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The Effects of Pollution and Business Environment on Firm Productivity in Africa¹

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Abstract: In this paper, we explore the links between city competitiveness and air pollution and business environment. Because competitive cities not only attract more productive firms but also facilitate their business, we choose to look at firm performance as a proxy for city competitiveness. We particularly focus on African firms because this region is developing fast, experiencing increasing pollution levels and the effects of agglomeration economies. We find two interesting results. First, the negative association between air pollution and firm performance can be seen at lower than expected levels of pollution. Second, the effects of capacity agglomeration on labor productivity growth are stronger compared to other regions. These findings suggest that cities in this region should address pollution issues soon, as they continue to grow fast and pollution levels becoming an increasing concern.

JEL: Q53, O1, L5, D9

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Introduction

This paper aims to explore how air pollution affects city competitiveness, particularly for African cities. Although different alternatives to measure city competitiveness have been explored in the literature (see for example Porter (1990), Faberberg (1996), Boltho (1996), World Bankl (2016)), we choose to look at firm productivity. Our decision is motivated by two arguments. First, firms that are more productive, tend to locate in an environment where they can maximize profits. To achieve this, they seek to hire the best, most productive workers as well as to have access to high quality infrastructure, amenities and services (Gottlieb, 1994; Frenkel, 2001). More productive firms will then tend to cluster in cities that provide such workers and offer a bundle of high-quality services. Second, Cities that offer a good quality of life will be better positioned to attract firms and qualified workers. Since good quality of life and the standard of living is determined by the productivity of an economy, then productivity defines competitiveness (Porter, 2000, p.19). Porter's argument stresses that cities cannot become more productive and competitive unless firms become more productive. High city GDP, employment, and productivity (the three measures of competitive highlighted by the World Bank Report, 2016) are actually a consequence of how well firms perform. This close relationship between city performance and firm performance provides the foundation for our focus on firm productivity as a good proxy for assessing and measuring a city's competitiveness.

Between 2000 and today, African economies have strengthened their position in the global economy, showing average growth rates of 5.9 between 2000 and 2008 (World Economic Forum 2009), and 5.2 in the last 10 years.² Furthermore, not only per capita GDP is growing, but also total factor productivity shows an average positive growth rates of just above 1% for the first time since the 1970s (Rodrik 2016).³ At the same time, air pollution has climbed to dangerous levels, increasing annual deaths by 36 percent between 1990 and 2013 (Roy 2016).⁴ While some

² Based on national GDP growth from Oxford Economics Dataset.

³ Even though there is some heterogeneity across the continent, the growth in total factor productivity ranges between 0.5% for the East Region and 2% for the Southern Region (with the exception of the North Region that shows a negative total factor productivity growth rate of -0.5%).

⁴ As mentioned in Roy (2016), "...the information gaps in regard to air pollution in Africa, resulting from the absence of regulation and the regular monitoring that it entails, are significantly larger than is the case elsewhere (see inter alia Knippertz et al., 2015 and Evans, 2015). Thus, there are no emissions inventories for African cities...". Moreover,

literature exists on the determinants of firm productivity for some African countries, to the best of our knowledge there is not comprehensive study that compares such determinants across regions, and none that links productivity at the firm level with air pollution measures for a sample of firms that spans all continents and regions. What are the key determinants of firm productivity in Africa and how do they compare to the rest of the world? Are there any links between firm productivity and air pollution?

To shed light on these questions, we choose to focus on exploring the links between two sets of variables that may affect firm productivity: a group of business environment characteristics and air pollution. Business environment has been identified as one of the key factors that contribute to development (Stern 2002, World Bank 2005, World Bank 2010). It provides the framework where firms interact, trade, and compete. It includes not only the basic legal structure, but also other city characteristics that can affect firms' performance, such as human capital or agglomeration economies.⁵ The same firm in a different environment will probably experience different challenges that can affect its productivity levels and outcomes.

Air pollution has also been considered an important factor affecting workers and firms through two main channels. On the one hand, pollution levels can affect workers' health and productivity. Recent studies on the effects of air pollution on worker productivity have quantified the negative effects on different production sectors (Graff-Zivin and Neidell 2012, T. Chang, J. S. Graff-Zivin, et al. 2014, T. Chang, J. Graff-Zivin, et al. 2016, Adhvaryu, Kala and Nyshadham 2014). On the other hand, environmental regulations can impact firms' costs and influence their location. For example, studies such as Henderson (1974) and Kahn and Mansur, (2013) have shown that manufacturing firms cluster in areas where environmental regulations are not too strict. In developing countries, cities often limit such regulations, offering "pollution havens" that can attract major factories and contribute to development (Birdsall and Wheeler 1993, Cole

natural processes such as Saharan dust storms usually exacerbate pollution effect. Hence, a certain level of emissions in Africa could have a greater effect compared to the same level of emissions in other areas.

⁵ There are many studies on the effects of agglomeration economies on long-term growth. See for example Glaeser and Gottlieb (2009); Jones and Romer (2010); Clarke, Li and Xu (2016); Li, Long and Xu (2017)).

2004, Eskeland and Harrison 2003), while exacerbating the negative consequences on the environment.⁶

We build upon related work by Harrison, Lin and Xu (2014), and Reyes, Robert and Xu (2017). Harrison et al. (2014), use the World Bank Enterprise Survey data to provide evidence that key factors for improving African firm performance are political competition, infrastructure, and access to finance. Reyes et al. (2017) offered a more comprehensive list of the business environment factors and add measures of BE elements such as taxes, labor regulation, entry and exit, along with the agglomeration environment. They conduct a global analysis while controlling for country fixed effects, offering better control of country heterogeneity. They also explore how the effects of BE variables are different depending on firms' characteristics (such as age, size) and country level of development.

The literature on the effects of pollution in Africa is less developed. Although the topic has gained attention in recent years, the scarcity of pollution data for the region had limited long-term analysis (Petkova et al., 2013).⁷ However, some recent examples that look at air pollution in Africa exist. Roy (2016) focuses on the health effects of air pollution and some economic costs, emphasizing the simultaneous challenges the continent faces: economic development and pollution control. Kirchberger (2016) looks at the spatial links between pollution (and other disamenities) and living standards in Sub-Saharan Africa, while Bishop (2017) develops a broader approach by concentrating not only on pollution but also on the health and economic effects of climate change in general. However, to the best of our knowledge, there is no study that focuses on the links between pollution and productivity in Africa.

The contribution of our paper is twofold. First, it extends the literature, particularly Reyes et al. (2017) work, to focus on Africa, looking at how Business Environment (BE) variables affect firm productivity. We follow the same approach by allowing the BE factors to affect firm growth different for African firms than for those in the rest of the world, and then offer quantitative assessment of key factors for improving African firm growth. We offer diagnoses of hindering BE

⁶ For a more recent list of references, see Kahn et al. (2017). The authors provide a survey of the literature focusing on the effects of pollution on productivity and human capital formation, as well as on how environmental regulations affect firm location and performance, particularly in developing countries.

⁷ Petkova et al. (2013) provide an overview of available studies.

factors for firm performance in Africa with a focus on issues related to agglomeration (or urban factors). Second, it contributes to the pollution literature by focusing on air pollution as another possible determinant of firm productivity and exploring whether its relationship with African firm performance is different, compared to the rest of the world. Although the link between pollution and productivity is well established (see Kahn et al. (2017) for a survey on this topic), this paper focuses on Africa and how air pollution is correlated to worker and firm productivity in that region.

Following Reyes et. al (2017), we use the World Bank Enterprise Survey dataset. We distinguish three different classifications for business environment (BE): Basic BE, Refined BE, and Agglomeration Environment. Basic BE is likely essential for facilitating firm growth. It consists of Basic Protection (corruption, basic property rights protection, and basic physical safety), infrastructure (power supply and modern telecom), human capital, and access to finance (such as bank finance and trade credit). Refined BE covers other BE elements that have been frequently mentioned in the literature, but perhaps less frequently mentioned than Basic BE. It includes topics such as barriers to entry and exit (such as access to land), labor regulations, tax burdens. The Agglomeration Environment is a new category that has not been emphasized in the literature, but recent papers find important for explaining firm performance across the world (Clarke, Li and Xu 2017). It incorporates whether or not a firm is located in a large city, the extent to which a firm is surrounded by “capable firms”, measured as the share of firms whose number of employees exceeds 50 (capacity agglomeration), and whether the firm competes with firms on the informal sector (informal competition).

When looking at air pollution, we focus on measures of particulate matter. Even though many pollutants contribute to contaminate the air, particulate matter is the one that affects human health the most. In particular, small particles, those with a diameter of 2.5 microns or less, are the most dangerous because they can travel the blood stream and sit into the lungs, producing long lasting health consequences.⁸ We use remote sensing data (van Donkelaar, 2016) and assign pollution measures to each particular firm.

⁸ Deaths attributable to ambient PM2.5 increased from 3.5 million in 1990 to 4.2 million in 2015. Ambient PM2.5 was the fifth-ranking mortality risk factor in 2015 (Cohen, et al. 2017).

Finally, in order to measure firm performance, we use the same two variables as Reyes et al. (2017): employment growth and labor productivity growth. Employment growth corresponds to the one-year employment change, and labor productivity is measured as sales over the number of permanent employees.

Our findings can be summarized in two main points. First, among the business environment variables, capacity agglomeration is the only variable that shows a different effect for African firms. Capacity agglomeration (the share of firms with at least 50 employees) has a stronger positive effect in this region, increasing labor productivity growth. Second, concentration levels of PM 2.5 also have a distinct effect for African firms. The relationship between pollution and firm performance goes through three stages: negative, positive, and negative again (cubic relationship between PM 2.5 and labor productivity growth). Although, as expected, we find a range of pollution levels where the correlation with productivity is positive, it is interesting to see that pollution effects turn negative at considerably low levels of PM 2.5 (approximately $30 \mu g/m^3$).

The rest of the paper is structured as follows. Section two describes the data and methodology. Section three presents the analysis of how business environment affects African firms, Section four does the same for pollution, and Section five briefly focus on the effects of improving these key variables. Section six concludes and hints to some possible course of action for African cities.

Data and Methodology

Because this paper builds on Reyes, Roberts, and Xu (2017), the main data source we use is also the World Bank Enterprise Survey Dataset. This survey, conducted by the World Bank, takes place in 709 cities, in 128 countries, and collects information on the business climate to understand how this affects firms' performance.⁹ This dataset includes information on firm characteristics (such as size, age, number of employees), firm performance (such as employment growth rate, labor productivity, total factor productivity), and business environment variables

⁹ A list of countries by region and income group can be found in Annex III. For more details on WBES, see <http://www.enterprisesurveys.org>

(such as obstacles to grow, overdraft facility). A list of key variables and sources is presented in Table 1. Summary statistics are shown in Table 2.

It is worth noting that WBES data is a representative sample of the non-agricultural economic activity at the country level. Although the data is geographically stratified, this is done on a country-by-country basis, which results in no common stratification for all firms. Moreover, because the population of interest is limited to registered firms with more than 5 employees, most of these firms are clustered around the main urban centers. This could introduce some bias because more productive or fast-growing firms may be attracted to big cities. However, when estimating the model for different subsamples depending on city size, results do not show significant differences.¹⁰

Furthermore, even though firms' geographic distribution is representative for the country, representativeness at the city level is not automatically assured. Because this paper focuses on the correlation between pollution and firm performance -at the firm level, representativeness at the city level is not a concern. We choose to focus on firm productivity and employment, exploiting the variability of the data at the firm level. Even though we include a variable on capacity agglomeration, we do not intend to draw conclusions that involve the interpretation of firm agglomeration and sorting variables at the city level. The limitations of the data will become more pressing if the analysis wants to be extended at the city level.

Table 1. Variable definitions and Sources

Variables	Definition and source
L-grow	One-year employment growth rate. First calculate 3-year growth rate as the change in permanent employees in 3 years divided by initial number of permanent employees. Then convert it to one-year growth rate (g_1). The L-growth = $2 \cdot g_1 / (2 + g_1)$, which is the Haltiwanger measure of labor growth, bound by -2 and 2 to avoid the typical extreme outlier problem associated with the un-transformed g_1 .
lnLP	The logarithm of labor productivity (LP). LP is measured as sales over the number of permanent employees. Winsorized at tail 2 percent to avoid the outlier issue.
LP-growth	The annualized (Haltiwanger) LP growth rate. The procedure is the same with L-growth except that the basic building block is LP instead of L.

¹⁰ Results appear to be slightly stronger (higher coefficients) for a subsample of firms located in cities with a population between 250,000 and 1 million people.

TFP	Total factor productivity, estimated as the residual from industry-specific production function with log value added as the dependent variable and log capital and log labor as the independent variables. K is replacement cost of land and machine. L is the number of permanent employees plus 0.5 times the number of temporary employees.
Foreign	The share of foreign ownership of the firm.
OwnBiggest	The ownership share of the largest owner.
L ₀ 20-100 (100+)	The firm's number of employees three years ago was 20-100 (more than 100).
Age 6-10 (10+)	The firm's age is between 6 and 10 years (or 10 or more years).
BigCity	The firm is located in a city of a million residents or the capital. This variable has 20.5% of missing, and to avoid loss of sample, we impute the missing with World Bank income group dummies, regional dummies (LAC, MNA, SAR, ECA, EAP, Africa), service industry dummy, size dummies (10-20 employees, 20-60 employees, 60+ employees), age dummies (firm age between 6 and 10 years old; 10 years plus).
Small	The firm is a small enterprise, that is, employing fewer than 50 employees.
Young	The firm's age is younger than 10 years.
Rich	The firm is located in a country that is below the medium GDP per capita in the sample.
Exporter	The firm is an exporter.
High-k	Log of the industry average capital-labor ratio is above the medium of the industries.
InPop1	Log(once-lagged population level)
InGDPPC1	Log(once-lagged GDP per capita in real US dollars).
InPopDen1	Log(once-lagged population density)
XX Obstacle _c	City-level average of the firm's answer on whether "XX" constitutes an obstacle, ranking from 0 to 4 (with 4 being more severe obstacles). XX is one of the following: corruption, skilled labor availability, labor regulation, tax rate burdens, land acquisition. The subscript c for these variables indicate that it is based on city-level average rather than a firm's answer.
Overdraft Facility _c	City share of firms with overdraft facility. Based on WBES calculation.
Trade Credit _c	City average of the proportion of total annual sales of goods and services that are paid for after delivery. Based on WBES calculation.
Inf Competititon _c	City share of firms who say that they directly compete with informal firms. It is a measure of the importance of the informal sector and its competition with the formal sector. Based on WBES calculation.
Outage _c	City share of firms that experienced a power outage in the survey year. Based on WBES.
Web _c	City share of firms that answer that they use websites to conduct business.
Security Cost _c	City average of the share of a firm's sales paid for security. Based on WBES.
Capacity Agglomeration _c	The share of firms whose number of employees exceeding 50, as a proxy of capacity agglomeration. Computed based on sample firms.

Table 2. Summary Statistics

	N	mean	sd	p10	p25	p50	p75	p90
L-growth	97669	0.041	0.143	-0.084	0.000	0.007	0.096	0.179
L-growth for high-growth firms	5,412	0.370	0.197	0.170	0.230	0.321	0.454	0.627
L-growth for non-high-growth firms	92,257	0.022	0.113	-0.096	0.000	0.000	0.074	0.135
LP-growth	70068	-0.026	0.299	-0.270	-0.126	-0.040	0.051	0.199

LP-growth for high-growth firms	3,582	0.655	0.452	0.190	0.305	0.570	0.815	1.361
LP-growth for non-high-growth firms	66,486	-0.063	0.239	-0.279	-0.133	-0.047	0.032	0.130
TFP	33288	-0.133	1.351	-1.856	-1.032	-0.137	0.709	1.549
lnLP	85803	9.534	1.554	7.431	8.496	9.632	10.635	11.517
Export share	106384	0.100	0.253	0.000	0.000	0.000	0.000	0.400
Foreign share	106284	0.075	0.246	0.000	0.000	0.000	0.000	0.030
OwnLargest	103061	0.795	0.264	0.400	0.510	1.000	1.000	1.000
L0 20-100	97930	0.300	0.458	0.000	0.000	0.000	1.000	1.000
L0 100+	97930	0.153	0.360	0.000	0.000	0.000	0.000	1.000
Age 6-10	106338	0.221	0.415	0.000	0.000	0.000	0.000	1.000
age 10+	106338	0.635	0.481	0.000	0.000	1.000	1.000	1.000
BigCity	107777	0.481	0.450	0.000	0.000	0.474	1.000	1.000
Small	107777	0.714	0.452	0.000	0.000	1.000	1.000	1.000
young	106338	0.365	0.481	0.000	0.000	0.000	1.000	1.000
rich	102222	0.488	0.500	0.000	0.000	0.000	1.000	1.000
cityBig	85700	0.476	0.499	0.000	0.000	0.000	1.000	1.000
service	107777	0.446	0.497	0.000	0.000	0.000	1.000	1.000
exporter	106384	0.219	0.413	0.000	0.000	0.000	0.000	1.000
High-k	107,716	0.486	0.500	0.000	0.000	0.000	1.000	1.000
Country level								
lnPop1	122	15.764	2.001	12.779	14.802	15.999	17.111	18.260
lnGDPPC1	121	7.583	1.264	5.920	6.596	7.666	8.578	9.277
lnPopDen1	122	4.084	1.260	2.418	3.446	4.240	4.867	5.660
City level variables								
Corruption obstacle	638	0.489	0.276	0.092	0.279	0.493	0.697	0.878
Overdraft facility	636	0.377	0.263	0.070	0.146	0.325	0.585	0.771
Trade credit	638	0.427	0.198	0.178	0.272	0.414	0.574	0.706
Inf competition	633	0.499	0.208	0.246	0.338	0.478	0.659	0.783
Skilled labor obstacle	642	0.408	0.223	0.125	0.224	0.388	0.567	0.712
Labor regulation obstacle	638	0.282	0.200	0.058	0.140	0.243	0.402	0.554
Tax rate obstacle	642	0.582	0.224	0.267	0.446	0.594	0.757	0.870
Land access obstacle	638	0.334	0.212	0.100	0.177	0.284	0.469	0.664
Outage	638	0.575	0.269	0.220	0.340	0.578	0.832	0.933
Web Intensity	642	0.440	0.239	0.114	0.241	0.448	0.618	0.766
Security Cost	642	0.018	0.018	0.004	0.008	0.014	0.022	0.037
Capacity agglomeration	648	0.268	0.146	0.077	0.161	0.260	0.354	0.456

In order to include pollution measures in our analysis, we need access to the GPS location of each of the firms of the survey. Because this information is confidential, we only have access to a masked location for each firm, randomly assigned within a radius of 2km of the true firm location. Although not all firms in the WBES dataset have GPS locations, comparing the

distribution of the key variables between the whole sample and the sample of geo-referenced firms show no significant differences (see Annex I for details). We have a sample of 56,977 geo-referenced firms.

Originally, we have air pollution data for two pollutants, nitrogen dioxide (NO₂) from NASA OMI satellite and PM 2.5, from NASA MODIS and MISR Aerosol Optical Depth. Both datasets are in raster format, with a resolution of 0.1x0.1 degrees, approximately 11km by 11km at the equator. Each pixel contains the annual mean of the corresponding pollutant. For nitrogen dioxide, the data spans between 1997 and 2011, while for PM 2.5, the period is 1998 to 2015. Because different models may differ in how they estimate the PM 2.5 surface concentration levels, we complement NASA data with PM 2.5 raster data (with the same resolution) estimated by van Donkelaar et al. (2016). Their work uses geographically weighted regression to calibrate ground-based PM 2.5 concentration levels using satellite data and ground level data were available.

We overlay WBES masked firm locations with pollution data rasters and extract NO₂ and PM 2.5 levels for each location. WBES data includes a cross section of firms surveyed between 2006 and 2015. Only two countries have three waves of the survey (Bulgaria and The Democratic Republic of Congo), approximately half of the countries have two waves (20% of them are African countries), and the rest has only one wave. Although this is not a panel, firms were asked information on sales and employment for the year of the survey and the three previous years, which allowed the construction of annualized growth rates. To assign pollution data to each firm, we use the year of the survey wave and assign the pollution level that corresponds to that same year. For example, Yemen has two waves, 2010 and 2013. Then for firms surveyed during the wave 2010, we assign 2010 pollution mean values, and for firms surveyed in 2013, we assign 2013 pollution mean values. In the end, because firm that has GPS location are mostly surveyed after 2010, our sample is reduced to 80 countries with only one wave of the survey (with the exception of the aforementioned example of Yemen that keeps the two waves).

For our estimation, we only use PM 2.5 data. NO₂ data is only available until 2011 and geo-reference information is available starting at 2010, which results in most of the geo-referenced firms with no available NO₂ data. In the end, the sample for the second half of our analysis

consists of 56,841 firms, distributed in 412 cities, in 79 countries. From these firms, 17.4% are in Africa, 6.2% in East Asia Pacific, 12.3% in Europe and Central Asia, 14.3% in Latin America, 12.6% in Middle Eastern and North Africa, 21% in South Asia, and 16.2% in high-income countries.

PM 2.5 concentration levels vary widely across our sample (Figure 1). Only 30% of the firms are located in cities where PM 2.5 levels are considered safe by the WHO, i.e., PM 2.5 annual mean below $10 \mu\text{g}/\text{m}^3$. Half of the firms are still exposed to low levels, around $13 \mu\text{g}/\text{m}^3$, and approximately 10% of the firms are in cities with PM 2.5 concentration levels above $50 \mu\text{g}/\text{m}^3$. Moreover, the distribution is not homogenous across regions (Table 3). High income countries show low levels of PM 2.5, while regions like South or East Asia are among the most polluted ones, with an average around 45 and maximum levels of 111 and 94 respectively.

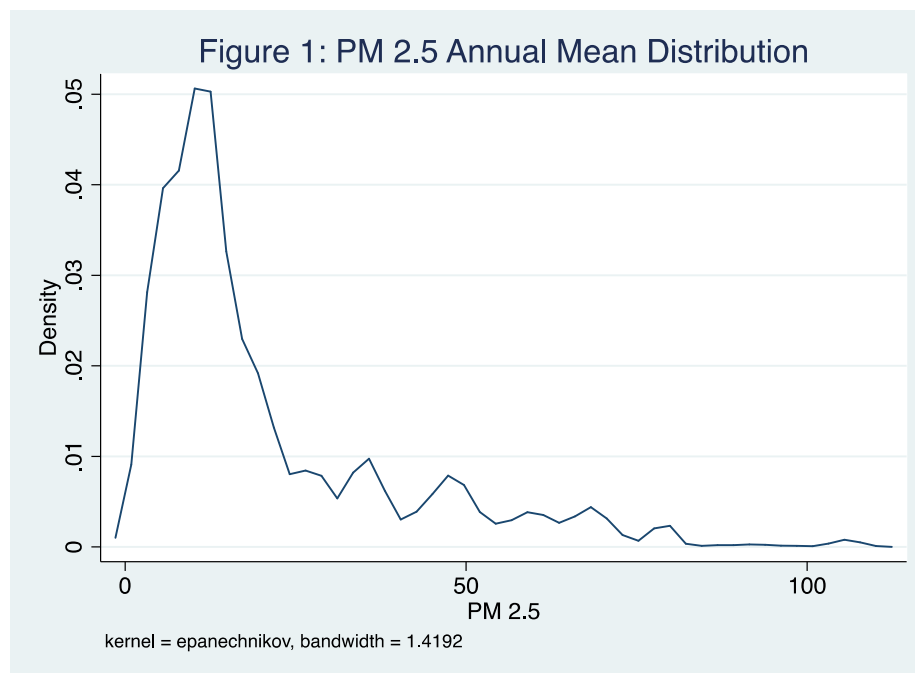


Table 3. PM 2.5 Summary Statistics by Region

	Obs	Mean	Std. Dev.	Min	Max
<u>Region</u>					
Africa	9,889	13.68	8.06	1	35
East Asia Pacific	3,509	45.70	22.51	2	94
East Europe and Central Asia	7,004	14.64	4.97	5	30
Latin America	8,148	6.13	3.25	1	23
Middle East and North Africa	7,157	10.08	2.99	4	21

South Asia	11,968	45.89	18.38	6	111
High income OECD	3,517	12.58	4.80	0	23
High-income non-OECD	5,649	12.50	4.60	2	24

For our analysis, we follow the same approach as in Reyes et al. (2017). Focusing on dynamic firm performance as captured by firm employment growth rate and firm labor productivity growth rate,¹¹ the authors link firm growth with basic firm controls (i.e., firm size, age, foreign ownership), industry, year dummies, and of course, the BE variables. A key advantage of their specification is that they control for country fixed effects, which essentially hold constant all country-specific characteristics such as political institutions, culture, geography, size. Their identification of the impacts of the various dimensions of the BE thus comes from comparing firm performance across city-industry cells within countries. Moreover, since they capture the BE using city-industry average of firm-level response on aspects of the business environment (such as access to bank loans, trade credit, spending on security as a share of sales, specific BE aspect considered an obstacle), they have thousands of unique values of the BE variables, and thus effectively circumvent the serious multicollinearity issue embedded in cross-country studies of the BE effects. To avoid outlier issues when using growth rates, we use the same approach as in Reyes et al. (2017).¹² We also cluster the standard errors at the city level.

We focus on two main concerns: how does the business environment affect African firms, and how air pollution is correlated with firm productivity. To answer the first question, we allow the BE effects to differ for African firms and firms in the rest of the world, and see what

¹¹ Following Reyes et al. (2017), we define the dependent variable as the growth in employment and productivity. As stated by these authors, “static measures of performance such as labor productivity or total factor productivity are more likely to be subject to persistent sources of measurement error and to be influenced by firm-specific market power than are measures of firm growth. By using firm growth and taking a difference of static firm performance, we essentially filter out time-invariant measurement errors.” Other papers looking at the effects of pollution on labor productivity, such as Fu et al. (2018), have used the performance measures in levels. To ensure comparability of our results with such literature and as a robustness check, we followed Fu et al. (2018) and use the logarithm of employment and the logarithm of productivity as dependent variables (see Annex II). Results for both, the global firms sample and the African firms sample do not present significant changes.

¹² From Reyes et al. (2017): “... we follow Davis and Haltiwanger (1999) by calculating mid-point growth rates by dividing the change in employment (or labor productivity) between the survey year and three years earlier by the simple average of employment (or labor productivity) in the beginning and ending years. This bounds the resulting growth rate between – 2 and +2, thereby significantly reducing the influence of outliers”.

implications emerged from the investigation. To aid interpretation, we show that there is no strong evidence of sorting along city size in our sample. For the second set of questions, we introduce PM 2.5 measures of air pollution as another determinant of firm productivity and look at the effects on employment and labor productivity. When following this strategy for the whole world, we expect to find lower employment growth and labor productivity growth rates for firms with higher PM 2.5 concentration levels. We then focus only on a subsample of African firms. Because there is not enough variability of pollution data at the country level, we do not control for country fixed effects in this last specification.

We estimate an equation of the form:

$$Y_{ickjt} = FIRM_{ickjt}\theta + E_{ckt}\beta + P_{ickjt}\delta + u_j + v_t + \epsilon_{icjt}$$

where i, c, k, j, t index firms, countries, cities, industries, and year, respectively. $FIRM_{ickjt}$ is a vector of firm level controls, such as, age, size, type of ownership, E_{ckt} is a vector of underlying BE effects at the city-level, and P_{ickjt} is a vector with the corresponding pollution measure. We also control by country and year dummies.

The problem when trying to correctly identify the effects of pollution on labor productivity and employment, is that pollution is usually accompanied by other variables that can bias the estimates. For example, pollution may be accompanied by economic growth that can also impact firm performance.¹³ Another possible bias may come from the fact that workers and firms may respond to pollution by adjusting their behavior, and through that mitigate the effect that pollution would otherwise have on their productivity levels. They may adopt some measures that could include the use of individual masks, or using air filters, or even decisions to relocate. The data at hand limits our ability to control for all these variables and restricts the conclusions we can draw from this analysis. Hence, we do not claim that the effects of pollution on labor productivity and employment are well identified, but instead, this work makes an effort to

¹³ Although pollution levels could be affected by local economic activity, this is not likely to be an issue in this context for two reasons. First, because PM 2.5 travel far and remain suspended in the air for long periods of time, they are less driven by local activity (Chang et al. 2014). Second, many studies have documented that most of air pollution measures are not caused by local sources (for example, Ault et al, 2009 and Brook et al. 2007).

effectively track the evolution of these two connected variables and see how their correlation differs for Africa with respect to other regions.

Moreover, as mentioned by Graff-Zivin and Nediell (2012), estimating the effect of pollution on worker productivity could be challenging due to two main reasons. First, measures of output per worker usually do not isolate worker productivity from other inputs. Second, exposure to pollution is often endogenous. For example, there may be sorting of high productivity-high income workers in less polluted areas (Banzhaf and Walsh, 2008). Moreover, even if exposure to pollution is exogenous, some workers may decide on how much exposure they get (by changing shifts, for example) making exposure still endogenous (Neidell, 2009). With these restrictions in mind, we use labor productivity as a measure of firm performance and look at the correlation between pollution and labor productivity. Measuring individual worker productivity and estimating the marginal effects of pollution exceeds the scope of this paper.

Allowing Africa-Specific Business Environment Effects

We look at how BE effects are different for African cities. We report the specification in which the Africa dummy is interacted with our key business environment (BE) variables. To report a parsimonious specification and to avoid multicollinearity, we first interact the Africa dummy with all BE variables that are statistically significant in at least one of the two outcomes regressions. We then drop those African-interaction terms, and re-run. We continue this process so that we keep only the African interaction terms that are significant in at least one of the two outcomes regressions. In the end, only Capacity Agglomeration has a significant interaction term with the Africa dummy. Table 4 only presents the results of this iteration.¹⁴

Table 4. How African Countries Differ in Effects of the Business Environment

	L-growth		LP-growth	
	coef	se	coef	se
Security Cost	-0.076	0.049	-0.112	0.108
Corruption obstacle	-0.015*	0.006	0.019	0.013
Overdraft facility	0.014*	0.006	0.034*	0.014
Trade credit	-0.008	0.008	0.036*	0.016

¹⁴ All regressions include dummy variables for firm size (small, medium, large). The particular effects of BE for different firm sizes are further explore in Reyes et al. (2017)

Skilled labor obstacle	0.004	0.006	-0.011	0.013
Labor regulation obstacle	0.002	0.007	0.003	0.015
Tax rate obstacle	-0.007	0.007	0.008	0.015
Land access obstacle	-0.006	0.007	-0.002	0.014
Outage	-0.001	0.007	-0.003	0.013
Web Intensity	0.018**	0.006	0.036**	0.013
In Big City	0.006*	0.003	-0.001	0.005
Capacity agglomeration	0.042*	0.016	-0.001	0.027
Capacity agglomeration * Africa	0.032	0.035	0.171*	0.076
Inf competition	-0.012*	0.005	0.006	0.011
Other controls	Yes		Yes	
Industry dummies	Yes		Yes	
Observations	57,455		44,279	
Adj. R squared	0.131		0.286	

*, ** represent statistical significance at the 5 and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.

Other controls include year dummies, missing dummy for BE variables, and base controls

Capacity agglomeration had much more positive association with labor productivity growth only in African cities. One standard deviation increase (0.12) is associated with a labor productivity growth increase of almost 2 percentage points, a considerably large effect. In other regions, the coefficient is not statistically significant, showing there is no association between capacity agglomeration and labor productivity growth. This is suggestive evidence that capacity agglomeration is a key issue for Africa. Moreover, compared to other regions, Africa shows the lowest level of capacity agglomeration (Table 5).

Table 5. Regional summary statistics

	AFR		EAP		ECA		LAC		MNA		SAR		High Income	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
L-grow	0.041	0.172	0.054	0.093	0.022	0.124	0.027	0.140	0.016	0.148	0.029	0.083	0.027	0.140
LP-grow	-0.059	0.596	-0.042	0.148	-0.014	0.269	-	0.234	-0.126	0.248	-0.026	0.149	-0.032	0.249
Foreign Share	0.086	0.253	0.036	0.169	0.052	0.197	0.100	0.283	0.054	0.207	0.008	0.077	0.066	0.236
Own Largest	0.873	0.226	0.849	0.223	0.812	0.252	0.718	0.274	0.752	0.285	0.781	0.266	0.794	0.265
Exporter	0.190	0.392	0.197	0.398	0.235	0.424	0.297	0.457	0.234	0.424	0.164	0.370	0.246	0.431
Once-lagged GDP (log)	6.501	0.710	7.975	0.217	8.050	0.900	8.251	0.593	7.550	0.585	6.921	0.326	9.170	0.567
In Big City	0.584	0.493	0.856	0.334	0.189	0.303	0.705	0.456	0.454	0.498	0.436	0.496	0.297	0.444
Corruption Obstacle	0.446	0.285	0.140	0.199	0.441	0.247	0.644	0.190	0.800	0.236	0.444	0.310	0.395	0.174
Overdraft Facility	0.271	0.212	0.282	0.286	0.369	0.266	0.579	0.233	0.323	0.256	0.522	0.262	0.416	0.312
Trade Credit	0.244	0.149	0.521	0.244	0.364	0.189	0.562	0.186	0.384	0.191	0.501	0.214	0.538	0.174
Inf. Competition	0.653	0.212	0.499	0.269	0.416	0.198	0.690	0.156	0.440	0.195	0.408	0.223	0.367	0.216

Skilled Labor Obstacle	0.311	0.193	0.233	0.218	0.322	0.193	0.644	0.144	0.320	0.203	0.316	0.223	0.457	0.209
Labor Regulation Obstacle	0.259	0.179	0.112	0.161	0.161	0.134	0.532	0.186	0.287	0.161	0.293	0.202	0.299	0.215
Tax Rate Obstacle	0.599	0.230	0.295	0.280	0.525	0.211	0.641	0.199	0.548	0.178	0.540	0.240	0.682	0.217
Land Access Obstacle	0.460	0.209	0.188	0.204	0.209	0.158	0.297	0.119	0.323	0.217	0.340	0.255	0.224	0.157
Outage	0.824	0.183	0.506	0.315	0.442	0.214	0.543	0.196	0.669	0.320	0.674	0.282	0.317	0.177
Web Intensity	0.314	0.213	0.589	0.320	0.553	0.227	0.607	0.186	0.486	0.239	0.475	0.255	0.679	0.197
Security Cost	0.032	0.027	0.009	0.011	0.018	0.019	0.018	0.014	0.012	0.015	0.012	0.010	0.012	0.012
Capacity Agglomeration	0.183	0.109	0.489	0.203	0.263	0.099	0.369	0.104	0.261	0.132	0.367	0.128	0.266	0.091
PM 2.5	13.682	8.064	45.697	22.510	14.636	4.974	6.128	3.249	10.085	2.986	45.894	18.379	12.528	4.675

As an additional exercise, we look at how BE effects differ by city size of a firm's location and explore whether there are sorting effects of firms across cities. Sorting effects can be present for different reasons as specific characteristics of cities may attract certain types of firms. For example, big cities could provide better infrastructure and access to finance. They also usually provide better amenities that can attract more technologically-advantaged firms and access to better education that could impact workers' qualifications.

Significant differences in the coefficients of the effects by city size, would be indicative of sorting. To test the hypothesis of sorting, we investigate how BE effects differ by city size of a firm's location, we interact the dummy variable of whether the firm is located in a city of more than a million residents with the BE variables.¹⁵ To reduce multicollinearity, we drop those interaction terms that are statistically insignificant in both employment growth (L-growth) and labor productivity growth (LP-growth) regressions (Table 6).

Table 6. How the BE Effects Differ by City Size

	Lgrow		LPgrow	
	coef	se	coef	se
In Big City	0.017*	0.007	0.019	0.015
Corruption Obstacles	-0.015*	0.006	0.023	0.014
Overdraft Facility	0.015*	0.006	0.031*	0.014
Trade Credit	-0.008	0.009	0.045**	0.016
Inf Competition	-0.012*	0.006	0.002	0.012
Skilled Labor Obstacle	0.000	0.006	-0.001	0.013

¹⁵ The data allow us to potentially delve in richer ways of how city size affects firm growth. In particular, we know whether the firm is located in a small city (i.e., less than 50,000, between 50,000-250,000, 250,000 to one million, capital city). In empirical explorations, we found that being affiliated with medium cities (i.e., 250,000 to a million) or small cities (i.e., 50,000 to 250,000) did not have statistically significantly different effects from being affiliated with little cities (i.e., fewer than 50,000 people). We thus only keep the dummy of being affiliated with big cities.

Labor Regulation Obstacle	0.002	0.009	0.021	0.017
Labor Regulation Obstacles * In Big City	-0.001	0.009	-0.047**	0.017
Tax Rate Obstacle	-0.005	0.007	0.004	0.016
Land Access Obstacles	-0.005	0.007	-0.006	0.015
Outage	0.003	0.007	-0.009	0.014
Web Intensity	0.019**	0.006	0.029*	0.013
Security Costs	-0.105*	0.053	-0.049	0.115
Capacity Agglomeration	0.047*	0.019	0.032	0.028
Capacity Agglomeration * In Big City	-0.034	0.019	-0.023	0.035
Other Controls as in Reyes et al. (2017)	Yes		Yes	
Observations	52,614		40,507	
Adjusted R squared	0.123		0.287	

^x, ^{*}, ^{**} represent statistical significance at the 10, 5, and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.

Other controls include year dummies, missing dummy for BE variables, and base controls.

Interestingly, most BE variables do not have different effects in big versus non-big cities, which may point at the fact that many business environment constraints are still due to national level restrictions, such as tax or trade regulations. However, labor inflexibility seems to have more harmful association with labor productivity growth in big cities. Only in big cities, increasing Labor Regulation Obstacles by one standard deviation (0.2) is associated with a drop in labor productivity growth by 0.5 percentage points. This makes sense since in large cities the benefits of a flexible labor market should be larger due to better opportunities for labor-employer matching, and labor inflexibility is likely to cause more harm in terms of productivity growth. In contrast, the benefits of capacity agglomeration, while present in both big and non-big cities, are more pronounced in non-big firms. Increasing capacity agglomeration by one standard deviation (0.15) is associated with higher employment growth by 0.7 percentage points in non-big cities, and by 0.2 percentage points in big cities. The stand-alone Big City effect is also pronounced: its premium for employment growth is 1.7 percentage points.

To see if there is sorting of firms in big cities, we use the affiliation of high-tech industries by firms as a proxy of firm quality or technology. We want to see if firms located in big cities are more likely to be in high-tech industries. High-tech industries are those in metals and machinery, electronics, chemicals and pharmaceuticals, non-metallic and plastic materials, auto and auto components. The rest of the manufacturing firms are then classified as low-tech manufacturing,

such as those in textiles, leather, garments, food, wood and furniture, and other manufacturing.¹⁶ After controlling for country dummies, the coefficient that relate the high-tech dummy with the In Big City dummy clearly shows that there is no statistically significant correlation between the high-tech status and In Big City (Table 7).¹⁷

Table 7. A Check on Sorting of Firms and Cities

	High-Tech dummy		High-Tech dummy	
	coef	se	coef	se
In Big City	0.040	0.033	0.004	0.011
Country Dummies	no	no	yes	yes
N	45,839		45,839	
r2_a	0.002		0.155	

Coefficients show the correlation between high-tech dummy and In Big City dummy (estimated by regressing the High-Tech dummy on In Big City dummy, using OLS. The second model includes country fixed effects. Standard errors are clustered at the city level.

Pollution effects on Firm Productivity

We now move our focus to the second question: is firm performance affected by air pollution? Following a similar strategy, we estimate the effect PM 2.5 on employment growth and labor productivity growth. As mentioned earlier, because location data is missing for some of the firms, we restrict our sample to only those firms for which we have location and PM 2.5 concentration values. Additionally, data on PM 2.5 from van Donkelaar has better coverage than PM 2.5 obtained from NASA directly, so we opt to use the first one.

We explore different model specifications and present the results of the model that better fits the data. Globally, pollution seems to be associated with employment growth positively and linearly, while for labor productivity growth a quadratic specification fits the data better. Intuitively, on the one hand, we expect labor productivity to grow at the beginning, until a certain point, beyond which higher levels of pollution will start leading to declining values of labor productivity. On the other hand, the positive linear relationship between pollution and employment growth may indicate that firms will always try to hire more employees, even while pollution levels are rising. Since we find that productivity decreases while pollution increases

¹⁶ This exercise is only do-able for manufacturing firms, and we thus only use the manufacturing firms.

¹⁷ A similar test for firm size and in Big City dummy is included in the Annex II. Results show that there is no statistically significant correlation between the size of the firm and in Big City, when including country dummies.

(after a certain point) this positive relationship between pollution and employment growth is not surprising. Firms need to hire more employees to achieve similar production levels. When focusing on African firms, however, we find that a cubic specification of pollution fits better, for both dependent variables.

When looking at the effect of pollution on firm performance around the world, we find that results differ for employment growth versus labor productivity growth (Table 8). Because PM 2.5 and employment growth are linearly correlated, we only see constant effects. As expected, the effect is negative (-0.0002). An increase of PM 2.5 in 10 units, is associated with a reduction in employment growth of 0.2%. This effect appears to be constant over time, which implies considerably big effects for firms in cities experiencing high levels of pollution. For example, in China and India, firms in cities like Chengdu or Bihar are exposed to pollution levels above $90 \mu\text{g}/\text{m}^3$. For these firms, employment growth could be approximately 1.4 percentage points compared to what it could be if pollution levels were below the WHO guideline ($10 \mu\text{g}/\text{m}^3$).

Table 8. Pollution Effect on Firm Performance (Global)

	L-growth		LP-growth	
	coef	se	coef	se
Security Cost	-0.165*	0.073	-0.027	0.141
Corruption obstacle	-0.028**	0.008	0.019	0.017
Overdraft facility	0.013*	0.007	0.033 [×]	0.017
Trade credit	-0.010	0.009	0.049**	0.018
Skilled labor obstacle	0.001	0.007	-0.005	0.016
Labor regulation obstacle	0.013	0.008	-0.003	0.018
Tax rate obstacle	-0.004	0.008	0.008	0.018
Land access obstacle	-0.010	0.008	0.005	0.021
Outage	0.007	0.007	-0.019	0.015
Web Intensity	0.019**	0.007	0.034*	0.014
In Big City	0.004	0.003	-0.003	0.006
Capacity agglomeration	0.023	0.018	-0.004	0.030
Informal competition	-0.013*	0.007	0.001	0.013
PM 2.5	-0.0002 [×]	0.0001	0.003**	0.001
PM 2.5 ²			-0.00002**	0.00001
Other controls	Yes		Yes	
Industry dummies	Yes		Yes	
Observations	35,736		26,910	
Adj. R squared	0.111		0.289	

[×], *, ** represent statistical significance at the 10, 5, and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.
Other controls include year dummies, missing dummy for BE variables, and base controls.

The relationship between PM 2.5 and labor productivity, on the contrary, appears to be non-linear. The effect is positive (0.003) at low levels of pollution, although decreasing as pollution levels rise (-0.00002). The intuition behind this result is that lower levels of this pollutant may identify an area in the earlier stages of development. There, the negative effects of pollution on productivity are offset by the positive effects of growth. As the level of pollution rises, the negative effects are more notable and start to show a negative correlation with labor productivity. This seems to show evidence of an Environmental Kuznets Curve.¹⁸

The next step is to analyze this correlation between air pollution and firm performance is different (or stronger) for African firms. To do this, we limit our sample to only African firms, and run our analysis. A cubic specification helps explain the relationship between pollution and both dependent variables better. We show these results in Table 9.

Table 9. Pollution Effects on African Firms

	L-growth		LP-growth	
	coef	se	coef	se
Security Cost	-0.163	0.130	-0.166	0.313
Corruption obstacle	-0.043*	0.018	-0.178*	0.068
Overdraft facility	-0.015	0.018	0.104×	0.053
Trade credit	-0.026	0.028	0.160×	0.092
Skilled labor obstacle	0.042×	0.022	0.038	0.083
Labor regulation obstacle	0.036	0.024	-0.176**	0.061
Tax rate obstacle	0.001	0.018	0.112	0.078
Land access obstacle	-0.028	0.020	0.069	0.067
Outage	0.082**	0.019	-0.117	0.083
Web Intensity	0.025	0.019	0.070	0.069
In Big City	0.010	0.008	-0.023	0.028
Capacity agglomeration	0.052	0.052	0.398*	0.155
Inf competition	-0.075**	0.017	0.036	0.063
PM 2.5	-0.009×	0.005	-0.083**	0.015

¹⁸ The Environmental Kuznets Curve (Grossman and Krugman, 1991) states that countries in their earlier face of development will increase pollution levels until they reach a maximum where they learn to manage pollution and still be able to keep developing. Developing nations are then on the positive segment of the Environmental Kuznets Curve, while more developed nations are placed at the end, on the negative segment. Our results are in line with this notion, suggesting that the same firm, if located in an area that it is at an early stage of economic development, may benefit from the positive effects of pollution. As these areas attract more firms and pollution increases, the benefits are offset by the negative effects pollution brings on health and productivity.

$PM\ 2.5^2$	0.001*	0.0003	0.005**	0.001
$PM\ 2.5^3$	-0.00001*	0.00001	-0.00007**	0.00002
Other controls	Yes		Yes	
Industry dummies	Yes		Yes	
Observations	4,563		2,742	
Adj. R squared	0.167		0.484	

[×], ^{*}, ^{**} represent statistical significance at the 10, 5, and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.

Other controls include year dummies, missing dummy for BE variables, and base controls.

These results shed some light on how pollution correlates with productivity for African firms differently. Since the relationship appears to be cubic, the effect of pollution on employment growth and labor productivity growth differ depending on the level of pollution. At low levels of pollution, the effect on both dependent variables is negative (-0.009 and -0.083, respectively). Because the quadratic term is positive, these negative effects will have less impact as pollution levels rise, turning into positive effects. The negative cubic coefficients show that after a certain point, pollution will again have a negative effect on employment and labor productivity growth.

The effects on both dependent variables are similar. In terms of employment growth, African firms experience negative effects of pollution at extremely low levels of PM 2.5, approximately until $8\ \mu g/m^3$. At these levels, African firms may not be experiencing enough of the positive benefits from growth needed to offset pollution negative effects. From there, the effects of pollution increase for higher levels of PM 2.5, until approximately $26\ \mu g/m^3$, where the effects turn negative again. For labor productivity growth, the effects are negative for PM 2.5 levels below $13\ \mu g/m^3$. From that level until approximately $32\ \mu g/m^3$, the effect of pollution is positive, again, as a consequence of the positive effects of growth offsetting the negative pollution effects. After that, pollution effect on labor productivity growth is negative again. Pollution then has negative effects on employment growth sooner than on labor productivity growth.

As a robustness check, we run the same regression using a spline specification for the pollution variable. Splines allow for more flexibility in the relationship between the variables being considered -in this case, pollution and firm performance, and reduce model misspecification. We follow Harrel (2010) and choose four knots at specific quantiles of the

independent variable.¹⁹ While overall results are consistent with our previous findings and our final conclusions still hold, the significance of the coefficient of the first spline is slightly reduced. For a full characterization of these robustness checks see Annex II.

Gains from improving Business Environment and Pollution

To shed light on what African countries can do to facilitate firm growth, we conduct some back of the envelope calculation of potential gains from improving key BE variables relevant to Africa and managing PM 2.5 levels. For the BE variables, we only report those “policy instruments” that proved to be statistically significant for either employment growth or labor productivity growth for the African countries.

We conduct the following thought experiment. Using the Africa-specific coefficients of BE variables, if a key BE element improves by one standard deviation (i.e., increase by one standard deviation for “good” BE elements and reduce by one standard deviation for “bad” BE elements), what percentage of the standard deviation of the outcome in Africa can be expected to change (assuming causality). The results are in Table 10.

Table 10. Potential Growth Effects of Improving Key Policy Instruments for African Firm

Here, we only report those “policy instruments” with the following characteristics. First, the instrument must be statistically significant for the specific growth result for the African countries. Second, the instrument must be something that the government might be able to do something.

	African coeff.	Improve by one Africa-SD	% African SD in the outcome explained by one Africa-SD improvement in the instrument $\frac{\beta_{africa} * \sigma_{X,africa}}{\sigma_{Y,africa}}$
For L-Growth:			
$\sigma_{Y,africa} = 0.16$			
Corruption Obstacles	-0.015	-0.3	2.9%
Overdraft Facility	0.014	0.23	2.7%
Informal Competition	-0.012	-0.21	1.6%
Web Intensity	0.018	0.17	1.9%
Capacity agglomeration	0.074	0.12	5.6%

¹⁹ Harrell (2010) argues that for most datasets choosing 4 knots is “an adequate fit of the model and is a good compromise between flexibility and loss of precision caused by overfitting a small sample”. These four knots correspond to 5%, 35%, 65%, and 95% quantiles, and take the following PM 2.5 values: 4, 10, 17, 31.

For LP-Growth			
$\sigma_{Y,africa} = 0.42$			
Overdraft Facility	0.034	0.23	1.9%
Trade Credit	0.036	0.14	1.2%
Web Intensity	0.036	0.17	1.5%
Capacity agglomeration	0.170	0.12	4.9%

Note. The coefficients are for the African regions. That is, they are based on Table 4. African Standard Deviations correspond to the whole sample.

This table reports the associated change (in percent of one standard deviation of the outcome in Africa) when the key variable changes by one standard deviation (in Africa).

The most important BE element is clearly capacity agglomeration. Increasing it by one African standard deviation is associated with an increase in African employment growth and labor productivity growth standard deviations by 5.6 and 4.9 percent, respectively. This is the largest positive association we observe in all BE variables. Relatedly, improving Informal Competition by one standard deviation is associated with increasing 1.6 percent of labor growth standard deviations.

As a group, improving Basic BE is clearly important. First, improving corruption obstacles by one African standard deviation is associated with higher employment growth by slightly less than 3 percent of one employment growth standard deviation. Second, improving modern infrastructure (i.e., Web Intensity) by one African standard deviation is associated with increasing employment growth and labor productivity growth standard deviations by 1.9% and 1.5%, respectively. The effects are thus also potentially large. Finally, access to finance appears to be an important area to work on. Improving access to bank finance by one African standard deviation is associated with increasing 2.7% of one employment growth standard deviation, and 1.9% of one labor productivity growth standard deviation. Similarly, improving trade credit by one African standard deviation is associated with increasing 1.2% of one labor productivity growth standard deviation.

Table 11. Potential Growth Effects of Improving PM 2.5 Levels for African Firm

Here, we only report those “policy instruments” with the following characteristics. First, the instrument must be statistically significant for the specific growth result for the African countries. Second, the instrument must be something that the government might be able to do something.

	African coeff.	Improve by one Africa-SD	% African SD in the outcome explained by one Africa-SD improvement in the instrument $\frac{\beta_{africa} * \sigma_{X,africa}}{\sigma_{Y,africa}}$
For L-Growth:			
$\sigma_{Y,africa} = 0.172$			
<i>PM</i> 2.5 (at x=mean)	0.0032	8.064	14.89%
<i>PM</i> 2.5 (at x=40)	-0.0199	-8.064	92.99%
For LP-Growth:			
$\sigma_{Y,africa} = 0.596$			
<i>PM</i> 2.5 (at x=mean)	0.0041	8.064	5.48%
<i>PM</i> 2.5 (at x=40)	-0.0479	-8.064	64.78%

Note. The coefficients are for the African regions. That is, they are based on Table 9. They have been calculated at two different values for x, with the following equation: $\delta_1 + 2\delta_2x + 3\delta_3x^2$, where δ_1 is the coefficient for *PM* 2.5, δ_2 the coefficient for *PM* 2.5², and δ_3 the coefficient for *PM* 2.5³. This table reports the associated change (in percent of one standard deviation of the outcome in Africa) when pollution changes by one standard deviation (in Africa).

The impact is even more shocking when looking at pollution levels (Table 11). After relatively low *PM* 2.5 concentration levels, the effects turn negative, with a huge impact on both, employment growth and labor productivity growth. For example, at 40 $\mu g/m^3$, a reduction in one standard deviation of *PM* 2.5, approximately 8 units, is associated with an increase in employment growth in 93% of its standard deviation (0.172), for African firms. This huge effect translates in an increase of 16.03% in employment growth rate. At the mean level, the annual employment growth rate in Africa will go from 4.1% to 20.1%. For labor productivity, the same exercise yields an increase in labor productivity growth of 38.63 percentage points, which at the mean translates in a positive growth rate of 32.8%.

Conclusions

In this paper, we shed some light on how air pollution and business environment affect city competitiveness through firm performance, particularly for African firms. We measure firm performance with two variables, employment growth and labor productivity growth. We use firm-level data from the World Bank Enterprise Survey and combine it with *PM* 2.5 data estimated by van Donkelaar et al. (2016) (based on NASA MODIS and MIRS satellite data). We

perform the analysis at the global level and then focus on how these effects are different for African firms.

When compared to the rest of the world, African firms experience different effects in terms of pollution. While a global analysis shows that the association between pollution and labor productivity is positive in the beginning and negative as pollution rises (quadratic), African firms experience a different story. PM 2.5 levels are negatively associated with labor productivity for these firms at low levels of pollution. Between approximately $8 \mu g/m^3$ and $25 \mu g/m^3$, the effects turn positive, showing that as pollution and growth rise, the positive effect from growth offset the negative effects of pollution. After a not so high level of pollution (an annual average equal to $25 \mu g/m^3$) its effects on employment and labor productivity growth are negative again.

The fact that African cities are growing fast but PM 2.5 levels have not yet reached the high levels experienced in places like China and India, poses an opportunity to plan ahead and avoid the mistake of not accounting for the negative effects associated with fast and unplanned growth. PM 2.5 has a negative effect on firm performance at levels that are not as high as the ones that these countries are currently experiencing. Pollution management is crucial to tackle the problem before it gets more serious. African cities could benefit from the examples we see now in cities that have experienced fast growth.

Looking at business environment and the effects on firm performance, we find that the only variable that affects African firms differently is capacity agglomeration. The effect of capacity agglomeration on labor productivity growth is stronger for firms in this region. An increase of 0.12 percentage points in capacity agglomeration results in an increase of almost 2 percentage points in labor productivity growth. There is no evidence of sorting of firms in big cities and most BE environment variables appear to have similar effects, regardless of the city size. This suggests that the stronger effect of capacity agglomeration for African firms is not clouded by sorting of firms or city size.

These results suggest that African firms face a few different challenges compared to firms in other regions. Moreover, addressing these problems could be key in pushing economic growth for the region, as many African countries are in early stages of development. Cities in Africa are urbanizing fast, trying to lift population out of poverty. Managing pollution and improving the

business environment could help their firms improve their performance and will certainly help African cities become more competitive.

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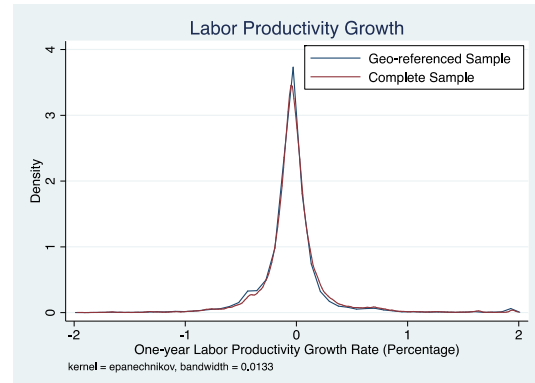
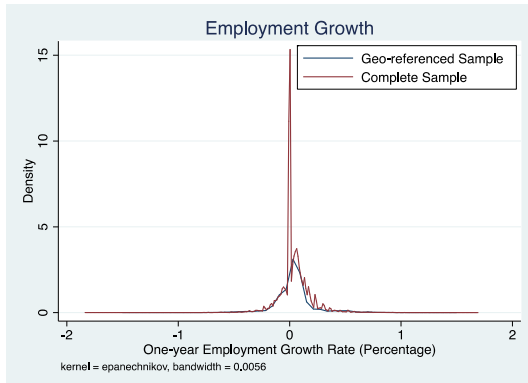
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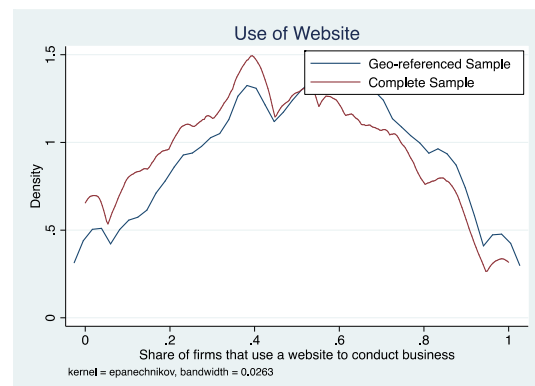
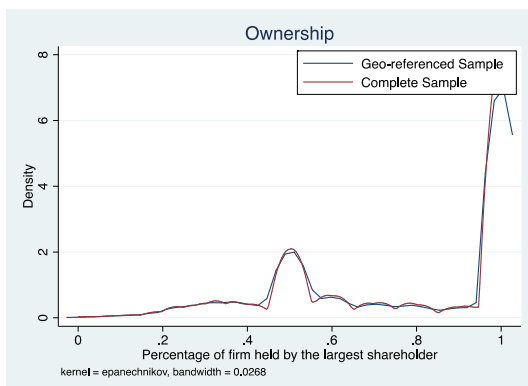
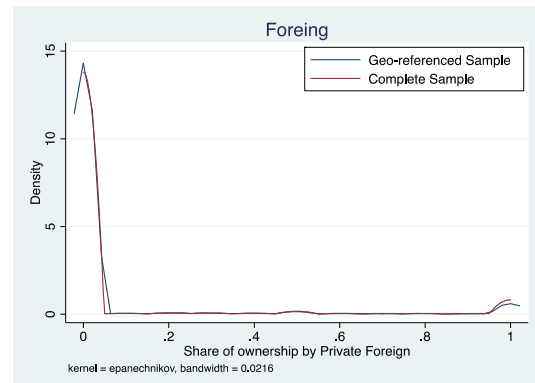
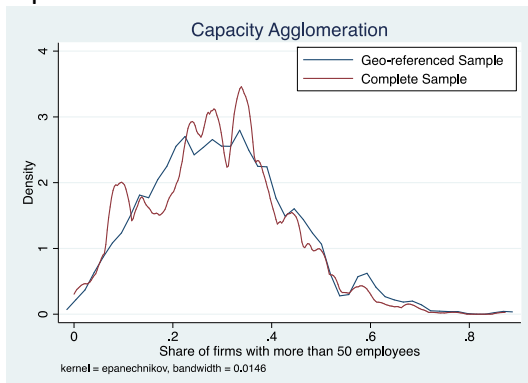
Annex I

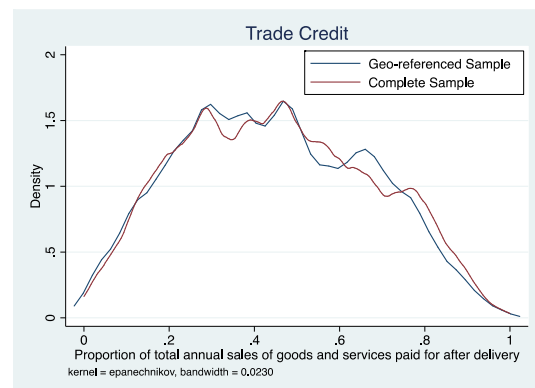
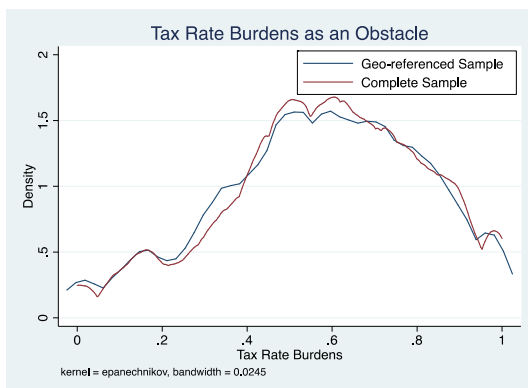
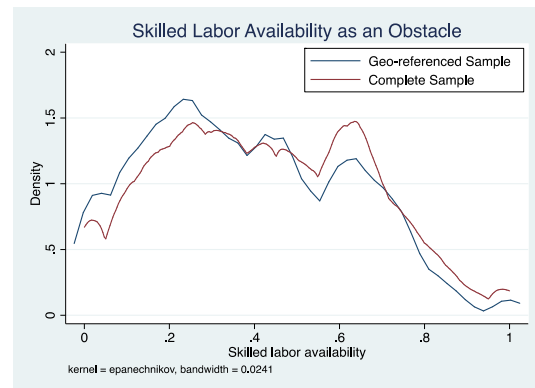
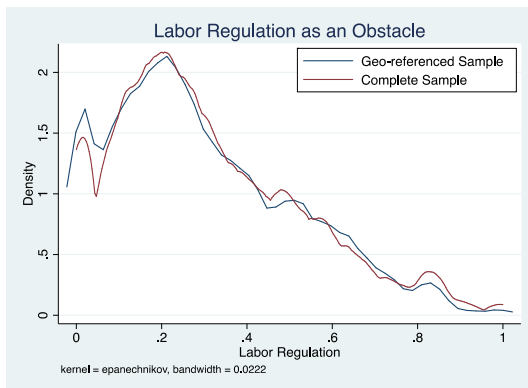
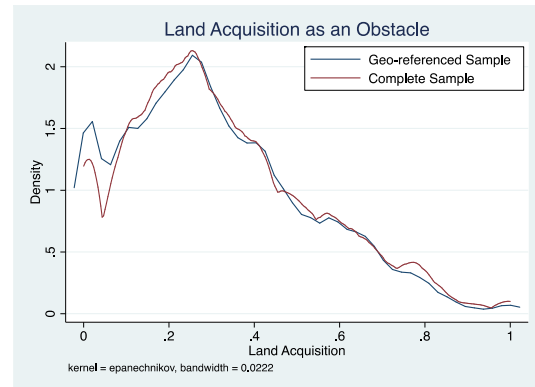
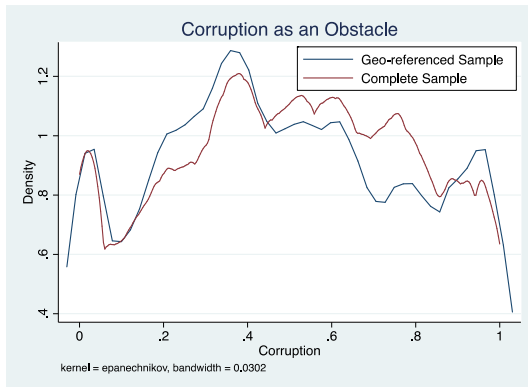
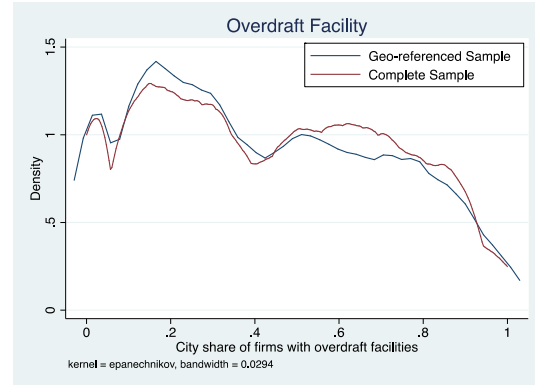
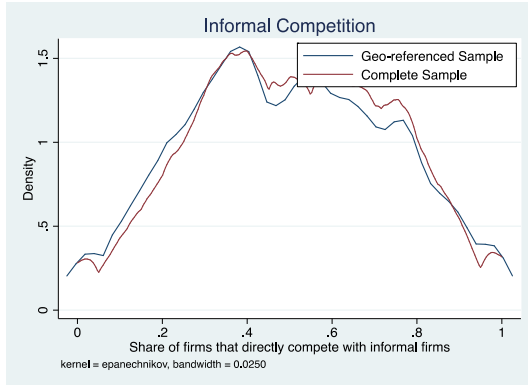
We compare the distribution for the dependent variables and the relevant independent variables for the two samples: complete sample and geo-referenced firms.

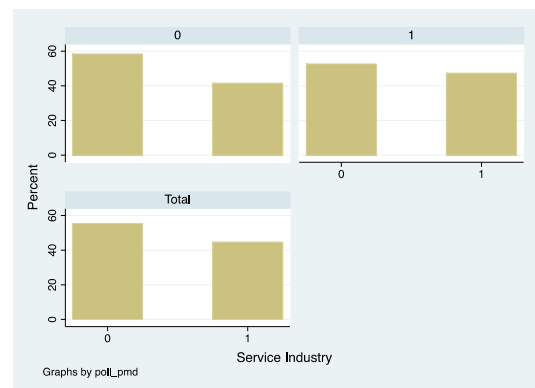
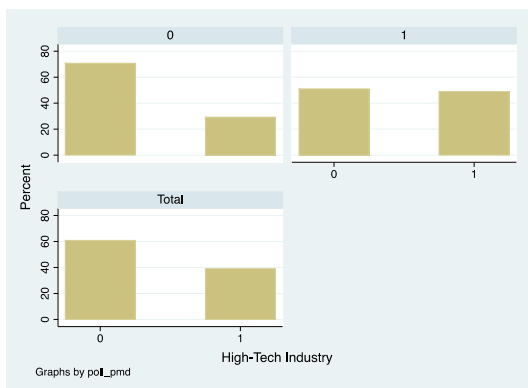
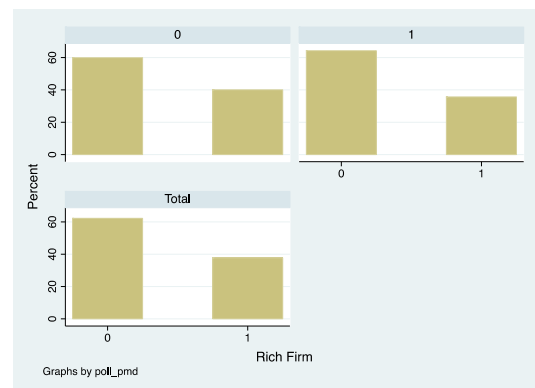
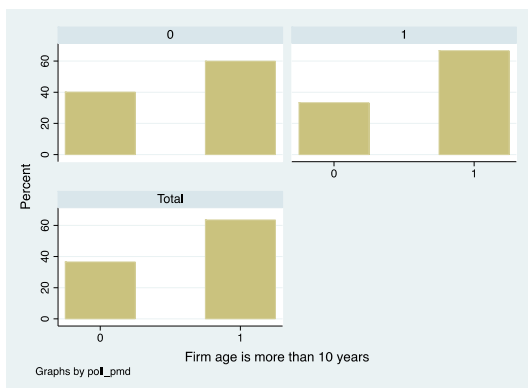
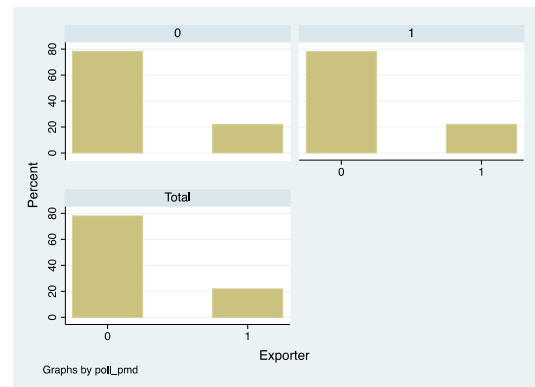
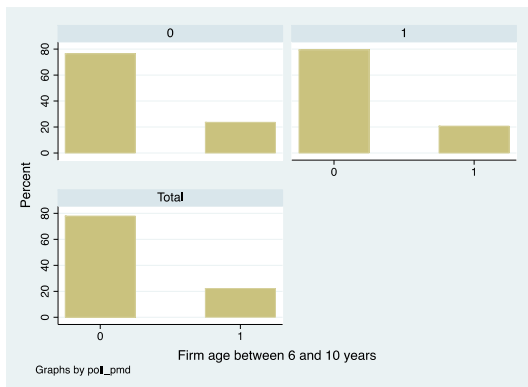
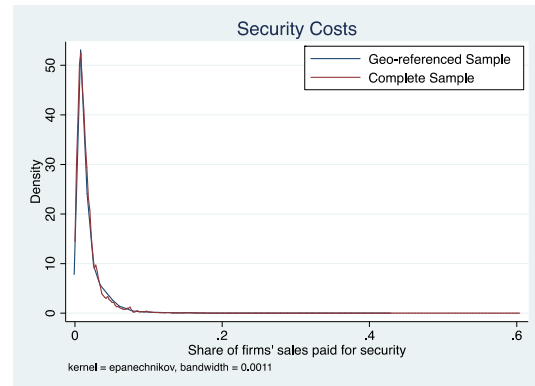
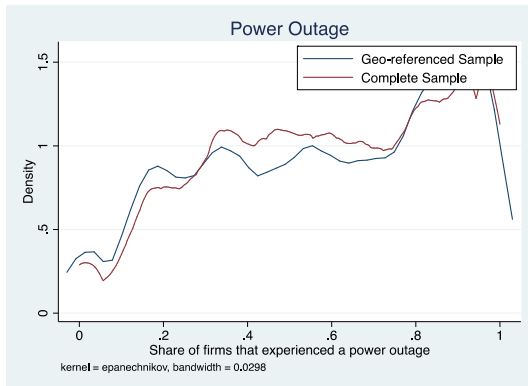
Dependent Variable:

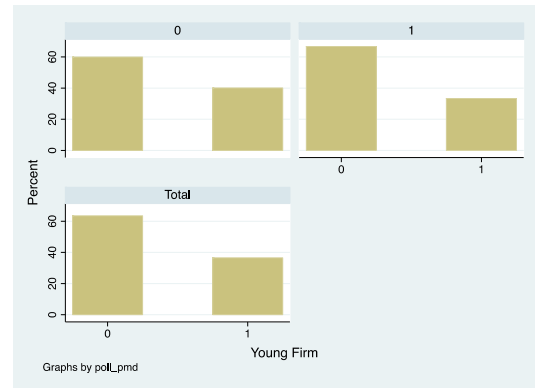
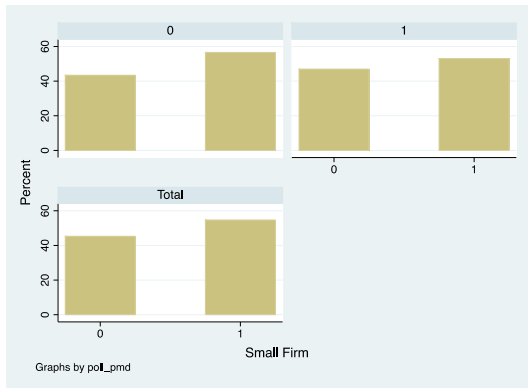


Independent Variables:









Annex II

As a robustness check, we re-run the regression for African firms using splines, finding the results presented in Table A1.

Table A1. Pollution Effects on African Firms – Model Specification using splines

	L-growth		LP-growth	
	coef	se	coef	se
Security Cost	-0.157	(0.134)	-0.167	(0.331)
Corruption obstacle	-0.0402 [×]	(0.0181)	-0.173 [×]	(0.0677)
Overdraft facility	-0.0131	(0.0177)	0.113 [×]	(0.0533)
Trade credit	-0.0254	(0.0280)	0.161	(0.0939)
Skilled labor obstacle	0.0436	(0.0222)	0.0444	(0.0853)
Labor regulation obstacle	0.0336	(0.0237)	-0.179 [*]	(0.0625)
Tax rate obstacle	0.00170	(0.0171)	0.113	(0.0775)
Land access obstacle	-0.0292	(0.0198)	0.0700	(0.0663)
Outage	0.0807 ^{**}	(0.0193)	-0.111	(0.0822)
Web Intensity	0.0241	(0.0186)	0.0706	(0.0695)
In Big City	0.00988	(0.00764)	-0.0251	(0.0278)
Capacity agglomeration	0.0611	(0.0508)	0.416 [×]	(0.157)
Inf competition	-0.0766 ^{**}	(0.0170)	0.0301	(0.0643)
<i>PM 2.5 (between 4 and 10)</i>	-0.00286	(0.00217)	-0.0384 ^{**}	(0.00787)
<i>PM 2.5 (between 10 and 17)</i>	0.0295 [×]	(0.0122)	0.166 ^{**}	(0.0434)
<i>PM 2.5 (between 17 and 31)</i>	-0.0686 [×]	(0.0274)	-0.312 [*]	(0.101)
Other controls	Yes		Yes	
Industry dummies	Yes		Yes	
Observations	4,563		2,742	
Adj. R squared	0.168		0.483	

[×], ^{*}, ^{**} represent statistical significance at the 10, 5, and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.

Other controls include year dummies, missing dummy for BE variables, and base controls.

In another iteration, we re-run the original regressions using the logarithm of the level of the dependent variable, for both, employment and productivity. We find similar results (Table A2 and A3).

Table A2. Pollution Effects on Firm Performance (Global) – Model Specification using levels

	Employment (log)		Productivity (log)	
	coef	se	coef	se
Security Cost	-0.522 [*]	(0.224)	0.186	(0.746)

Corruption obstacle	-0.0868***	(0.0238)	0.0783	(0.0590)
Overdraft facility	0.0389	(0.0198)	0.116*	(0.0576)
Trade credit	-0.0300	(0.0281)	0.161*	(0.0708)
Skilled labor obstacle	0.00245	(0.0225)	-0.0342	(0.0575)
Labor regulation obstacle	0.0390	(0.0253)	0.0164	(0.0678)
Tax rate obstacle	-0.0120	(0.0246)	0.0148	(0.0605)
Land access obstacle	-0.0310	(0.0242)	-0.00274	(0.0739)
Outage	0.0205	(0.0217)	-0.0601	(0.0576)
Web Intensity	0.0589**	(0.0202)	0.122*	(0.0552)
In Big City	0.0125	(0.0104)	-0.0174	(0.0214)
Capacity agglomeration	0.0716	(0.0558)	0.0452	(0.116)
Inf competition	-0.0405*	(0.0199)	-0.0196	(0.0522)
<i>PM 2.5</i>	-0.000741	(0.000427)	0.0109**	(0.00380)
<i>PM 2.5²</i>			-.0000913**	(0.0000324)
Other controls	Yes		Yes	
Industry dummies	Yes		Yes	
Observations	35,736		26,910	
Adj. R squared	0.931		0.745	

×, *, ** represent statistical significance at the 10, 5, and 1 percent levels.

Heteroskedasticity-corrected standard errors clustered at the city level.

Other controls include year dummies, missing dummy for BE variables, and base controls.

Table A3. Pollution Effects on African Firms – Model Specification using levels

	Employment (log)		Productivity (log)	
	coef	se	coef	se
Security Cost	-0.506	(0.399)	-1.083	(1.070)
Corruption obstacle	-0.131*	(0.0555)	-0.610*	(0.248)
Overdraft facility	-0.0503	(0.0553)	0.398	(0.233)
Trade credit	-0.0856	(0.0876)	0.313	(0.323)
Skilled labor obstacle	-0.0503	(0.0553)	0.398	(0.233)
Labor regulation obstacle	0.113	(0.0736)	-0.340	(0.256)
Tax rate obstacle	0.00496	(0.0543)	0.280	(0.299)
Land access obstacle	-0.0895	(0.0614)	0.168	(0.301)
Outage	0.250***	(0.0593)	-0.377	(0.348)
Web Intensity	0.0776	(0.0585)	0.252	(0.278)
In Big City	0.0308	(0.0237)	-0.0918	(0.109)
Capacity agglomeration	0.160	(0.159)	1.711**	(0.619)
Inf competition	-0.232***	(0.0527)	0.0327	(0.232)
<i>PM 2.5 (between 4 and 10)</i>	-0.0250	(0.0143)	-0.302***	(0.0699)
<i>PM 2.5 (between 10 and 17)</i>	0.00213*	(0.000936)	0.0178***	(0.00455)
<i>PM 2.5 (between 17 and 31)</i>	-0.0000425*	(0.0000175)	-0.000295**	(0.0000878)
Other controls	Yes		Yes	

Industry dummies	Yes	Yes
Observations	4,563	2,742
Adj. R squared	0.874	0.495

Finally, we include a test of sorting of firms size and cities, in Table A4.

Table A4. A Check on Sorting of Firms Size and Cities

	Firm Size		Firm Size	
	coef	se	coef	se
In Big City	0.07	0.027	0.031	0.020
Country Dummies	no	no	yes	yes
N	103,038		103,038	
r2_a	0.0014		0.0726	

Coefficients show the correlation between firm size and In Big City dummy (estimated by regressing firm size on In Big City dummy, using OLS. Firm size includes small firms (<20 employees), medium firms (between 20 and 99 employees) and large firms (100 employees or more). Results also hold when using a dummy for large firms as a dependent variable. The second model includes country fixed effects. Standard errors are clustered at the city level.

Annex III – List of countries

	Country	Obs	Obs with PM2.5 data	Region	Income Group
1	Afghanistan	901	373	SAR	Low Income
2	Albania	581	324	ECA	Upper-middle
3	Angola	737		AFR	Upper-middle
4	Antigua and Barbuda	149		HI_nonOECD	High income
5	Argentina	2,068	1,025	LAC	High income
6	Armenia	719	354	ECA	Lower-middle
7	Azerbaijan	763	385	ECA	Upper-middle
8	Bahamas, The	142		HI_nonOECD	High income
9	Bangladesh	2,937	1,433	SAR	Lower-middle
10	Barbados	132		HI_nonOECD	High income
11	Belarus	618	357	ECA	Upper-middle
12	Belize	150		LAC	Upper-middle
13	Benin	145		AFR	Low Income
14	Bhutan	501	253	SAR	Lower-middle
15	Bolivia	955	349	LAC	Lower-middle
16	Bosnia and Herzegovina	701	357	ECA	Upper-middle
17	Botswana	607		AFR	Upper-middle
18	Brazil	1,783		LAC	Upper-middle
19	Bulgaria	1,584	291	ECA	Upper-middle
20	Burkina Faso	380		AFR	Low Income
21	Burundi	426	156	AFR	Low Income
22	Cameroon	361		AFR	Lower-middle
23	Cape Verde	147		AFR	Lower-middle
24	Central African Republic	146	141	AFR	Low Income
25	Chad	142		AFR	Low Income
26	Chile	2,025	922	HI_OECD	High income
27	China	2,655	2,531	EAP	Upper-middle
28	Colombia	1,937	935	LAC	Upper-middle
29	Congo, Dem. Rep.	1,216	520	AFR	
30	Congo, Rep.	114		AFR	Lower-middle
31	Costa Rica	526	526	LAC	Upper-middle
32	Cote d'Ivoire	515		AFR	Lower-middle
33	Croatia	969	355	HI_nonOECD	High income
34	Czech Republic	471	243	HI_OECD	High income
35	Djibouti	240	240	MNA	Lower-middle
36	Dominica	150		LAC	Upper-middle
37	Dominican Republic	332		LAC	Upper-middle

38	Ecuador	1,012	362	LAC	Upper-middle
39	Egypt, Arab Rep.	2,815	2,812	MNA	Lower-middle
40	El Salvador	1,045	353	LAC	Lower-middle
41	Eritrea	167		AFR	Low Income
42	Estonia	523	269	HI_OECD	High income
43	Ethiopia	623	622	AFR	Low Income
44	Fiji	156		EAP	
45	Gabon	157		AFR	Upper-middle
46	Gambia, The	174		AFR	Low Income
47	Georgia	716	352	ECA	Lower-middle
48	Ghana	685	683	AFR	Lower-middle
49	Grenada	152		LAC	Upper-middle
50	Guatemala	1,105	583	LAC	Lower-middle
51	Guinea	223		AFR	Low Income
52	Guinea-Bissau	157		AFR	Low Income
53	Guyana	163		LAC	Lower-middle
54	Honduras	768	333	LAC	Lower-middle
55	Hungary	574	289	ECA	High income
56	India	9,088	9,087	SAR	Lower-middle
57	Indonesia	1,426		EAP	Lower-middle
58	Iraq	751	751	MNA	Upper-middle
59	Israel	480	480	HI_OECD	High income
60	Jamaica	344		LAC	Upper-middle
61	Jordan	573	573	MNA	Upper-middle
62	Kazakhstan	1,120	586	ECA	Upper-middle
63	Kenya	1,402	745	AFR	Lower-middle
64	Kyrgyz Republic	496	264	ECA	Lower-middle
65	Lao PDR	628		EAP	Lower-middle
66	Latvia	585	327	HI_nonOECD	
67	Lebanon	552	551	MNA	Upper-middle
68	Lesotho	137		AFR	Lower-middle
69	Liberia	149		AFR	Low Income
70	Lithuania	519	252	HI_nonOECD	
71	Macedonia, FYR	720	359	ECA	Upper-middle
72	Madagascar	745	266	AFR	Low Income
73	Malawi	627	476	AFR	Low Income
74	Mali	811		AFR	Low Income
75	Mauritania	363	126	AFR	Lower-middle
76	Mauritius	381		AFR	Upper-middle
77	Mexico	2,915	1,377	LAC	Upper-middle
78	Micronesia, Fed. Sts.	68		EAP	Lower-middle

79	Moldova	709	350	ECA	Lower-middle
80	Mongolia	710	349	EAP	Upper-middle
81	Morocco	398	398	MNA	Lower-middle
82	Mozambique	479		AFR	Low Income
83	Myanmar	629	629	EAP	Lower-middle
84	Namibia	877	548	AFR	Upper-middle
85	Nepal	849	481	SAR	Low Income
86	Nicaragua	800	323	LAC	Lower-middle
87	Niger	148		AFR	Low Income
88	Nigeria	4,243	2,334	AFR	Lower-middle
89	Pakistan	1,953	341	SAR	Lower-middle
90	Panama	951	353	LAC	Upper-middle
91	Paraguay	952	348	LAC	Upper-middle
92	Peru	1,612	980	LAC	Upper-middle
93	Philippines	1,285		EAP	Lower-middle
94	Poland	896	493	HI_OECD	High income
95	Romania	1,036	530	ECA	
96	Russian Federation	5,100	4,128	HI_nonOECD	High income
97	Rwanda	443	231	AFR	Low Income
98	Samoa	105		EAP	
99	Senegal	1,086	579	AFR	Lower-middle
100	Sierra Leone	72		AFR	Low Income
101	Slovak Republic	511	262	HI_OECD	High income
102	Slovenia	521	257	HI_OECD	High income
103	South Africa	935		AFR	Upper-middle
104	Sri Lanka	585		SAR	Lower-middle
105	St. Kitts and Nevis	149		HI_nonOECD	High income
106	St. Lucia	150		LAC	Upper-middle
107	St. Vincent and the Grenadines	153		LAC	Upper-middle
108	Sudan	649	649	AFR	Lower-middle
109	Suriname	152		LAC	Upper-middle
110	Swaziland	307		AFR	Lower-middle
111	Sweden	591	591	HI_OECD	High income
112	Tajikistan	691	341	ECA	Lower-middle
113	Tanzania	973	554	AFR	Low Income
114	Togo	150		AFR	Low Income
115	Tonga	150		EAP	Upper-middle
116	Trinidad and Tobago	364		HI_nonOECD	High income
117	Tunisia	592	592	MNA	Upper-middle
118	Turkey	2,284	1,261	ECA	Upper-middle
119	Uganda	1,226	667	AFR	Low Income

120	Ukraine	1,030	216	ECA	Lower-middle
121	Uruguay	1,209	587	HI_nonOECD	High income
122	Uzbekistan	754	388	ECA	Lower-middle
123	Vanuatu	124		EAP	Lower-middle
124	Venezuela	302	301	LAC	High income
125	Vietnam	1,033		EAP	Lower-middle
126	West Bank and Gaza	424	424	MNA	
127	Yemen, Rep.	819	816	MNA	Lower-middle
128	Zimbabwe	596	592	AFR	Low Income