienced by the poor or by other nations).

Since then, many studies have focused on this empirical phenomenon, looking at different measures of pollution and their relationship with growth. Stern (2004) and Dinda (2004) review some of these studies focusing on the theoretical and empirical approach. They find that despite the fact that many studies look at different pollutants, they all emphasize that the environment deteriorates with economic growth until a certain point beyond which the effect changes and the environmental quality starts improving. However, they do not agree on the level of per capita GDP at which pollution starts declining, partly because some studies look at emissions and others look at concentration levels. The turning point ranges from approximately $3,000 up to almost $23,000 per capita GDP (see Stern, 2004 for a list of these studies and the corresponding turning points).

More recently, studies have also tested the existence of an EKC for particular regions[10] or within particular countries.[11] However, although most studies have used urban pollution measures, they usually use national or regional per capita GDP to measure growth. The poor availability of city-level GDP data had resulted in only a few studies that look at the EKC at the city level. [12] Global city-level per capita GDP data allow us to start exploring if there is evidence of an EKC at the city level and try filling this gap in the literature.[13]

We test if the EKC found at the country level also holds at the city level. Following the standard approach, we regress a measure of pollution, in our case, the city annual mean concentration level of PM 2.5, against the natural logarithm of the per capita city GDP. Since we have a panel data set, between 2006 and 2015, we include fixed effects by year to account for unobserved time shocks. We use a cubic specification (as

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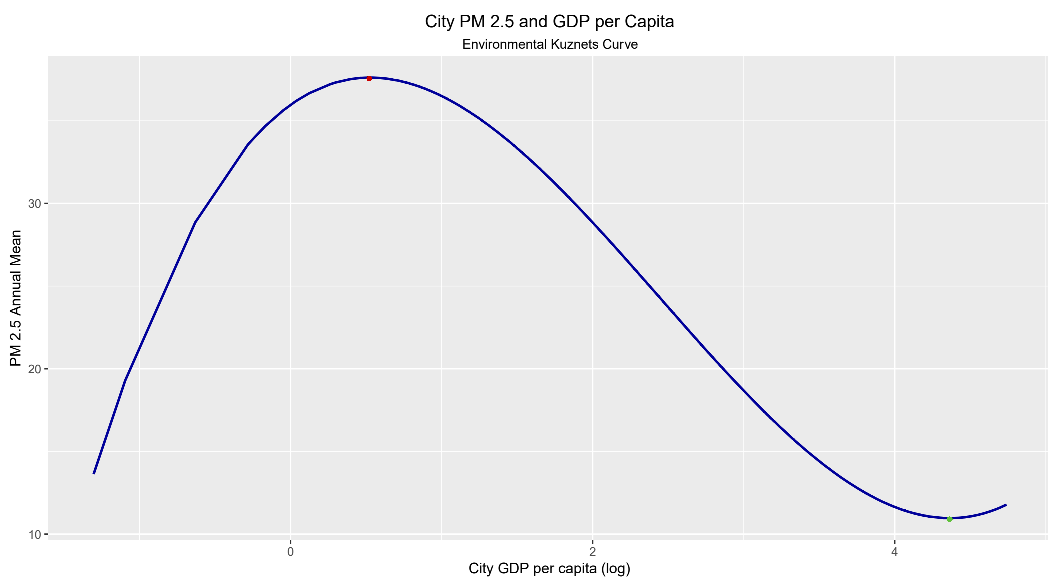
[10] For example, some studies have focused on Asian countries (Apergis & Ozturk, 2015) or OECD countries (Jebli, Youssef, & Ozturk, 2016).
[11] For example, China (Hu, Hernandez del Valle, & Martinez-Garcia, 2017), Vietnam (Al-Mulali, Saboori, & Ozturk, 2015), Cambodia (Ozturk & Al-Mulali, 2015).
[12] Some studies have used pollution and city-level GDP data for Chinese cities. See for example Brajer et al. (2011).
[13] Our goal with this approach is to contribute to the discussion on the relationship between pollution and development at the city level and quickly test the existence of an EKC. We do not intend to thoroughly analyze this topic.

in Grossman and Krueger, 1991).[14] The comparison between per capita city GDP and the city annual mean concentration of PM 2.5 results in an inverted U shape curve.

We find evidence of an Environmental Kuznets Curve at the city level, for our sample of 769 cities. Figure 3 shows a cubic relationship: a positive slope at lower levels of per capita GDP, a maximum point (red dot) beyond which the slope turns negative, and a minimum point (green dot) at the end where the curve starts turning positive again. This incipient positive change at the end of the curve may indicate a certain point of development where pollution levels will start to rise again. However, since the sample of cities beyond that point is relatively small (17 cities), this result cannot be viewed as strong evidence of a positive relationship beyond that point.[15]

Figure 3: Environmental Kuznets Curve at the City Level



Cities with low per capita GDP (first section of the curve, with a positive slope) are in the first phase of development, and pollution starts to rise as a consequence of growth. These growing economies are often transitioning from agriculture activities to more industrialized and (often) “dirty” sectors. As a natural consequence of this structural change in their economies these cities see their pollution levels raise. On the contrary, cities on the second section of the curve (negative slope), and particularly those at the end,

[14] We use cubic splines to allow for a more flexible estimation (Friedman, 1991; Durrleman & Simon, 1989).
[15] This is also evident when looking at the regression results: the coefficient for the cubic term is not statistically significantly different from zero.

are usually transitioning to the service sectors, regulating dirty industries or improving technologies and consequently reducing pollution levels.

When looking at the subset of cities in the first phase of development, some interesting examples arise. The first thing we notice is that all these cities are market towns and they are located primarily in Sub-Saharan Africa and South Asia regions. For example, we find cities like Kigali (Rwanda), Bujumbura (Burundi), Kabul (Afghanistan), and Lilongwe (Malawi). Their economies focus on agriculture and incipient industrial activities. Second, we find that all these cities are also in the list of cities that we identify as the top 10 most competitive (Table 1). Bujumbura, Kabul, and Lilongwe are outperforming their nation in terms of employment growth, while Kigali is a competitive city in terms of both, employment and per capita GDP growth. They are on the verge of development, growing fast and starting to face the negative externalities associated with growth. Third, none of these cities is in the list of top competitive cities in terms of productivity. This comes as no surprise, considering that most of the cities that do well in this area are often located in more developed nations. However, some of the cities in this phase are still performing well in terms of productivity. For example, Kigali's average productivity growth is above Rwanda's average productivity growth by 1%.

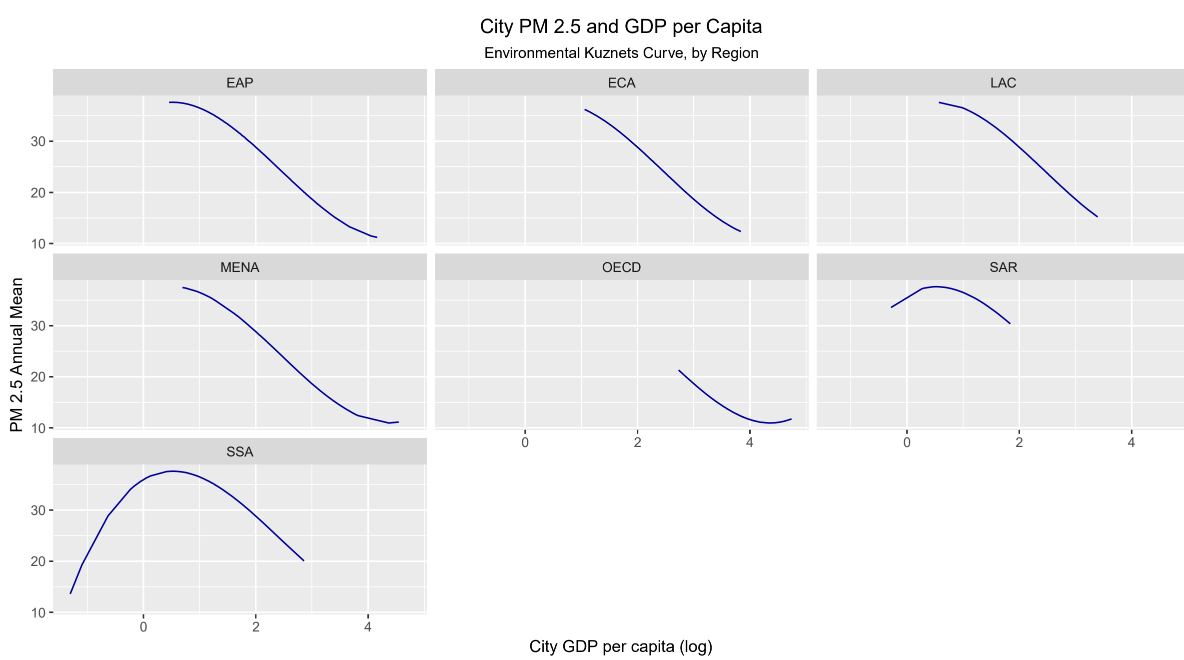
The turning point of this predicted relationship between pollution and growth comes at $1,693.[16] We define an arbitrary interval of +/- $100 around the turning point and look at the cities that fall in this interval. We find that most of these cities are located in South Asia. Some examples include Chittagong and Khulna (Bangladesh) and Patna and Bokaro (India). They are mostly industrial cities, focusing on a variety of light and heavy industries. Although none of these cities is included in our list of top 10 competitive cities (Table 1) some still show good performance. For example, during this 10-year period, Patna and Bokaro show an annual average GDP growth that is between 2 and 3 percentage points above India's average GDP growth. Furthermore, most of these cities are outperforming their nation in terms of employment growth.

[16] This is a relatively low level of per capita GDP compared to what other studies have found. For example, Grossman and Krueger (1991) find that the turning point comes at $4,119, while Panayotou (1993) finds a turning point of $3,137. However, most of these studies focus on emissions or concentrations of sulfur dioxide. Stern and van Dijk (2016) use PM 2.5 concentration levels and per capita national GDP and still find a relatively high turning point of $3,336. However, the fact that these turning points are higher than our findings is not surprising. Harbaugh et al. (2002) find that the location of the turning point is sensitive to not only the specific pollutant but also the sample used and the specification of the model.

Beyond the estimated per capita GDP turning point, PM 2.5 concentration levels start to fall as per capita GDP increases. This shows that even though pollution arises as a consequence of growth, cities that continue to develop above a certain threshold learn to manage its effects and are able to reduce pollution levels while still growing. However, the willingness to address these issues may depend on which population group (or country) faces the major burden of the negative externality (Shafik and Bandyopadhyay, 1992). In this section of the EKC we find a variety of cities at different stages of development, with no clear pattern regarding geographical location. However, as we approach the minimum turning point, most of the cities, as expected, are located in OECD countries.

The fact that different sections of the EKC can sometimes be associated with a particular region is shown in Figure 4. The only region that contributes to the first section of the curve (positive slope) is Sub-Saharan Africa. As discussed before, cities in this region are experiencing rapid growth and increasing pollution levels. Cities at the top of the curve are located in South Asia and Sub-Saharan Africa, with some cities beyond the turning point, experiencing lower levels of PM 2.5. The negative slope section of the EKC includes a mix of cities from almost every region: East Asia Pacific and Middle Eastern and North Africa extend throughout all this section, while Latin America, Europe and Central Asia concentrate on the middle part. As mentioned before, cities in OECD countries are at the bottom of the curve, highly developed with the lowest pollution levels.

Figure 4: Regional Environmental Kuznets Curve



These findings motivate a deeper analysis to try to characterize different city typologies. Can we find a pattern between competitiveness and pollution?

The relationship between pollution and city competitiveness

After this first look at the correlation between pollution and development, we move forward to outlining a typology of cities with respect to their competitiveness and pollution levels. For that, we use a two-dimensional mapping of the two indicators. Recalling from our previous definition of competitiveness, we measure city's performance with three measures: GDP per capita growth, employment growth, and productivity growth. Because cities often do not perform well in all three measures, it is worth analyzing each of them and the interaction with PM2.5. We focus on four different groups for the four possible combinations between city performance and pollution levels, identifying cities with:

1. High levels of PM2.5 and high performance
2. High levels of PM2.5 and low performance
3. Low levels of PM2.5 and high performance
4. Low levels of PM2.5 and low performance

The first group identifies cities with high concentration of PM 2.5 and that are outperforming their nation. This group of cities is interesting because it shows examples of cities that were able to grow even while experiencing the negative effects of high pollution levels. It also points out examples of cities that need to address the problems of high pollution in order to keep up with their growth rate and remain competitive.

The second group highlights cities that are experiencing high levels of pollution but are performing below their national average. These cities face both challenges: how to manage pollution and how to become more competitive. It could be the case that these cities are not performing as good as they could because of the high air pollution levels. They may still be growing and generating jobs, but the increasing pollution that comes as a consequence of this growth is hindering the potential of the city.

The third and fourth groups of cities are not the main focus in this study, but important lessons can be derived from their experience. They are doing well in terms of pollution, maintaining annual average levels below what is considered healthy for the WHO. In terms of competitiveness, some are performing better than their nation, and some are performing below average. The ones that are preforming above average can provide good examples to follow on how to manage air pollution and still be able to thrive. These cities can help focus the discussion on which are the best practice cities to learn how they successfully overcame this issue. The rest of the cities are probably on the verge of development, with an opportunity to address the problem of pollution and competitiveness before it starts. Lessons from competitive cities should help them tailor a path that allows for sustainable growth.

In what follows, we look at the three different indicators for city competitiveness to aim at building such typology. Figures 5 through 7 show the abovementioned typologies in four quadrants. The x axis shows PM 2.5 annual mean for the year 2015, and the y axis shows the yearly average of the corresponding variable, for the period 2006-2015. We choose to look at the annual GDP average for the whole period to avoid the bias that can come when analyzing city performance for one specific year. Because pollution levels are a byproduct of growth, we associate the GDP annual average with the pollution measure for the last year. By doing this, we avoid using a lower level of pollution that will result from a 10-year average and better reflects the current pollution state.

In these figures, each dot is a city, colored by region: East Asia Pacific in dark green, East Europe and Central Asia in yellow, Latin America in purple, Middle Eastern and North Africa in red, OECD in blue, South Asia in orange, and Sub-Saharan Africa in light green. The vertical line labeled WHO Guideline separates cities with PM 2.5 levels above and below what is considered safe by the WHO (annual mean of 10 $\mu g/m^3$). Examples of cities with high levels of pollution and that are outperforming their nations are located on the first quadrant, and cities with high pollution and performing poorly are on the fourth quadrant. The second and third quadrants show all cities with lower pollution levels, that are performing above and below their national average, respectively.

The first quadrant of Figure 5 shows cities with high levels of PM2.5 that are outperforming their nation in terms of GDP. Moreover, we also find the most polluted cities of our sample in this group (cities with PM 2.5 concentration levels above 87 $\mu g/m^3$). Most of these cities are located in East Asia Pacific (mainly in China), with a few examples from South Asia, mostly in India (Patna and Gorakhpur). Other less polluted (although still above the recommended WHO guidelines) and competitive cities are located in South Asia and Africa. Quadrant IV shows that cities that are struggling with high levels of pollution but growing below their national average are also located in East Asia Pacific and South Asia.

Figure 5: Pollution and City Competitiveness in terms of per capita GDP Growth

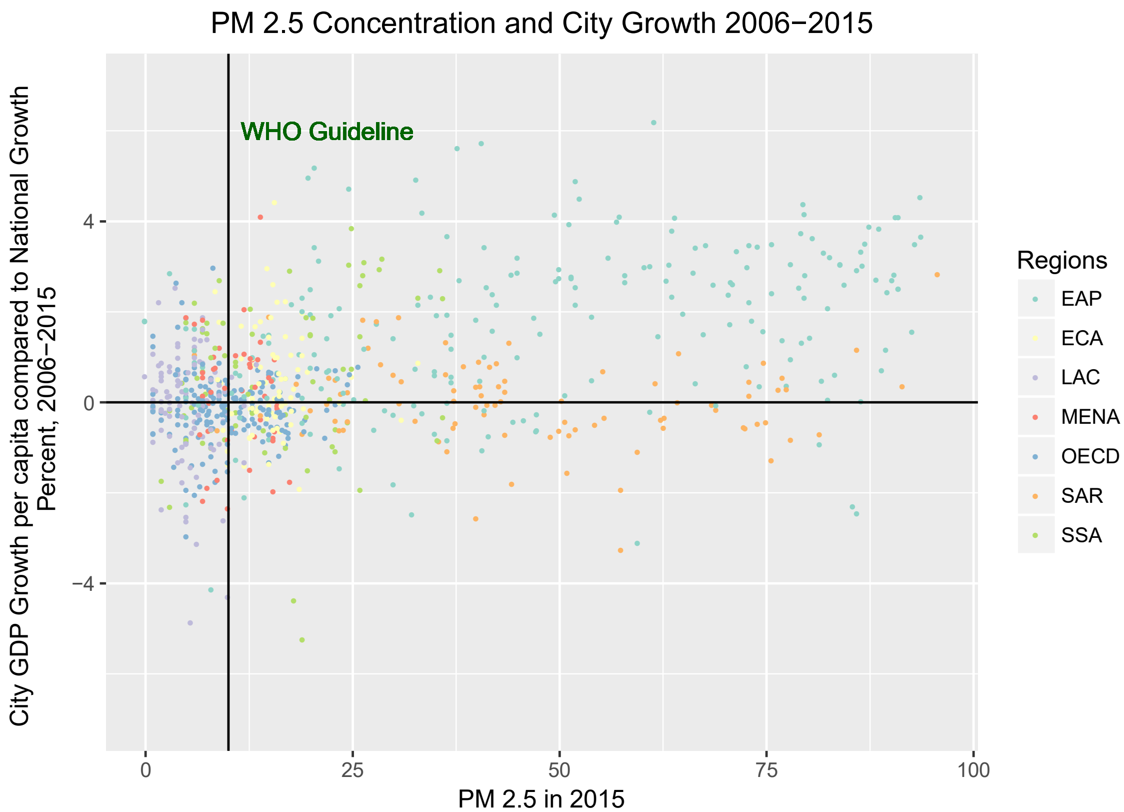


Figure 6: Pollution and City Competitiveness in terms of Employment Growth

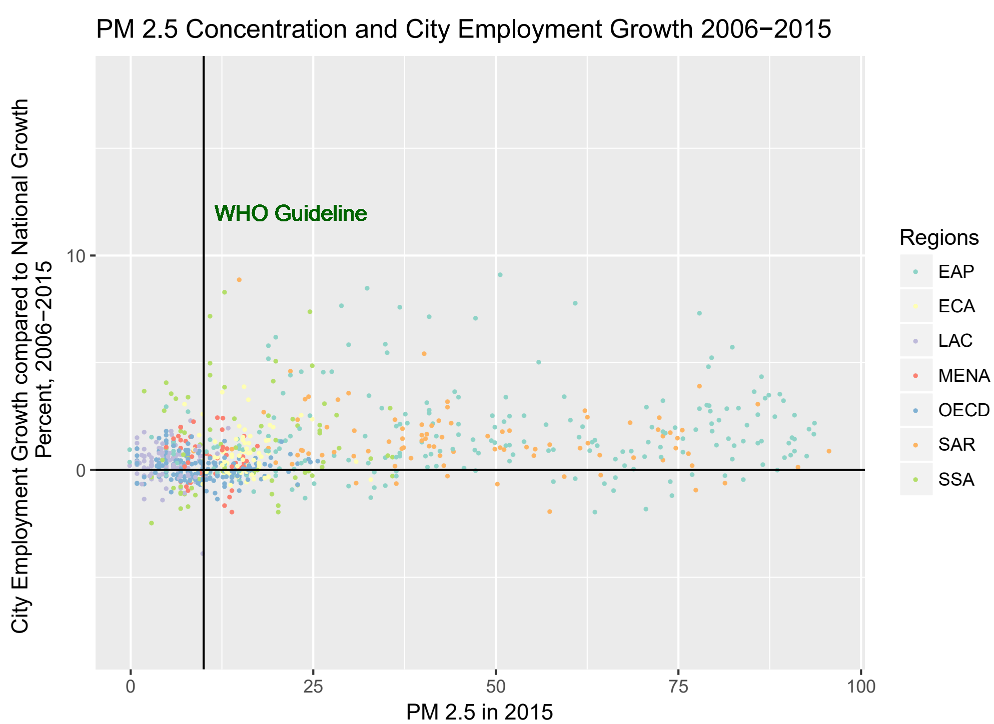
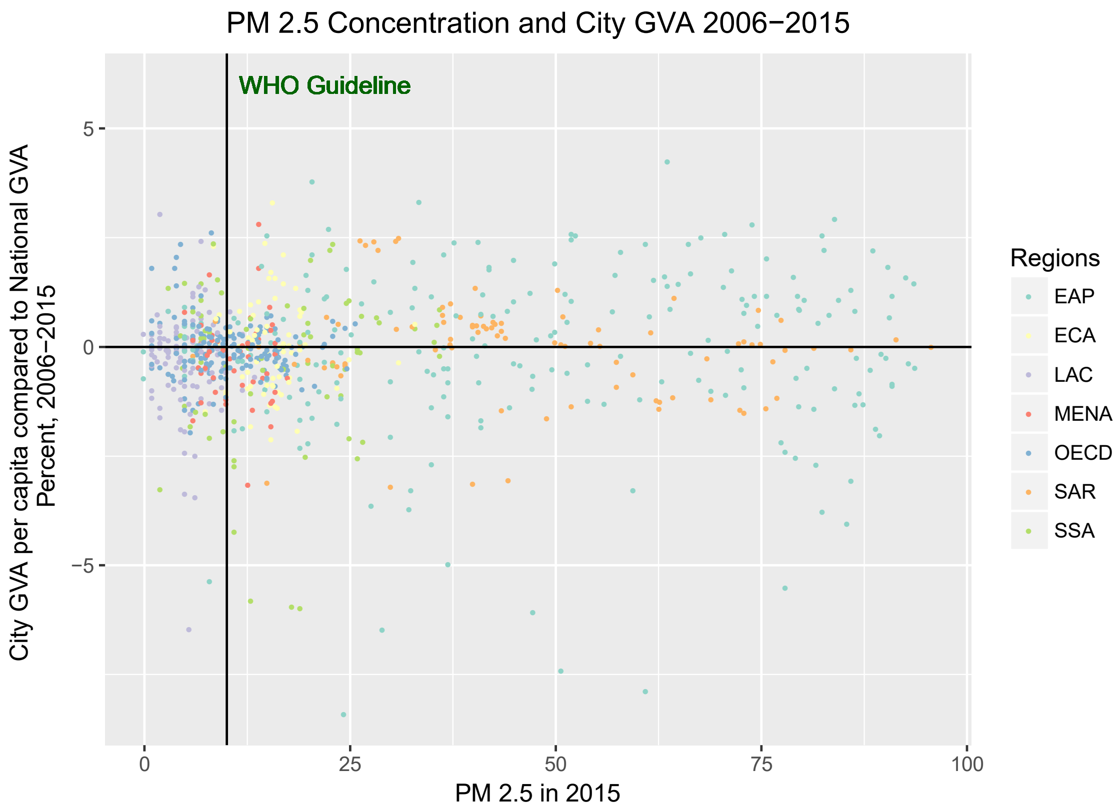


Figure 7: Pollution and City Competitiveness in terms of Productivity Growth



We find similar results when looking at employment growth and GVA growth. Most of the cities performing above the national average and experiencing high levels of pollution are located in East Asia Pacific and South Asia. However, when looking at performance in terms of GVA we see a slight distinction between East Asia Pacific and South Asian cities. Approximately half of the cities in East Asia are increasing their productivity well above their nation. Productivity is often easier to improve in upper-middle or high-income countries such as China or the Republic of Korea. However, cities in South Asia belong to the low or lower-middle country income group. Most of these cities struggle to make improvements in productivity, performing slightly above or below the national average, with the exception of a small group of six Indian cities which GVA is growing around 2.3 percentage points above the national average (Chennai, Madurai, Tiruchirappalli, Salem, Coimbatore, Tiruppur).

These figures show that there are certain patterns between pollution and city location. As previously discussed, this is likely a consequence of the average level of development each region experiences, and how pollution is associated with development, rather than a consequence of geographical location. However, when looking at the relationship between pollution and city competitiveness, the pattern is less evident. We find competitive cities at all levels of pollution, from below WHO guidelines to the highest PM 2.5 concentration levels. This shows that cities can achieve competitiveness without degrading the environment, and the questions that seem to follow are: how are these “cleaner” competitive cities facing this challenge? What are they doing differently? Although these questions motivate further analysis at different levels (for instance, a deeper look at examples of best practices), our first step is to focus on a group of low income and fast-growing cities.

A brief look into South Asian and African Cities

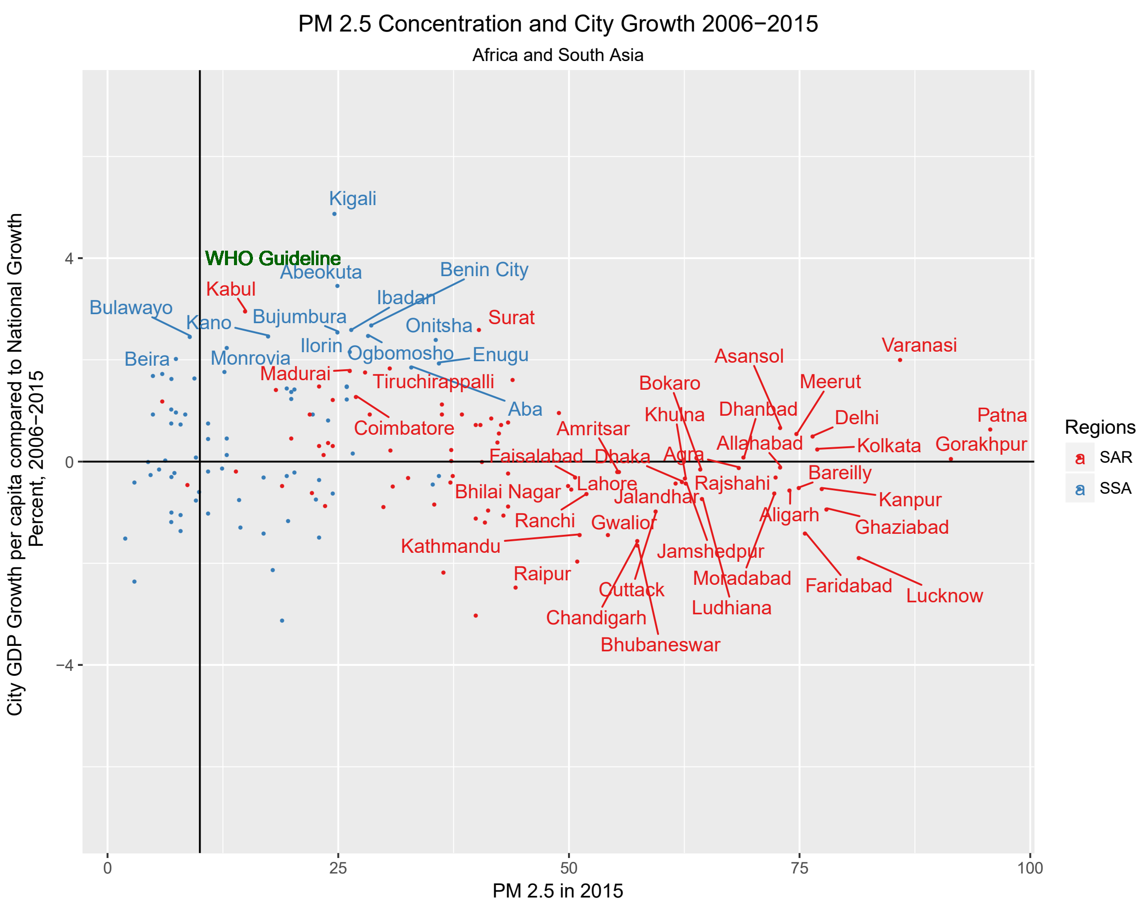
Although most of the examples of competitive cities that are also successfully managing pollution are in richer countries (such as Vancouver, in Canada), it is useful to find some cases in the developing world. As mentioned earlier, developing countries often face particular challenges and may need to follow different strategies than what developed nations do.

We now move the discussion to focus on cities located in South Asia and Africa. We choose to focus on this area for two reasons. First, these regions, particularly South Asia, include cities with pollution levels among the highest ones. Second, as previously discussed, most of the cities in these regions are in the phase where they experience a positive relationship between pollution and per capita GDP (EKC analysis). Many of them are starting to face the pollution challenges associated with rapid growth. This exercise aims to identify two types of cities: those that are good at managing pollution that could be held as examples of best practices in the developing world, and those that are struggling with this challenge and may use successful stories of pollution management. After a first characterization, the analysis of the second group of cities may require further research and deep dives studies could help to accomplish this.

Figures 8 through 10 show the relationship between pollution and city competitiveness for cities located South Asia and Africa. We use the same four typologies of cities described before and focus on examples of competitive cities at different stages of pollution management. We find two examples of competitive cities that show considerably low levels of pollution -Kigali (Rwanda) and Coimbatore (India)- and two examples of competitive cities that are struggling with high pollution levels -Patna (India) and Dhaka (Bangladesh).

Kigali, the capital of Rwanda, is a good example of a competitive city experiencing lower pollution levels compared to similar cities. With a population of approximately 1.2 million and a GDP per capita of $1,518 (in 2015), Kigali falls in the Market Town category, specializing in non-tradable services and some tourism. During the ten-year period between 2006 and 2015, Kigali has outperformed Rwanda’s national averages by almost 5 percentage points in terms of GDP per capita growth, and 7.5 percentage points in terms of employment growth. Devastated by years of violent conflict (ending in the 1994 genocide) Kigali had made strong efforts to rebuild itself, implement business reforms oriented to the private sector needs and improve human capital levels (Kulenovic and Cech, 2015). The city has also recognized the importance of managing pollution and recently conducted a study to learn more about the main sources of air pollution affecting the city. They find that the leading causes of air pollution are vehicle emissions in the city area and cooking in residential areas. In response, the government has passed new emissions regulations (January 2015), installed air quality monitoring stations, and conducted several campaigns to promote clean cooking.[17]

Figure 8: Pollution and City Competitiveness in terms of per capita GDP Growth – South Asia and Sub-Saharan Africa

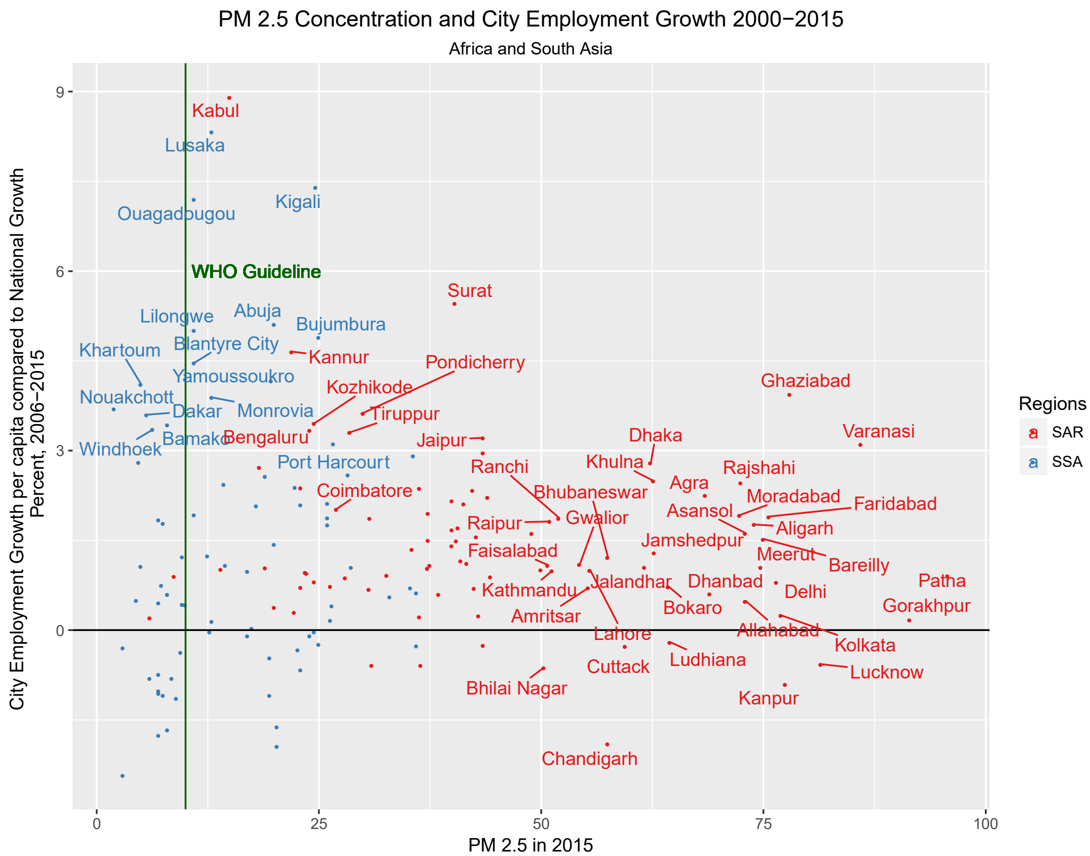


[17] The Rwanda Environment Management Authority (REMA) coordinates and regulates environmental management in Rwanda, focused on achieving the National Development Vision 2020 (www.rema.gov.rw).

Coimbatore is another interesting example of a successful city. It falls in the category of a Production Centers, with a population of 2.3 million and a GDP per capita of $4,132 (2015). Coimbatore is a fast-growing city and a major industrial hub, known for its mechanical engineering sector. The city has outperformed India in GDP per capita, employment growth, and productivity (1.3, 2, and 1.4 percentage points above the national average, respectively). To achieve its success, the city had the private sector to step up and promote the city as a thriving investment opportunity, with a highly educated workforce, leveraging the city's skill set and reinforcing its advantage on human capital (Kulenovic and Cech, 2015). On the pollution side, vehicular and industrial activities are the main contributors to air pollution. As part of their pollution management strategy, Coimbatore participates in The Smart Cities Mission, an initiative of the Indian Ministry of Housing and Urban Affairs. In this context, the city has successfully implemented three projects on the last three years and is on the verge of implementing 5 more projects during 2018 (such as bike sharing and developing green spaces in the city).[18] The annual average PM 2.5 concentration level in 2015 was 27 $\mu g/m^3$ (still above what is considered safe by the WHO), and the city keeps making efforts to reduce those levels. For example, there are proposals to plant specific types of trees that can help absorb certain pollutants.[19]

[18] Published in India Times, https://timesofindia.indiatimes.com/city/coimbatore/coimbatore-in-top-10-amongst-best-performing-smart-cities/articleshow/62575654.cms, accessed on May 2, 2018.
[19] Published in India Times, https://timesofindia.indiatimes.com/city/coimbatore/these-pollution-eating-trees-can-cleanse-citys-air/articleshow/62515148.cms, accessed on May 2, 2018.

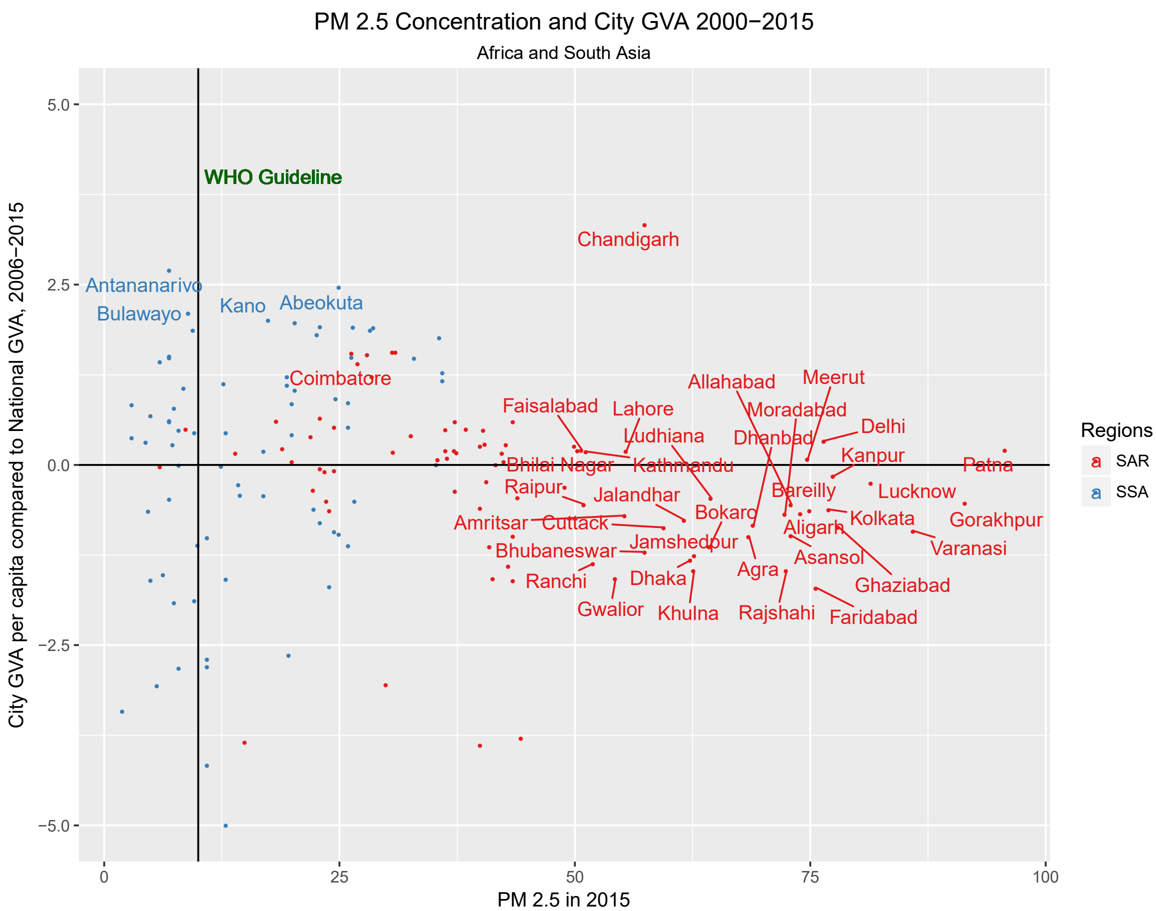
Figure9: Pollution and City Competitiveness in terms of Employment Growth – South Asia and Sub-Saharan



Looking back into cities with higher levels of pollution, we can also find examples of competitive cities. These cities are developing fast and generating jobs, but they are failing at managing pollution levels. As a consequence, the quality of life in these cities is decreasing, and they may be failing to attract cleaner firms and qualified workers that can boost development. In turn, this could lower the city's growth, and threaten its competitiveness.

Patna is a good example of a competitive city that may not be taking the necessary actions to tackle air pollution. With an annual average PM 2.5 level of 95.5 $\mu g/m^3$ in 2015, Patna is the city with the highest annual average concentration of PM 2.5 in our sample. Besides issuing health warnings on critical days, the government has no long-term plan to handle this problem. Recently, a voluntary organization (The Center for Environment and Energy Development) has urged the government to develop a clean air action plan. However, there is no action plan in place yet, only a set of recommendations to follow on particularly high polluted days.[20] In spite of that, the city has been outperforming the average GDP per capita growth of India and has managed to climb up the ladder from a low income to a lower-middle income city. Despite this high performance, during 2015, Patna experienced a considerably lower rate of employment growth (from above 7% in between 2012 and 2014, to 0.16% in 2015)[21] while the population growth rate is still high. Pollution may be one of the factors affecting this low employment rate, for example, the city may be failing to attract new firms that could generate more jobs.

Figure 10 Pollution and City Competitiveness in terms of Productivity Growth – South Asia and Sub-Saharan Africa



Dhaka is also struggling with high levels of air pollution, although levels are lower than what we can find in Patna for example. The Clean Air and Sustainable Environmental Project had certainly helped managing

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[20] Published in India Times, https://timesofindia.indiatimes.com/city/patna/patna-air-pollution-worse-than-that-of-delhi/articleshow/61664183.cms, accessed on May 4, 2018.

[21] It is worth noting that, during 2015, productivity had increased approximately 2.5%. However, a similar rate was observed in 2009, although employment was growing at 5.5% at that time.

pollution and keep it from rising to more dangerous levels.[22] However, according to the Department of Environment (Air quality Management), air quality has deteriorated since October 2017 due to an increase in production of brick kilns during winter months.[23] Pollution is an ongoing problem and is threaten the city's development rate. Even though Dhaka is outperforming Bangladesh in terms of employment, GDP per capita growth fell between 2006 and 2015, showing that the city is not growing fast enough to accommodate the growing population.

These examples show different types of cities and their struggles and success with pollution and competitiveness. Clearly, the outcome does not depend on the type of city or its economic structure. We find capital cities with a successful story or dealing with pollution and competitive challenges, like Kigali and Dhaka. We also find good examples of pollution management for Market Towns (Kigali), Production Centers (Coimbatore), or Creative and Financial Services (Vancouver). This shows that every city has the potential for developing an agenda that focuses on sustainable growth. The government's willingness to engage on these new challenges plays a decisive role in successfully addressing the natural consequences development brings.

Conclusions

Competitive cities grow fast, create jobs and improve living conditions for their citizens. They are able to attract foreign direct investment and provide a good environment where firms and people can get together, trade and interact. In this paper, we focus on three variables that help us identify these cities, toward understanding what makes a city outperform its nation and the challenges it may face.

Among all the challenges a growing city faces, from managing pollution and congestion, to providing its citizens with better amenities and a good quality of life, we chose to focus on air pollution. After identifying which cities are the most polluted, we analyze the relationship between pollution and competitiveness, to shed some light on how growing cities can overcome increasing pollution levels and avoid this problem that jeopardizes their competitiveness.

Air pollution is a natural consequence of growth and we find that cities experience different levels of air pollution depending on their path of development. We observed that the Environmental Kuznets Curve

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[22] This project (April 2009-June 2014) was funded by the World Bank and focused on improving traffic conditions in the city of Dhaka (including mass transportation options) and the technology on the brick industry.

[23] Published in The Dhaka Tribune, https://www.dhakatribune.com/bangladesh/environment/2018/01/30/us-aqi-dhaka-worst-air/, accessed on May 4, 2018.

also holds at the city level. Cities in their earlier steps of development experience increasing levels of pollution until they reach a turning point: a per capita GDP of $1,693. Beyond this point, pollution levels decrease. This relationship between pollution and per capita GDP also helps us identify specific cities' characteristics. For example, cities on the first section of the curve (positive slope) are market towns, mostly focused in agriculture and incipient industrial activities. Cities on the second section of the curve (negative slope) and some of the cities at the top of the curve are mainly productive centers, while cities in OECD countries, mostly focused on service sectors, are just before the minimum point of the EKC.

We also categorize cities in four types: high pollution and high competitiveness, high pollution and low competitiveness, low pollution and high competitiveness, and low pollution and low competitiveness. We do this exercise for the three different variables we identify as good measures of competitiveness: GDP per capita growth, employment growth, and productivity growth. We find that competitive cities with high levels of pollution are mainly located in Asia, particularly in China and India. African cities follow, with pollution levels still above what is considered safe by the WHO and a mix between cities that are growing fast and others not performing so well. Interestingly, Latin American cities still show, on average, pollution levels that are below the WHO threshold.

We pay special attention to cities located in developing countries, because congestion challenges are more difficult to tackle in these regions. Cities in developing countries lack the ability to adjust fast, mainly because efficient institutions and the proper channels are often not in place. At the same time, their growth and industrialization happen fast, giving them even less time to react. We find good examples of successful cities, like Kigali and Coimbatore, that were able to manage pollution while remaining competitive.

In this work, no strong patterns are identified between competitiveness and pollution, confirming that there are many pathways to increase a city's competitiveness. While a clear pattern arises between pollution and development, competitive cities can be found facing all different levels of pollution. However, other work looking at the costs of pollution has suggested that even if a city can increase its competitiveness at the cost of environmental quality, the costs of degradation of the environment can be high. For example, Bolt et al. (2001) estimate that in India and China, the annual losses from air pollution range between 2 and 3 percent of the GDP.

This study is a first step in characterizing the relationship between pollution and city competitiveness, but it is far from providing final answers. Future research should focus on the causal relationship between these two variables. Further work is needed to understand the channels through which pollution may have an impact on competitiveness, understand what policies at the city level can help curb pollution while fostering competitiveness, and identify successful examples of cities that have managed to achieve the two objectives in tandem. Interesting questions arise, but a deeper analysis is needed in order to answer them rigorously.

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