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Delegation of environmental regulation and perceived corruption in South Africa ☆

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ABSTRACT

I study the drivers of a reduction in the discretionary power of environmental inspectors and the impact that such reduction has on firms' perceptions. I examine the transition from the Air Pollution Protection Act of 1965 to the Air Quality Act of 2005 (AQA), a change from full to partial delegation of regulation in South Africa. By constructing a principal–agent model, I propose a theoretical explanation for why a society would restrict environmental inspectors' discretionary power. I then use my theoretical model to discuss the air quality regulation transition in South Africa. I suggest that the transition might have occurred because of increases in inspectors' rent-seeking motivation and capacity of appropriating rents after the end of Apartheid. Using microdata, I run difference-in-differences models in a two-period panel with 191 South African firms to show that the implementation of the AQA decreases affected firms' perceived corruption, but does not change perceptions on obtaining licences and on the functioning of courts. My work indicates that national governments in developing countries should consider the characteristics of the agents who are implementing regulation, and the system they are embedded in, when designing environmental regulation.

1. Introduction

As the demand for environmental quality increases in developing countries, their governments face challenges in reducing emissions (Jalan and Somanathan, 2008; Greenstone and Hanna, 2014; Oliva, 2015, and Hanna and Oliva, 2015). This discrepancy arises for several reasons. First, governments in developing countries may prioritize economic growth over environmental quality. Second, the environmental regulations they draft often do not provide the right incentives for firms to lower emissions. A third, less explored, factor relates to how environmental regulations interact with the characteristics of the agents responsible for enforcing them. Often, national governments overlook the preferences of environmental inspectors and the systems within which they operate, which can hinder effective regulation enforcement.[1]

Legislators often find it difficult to design regulations that give inspectors just the right amount of discretion. Too much discretion, combined with inefficient incentives, can lead to societal costs like corruption[2], whereas no discretion at all can lead to excessive

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[1] For a discussion on the determinants of environmental regulation at the country level, see Galinato and Chouinard (2018).

[2] I define corruption as "an act where public office power is used for personal gain in a way that breaks the rules of the game" (Jain, 2001 and Aidt, 2003).

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monitoring costs and poor environmental outcomes (Banerjee et al., 2012).[3] This challenge stems from two main issues. First, inspectors and legislators often have misaligned preferences—that is, they value society's welfare differently. Second, it is impossible for legislators to perfectly monitor inspectors' actions (Dhaliwal and Hanna, 2017 and Olken and Pande, 2012).

This paper is divided into two sections. In the first section, I provide a theoretical explanation for why legislators might limit the discretionary power of environmental inspectors. I explore how the characteristics of inspectors and the system they operate within influence the type of delegation of regulation that is implemented. I demonstrate that society benefits from partial delegation of regulation when there is either an increase in the misalignment of preferences between inspectors and legislators, or an increase in inspectors' capacity to appropriate rents. I then use this model to discuss the shift from full to partial delegation of air quality regulation in South Africa in 2005.

In the second part of the paper, I empirically assess the effects of this transition on the perceptions of South African firms. The findings indicate that reducing the discretionary power of air quality inspectors lowers firms' perceptions of corruption, but it does not alter their views on obtaining licenses or on the operations of courts. This suggests that, for the case of South Africa, reducing inspectors' discretion may have lowered corruption levels related to environmental regulation.

During the Apartheid era, air quality regulation in South Africa was governed by the Atmospheric Pollution Prevention Act (APPA), which granted significant monitoring and enforcement powers to inspectors[4]. However, it lacked strong legal guidelines for emissions. In 2005, the democratic government replaced APPA with the Air Quality Act (AQA), which sharply limited inspectors' discretion through increased supervision of their actions. This shift from APPA to AQA marked a move from a system of full regulatory delegation to one of partial delegation (see e.g. Cooter, 1996; Rose-Ackerman, 1975; Boyer and Laffont, 1999, and Epstein and O'halloran, 1994). Full delegation occurs when environmental inspectors have complete discretion to enforce and penalize polluting firms, while partial delegation occurs when this discretion is restricted by heightened supervision.

Building on earlier research (Nilssen and Kundu, 2018; Duflo et al., 2018, and Laffont and Tirole, 1991), I develop a principal–agent model where a bureaucrat (inspector) regulates a polluting firm. I assume that the bureaucrat's preferences partially align with those of the consumers (legislators) and are partially self-driven. The misalignment between these preferences is termed the bureaucrat's rent-seeking motivation. My model features two possible delegation regimes.

In the first regime, the consumer does not grant discretionary power to the bureaucrat and selects the emissions contract independently (partial delegation of regulation). In the second regime, the consumer gives power to the bureaucrat, who is able to observe the producer's pollution type and chooses the emissions contract (full delegation of regulation). I demonstrate that the characteristics of the bureaucracy and the system within which they function determine how much discretionary power the consumer entrusts to the bureaucrat. The consumer only delegates power to the bureaucrat when the advantages of her services (being able to identify the producer's pollution type) outweigh the negative impacts (increased pollution and rent appropriation) she causes.[5]

Reflecting on my theoretical findings, I discuss the change in air quality regulation in South Africa. I propose that the expansion and restructuring of South Africa's public service following the end of Apartheid likely initiated the shift from the APPA to the AQA. The swift inclusion of previously marginalized groups into the public service may have exacerbated the mismatch between society's environmental preferences and those of the average inspector (Hyslop, 2005). Furthermore, this integration could have increased the government's cost of monitoring inspectors, corrupt behavior. According to this perspective, these two developments – greater misalignment and enhanced capacity for rent appropriation – might have led legislators to limit the discretionary power of inspectors.

I then investigate empirically the impact of this transition on firms' perceptions. Using a panel of 191 South African firms from the World Bank Enterprise Survey across, I employ a difference-in-differences approach within a linear probability model, incorporating time and firm fixed effects along with several control variables. My findings reveal that the implementation of the AQA reduces the likelihood of affected firms perceiving corruption as a business obstacle by 58 percentage points, compared to firms not impacted by the regulation.[6] However, the AQA does not alter firms' perceptions regarding the acquisition of licenses and permits, or the functioning of judicial courts. These last two findings further support that, up to 2007, the primary effect of the AQA has been to limit inspectors' discretionary power. Note that I do not directly test the predictions of my theoretical model, as the available data does not permit it. Instead, the framework provided by the model serves as a guide for interpreting the empirical results.

My contribution to the literature is twofold. First, I illustrate how changes in the composition of the body of inspectors, along with the system they operate within, influence the design of environmental regulation. Second, I empirically demonstrate that reducing the discretionary power of regulators can decrease firms' perceptions of corruption. My findings suggest that national governments with limited resources should focus on aligning the environmental preferences of their inspectors with those of society. Additionally, investing in cost-effective supervision methods, such as mutual monitoring across different government sectors, could enhance economic efficiency by reducing perceived corruption.[7]

[3] There is a debate about whether regulatory discretion aids or obstructs environmental regulation enforcement. The prevailing opinion is that too much discretion can lead to inefficient outcomes (Zhang et al., 2018; Leaver, 2009; Burgess et al., 2012; Jia, 2017, and Damania, 2002). However, recent studies have shown that discretion can be beneficial (Duflo et al., 2018). Inspectors and local authorities might use their discretionary power to more effectively target polluting firms, thus reducing emissions.

[4] In South Africa, environmental inspectors responsible for air quality are referred to as air quality officials. I use the terms inspectors and air quality officials interchangeably.

[5] It is important to note that my model seeks a balance between simplicity and informativeness. Specifically, I abstract from more complex models of corrupt behavior, such as hierarchical models of corruption (see, e.g., Bac, 1996), which might better reflect reality but would require additional assumptions and reduce tractability.

[6] "Perceived corruption" is defined as the probability of listing corruption as an obstacle to a firm's operations.

This paper is divided as follows. The next section relates this work to the existing literature. Section 3 outlines the main characteristics of air quality regulation in South Africa. In Section 4, I present my theoretical model. Section 5 presents my empirical analysis, with main results. Section 6 presents my robustness checks. I conclude this paper in Section 7.

2. Related literature

This work contributes to the literature exploring the relationship between environmental regulation, discretionary power, and corruption (Damania, 2002; Duflo et al., 2013, 2018; Oliva, 2015; Pless and Fell, 2017; Dincer and Fredriksson, 2018, and Zhang et al., 2018). Similar to Damania (2002), I examine the link between corruption and the design of environmental regulation. However, my study diverges by not focusing on pollution control; instead, it investigates how changes in the characteristics of environmental inspectors might lead to alterations in their discretionary power.

I highlight three recent studies from this field. Duflo et al. (2018) investigate how variations in the discretionary power of environmental regulators impact enforcement in India. They discover that discretionary power enables regulators to target firms more effectively, aligning with one of my theoretical predictions. Although full delegation allows inspectors to retain a portion of emissions compensation, it also empowers them to impose stricter penalties on major polluters, benefiting society by increasing the pollution compensation received. Zhang et al. (2018) explore the effect of multiple governance levels on environmental enforcement. They find that central supervision enhances local enforcement and subsequently reduces emissions, supporting my theory that partial delegation could lower overall emissions. Lastly, Pless and Fell (2017) examine the influence of bribes for electricity connections on power reliability. Using data from 118 countries, they demonstrate that the likelihood of bribing for an electricity connection correlates with increased power outages. While this study also addresses corruption at the firm level, it differs from mine by focusing on instances where firms primarily drive corrupt behavior.

My theoretical framework is grounded in the classic literature that studies the principal–agent problem (Laffont and Tirole, 1991 and Boyer and Laffont, 1999). It draws inspiration from the model developed by Nilssen and Kundu (2018), which analyzes the delegation of environmental regulation. Their model allows the principal to implement various regulatory regimes – characterized by the discretionary power granted to agents – based on agent characteristics and the anticipated rent appropriation. My model adopts a similar approach but distinguishes between two specific types of delegation: partial and full delegation. In partial delegation, the consumer does not grant discretionary power to the bureaucrat to select the optimal contract; in full delegation, the bureaucrat is tasked with determining both the emissions compensation and the emissions level.

I provide two theoretical contributions. First, I formally define the degree of misalignment between the preferences of the agent and the principal, which allows me to analyze how the bureaucrat's characteristics influence the design of regulation. Second, I apply the mechanisms described in my model to discuss the potential drivers behind the significant shift in air quality regulation that occurred in South Africa in 2005.

This paper also engages with the literature examining the relationship between corruption, efficiency, and the composition of the public service in South Africa (Lodge, 1998; Posel, 1999; Hyslop, 2005, and Fernandez and Lee, 2016). Consistent with these studies, I contend that the post-Apartheid restructuring of the government heightened the misalignment between environmental inspectors' preferences and those of society; and also increased inspectors' ability to extract rents from the regulatory system. These two developments likely triggered the shift in the delegation regime observed in South Africa.

3. Air quality regulation in South Africa

3.1. The atmospheric pollution prevention act of 1965

Concerns about air quality emerged in South Africa during the 1950s (Republic of South Africa, 2014; Halliday, 1958, and Quass, 1953), driven by the rapid expansion of heavy industries which led to deteriorating air conditions in urban and industrial regions. There was a general consensus that some regulation was needed and, in 1965, the Atmospheric Pollution Prevention Act (APPA) was introduced.[8]

The APPA targeted industrial pollution and adopted a traditional command-and-control approach (Republic of South Africa, 1965 and Republic of South Africa, 2014). Industries identified as major polluters were mandated to obtain a license to operate. This license was issued by the chief air pollution officer, a centralized authority at the national level. After the issuance of the license, local authorities, who appointed air quality officials to perform the duties, were tasked with its enforcement at the municipal level.

The implementation of the APPA, both nationally and locally, was governed by the principle of "best practicable means" defined by the Act as measures that are technically feasible and economically viable, while considering the well-being of individuals in nearby areas. In practical terms, this allowed the chief officer at the national level considerable discretionary power in deciding whether to issue a license to an industry (Anonymous air quality official 1, personal communication, November, 2022). Without

[7] These results align with prior research indicating that perceived corrupt behavior – as reported by firms – increases with governmental complexity (Fan et al., 2009). Other studies on environmental regulation in developing countries have investigated its impact on employment in China (Liu et al., 2021), and its influence on foreign direct investment in China (Cai et al., 2016) and South Korea (Chung, 2014).

[8] The academic literature on air quality regulation and its implementation in South Africa is limited. The studies cited in this section have been supplemented by four semi-structured interviews with air quality officials from the Department of Environmental Affairs of the South African government.

national or regional emission standards, the chief officer had the autonomy to establish specific emission guidelines for each license tailored to the industrial process involved. As Shabala (2008) notes, these guidelines lacked a legal foundation and were often not enforceable.

At the local level, air quality officials also adhered to the best practicable means principle when ensuring compliance with the guidelines specified in the licenses (Anonymous air quality official 1, personal communication, November, 2022). They were tasked with enforcing penalties for non-compliance, ranging from fines to imprisonment (Rabie, 1973). However, most air quality officials lacked both the technical equipment and expertise required to conduct detailed air pollution analyses. Moreover, considering the extensive number of industries and industrial processes across the country, there was minimal communication between these officials and the chief air pollution officer.[9] Consequently, there was little oversight over the actions of these officials and the penalties they imposed (Anonymous air quality official 2, personal communication, November, 2022). Due to these factors, in practice, local air quality officials also possessed significant discretionary power to implement license guidelines and to determine the enforcement actions against polluting industries.

3.2. The Air Quality Act of 2004

By the 1990s, it had become evident that the APPA was insufficient for effectively reducing air pollution in South Africa (Naiker et al., 2012 and Bethlehem and Goldblatt, 1997). The adoption of the new Constitution in 1996 set the stage for a comprehensive reform of environmental laws. This reform process commenced in 1998 with the enactment of the National Environmental Management Act (NEMA).

The NEMA establishes fundamental principles for environmental management and implementation (Naiker et al., 2012 and Republic of South Africa, 1998). Two of these principles are particularly notable. First, the NEMA advocates for cooperative governance, ensuring alignment of policies, plans, and projects across the three spheres of government—national, provincial, and local.[10] Second, the NEMA establishes procedures that enable civil society to monitor and participate in environmental governance (Nel and du Plessis, 2001). For instance, it mandates the publication of regional environmental quality measures, such as air quality, by authorities.

Following the NEMA, the Air Quality Act (AQA) (Republic of South Africa, 2005) was implemented in September 2005, comprehensively reforming the legislation that regulates air quality in South Africa. Grounded in a holistic approach to environmental law, the AQA decentralizes the management and implementation of air quality, establishes ambient and emission standards, and provides mechanisms for measuring and evaluating progress.

The AQA divides its provisions into four main activity groups.

Standards setting. The Act mandates the establishment of national ambient air quality standards and emissions standards for industries, which were set in 2009 and 2010, respectively.

Monitoring. The AQA requires regular monitoring of ambient air quality at the local level. Local environmental offices must periodically publish air quality indicators for their regions. Additionally, the Act enforces a mutual supervision of monitoring objectives across the three governmental levels. This approach, known as the shared responsibility approach, involves setting targets and monitoring their progress. Moreover, supervision at the local level is intensified, particularly regarding the regulation of industrial emissions, with air quality officials responsible for it.

Control strategy. The AQA overhauls the APPA's licensing system by eliminating the role of the chief air pollution officer and decentralizing licensing to the provincial or district levels. Provincial and district air quality officials are now responsible for granting licenses, while local air quality officials, typically based in municipalities, are tasked with industry inspections and the daily implementation of emission guidelines.

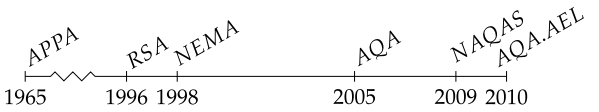
The AQA also specifies a list of sectors along with their respective emission standards. Industries on this list must apply for an Atmospheric Emission License (AEL), though this list was only introduced in an amendment to the AQA in 2010 (Republic of South Africa, 2010).

Progress management. The Act outlines mechanisms for reporting, such as the annual performance report, to assess the progress of each administrative area. These reports are made available to the public.

Fig. 1 displays a historical timeline of the air quality regulation in South Africa.

[9] According to Rabie (1973), in 1973, there were 745 industries involving over 1,000 industrial processes in South Africa that required air quality regulation. At that time, the office of the chief air pollution officer was staffed by only six employees.

[10] The South African government's structure includes national, provincial, and local spheres, with local government further divided into metropolitan, district, and local municipalities. Environmental legislation follows a tiered approach starting with national minimum emissions levels, allowing provincial governments to enforce stricter measures, and permitting municipal authorities to adopt even more stringent regulations (Naiker et al., 2012 and Republic of South Africa, 1996).



APPA: The Atmospheric Pollution Prevention Act;
RSA: The Constitution of the Republic of South Africa;
NEMA: The National Environmental Management Act;
AQA: Air Quality Act;
AQA.AEL: Atmospheric Emission Licences.
NAQAS: National Air Quality Ambient Standards.

Fig. 1. Air quality regulation in South Africa.
Note: this figure illustrates the main air quality legislation that has been approved from 1965 to 2010. There have been several amendments to the AQA of 2004. See Glazewski (2005) for a complete list.

3.3. From full to partial delegation of air quality regulation

I interpret the transition from the APPA to the AQA as a shift from full to partial delegation of air quality regulation. The critical factor in this transition is the discretionary power held by air quality officials and the chief air pollution officer. Under full delegation, these authorities largely made pivotal air quality decisions independently. They issued operational licenses to industries and imposed penalties based on the best practicable means, effectively determining acceptable pollution levels in a given area. In contrast, under partial delegation, their decision-making authority is curtailed. They must adhere to strict, legally sound emission standards, are subject to oversight by various levels of government, and are held accountable by civil society.

However, the reduction in discretionary power is not the only significant change introduced by the AQA. As outlined in the previous subsection, the AQA encompasses a comprehensive regulatory package that fundamentally alters and restricts the behavior of environmental authorities. A thorough examination of all these changes exceeds the scope of this paper. Fortunately, between the AQA's enactment in 2005 and the end of my sample period in 2007, only two major changes were fully implemented: the dismantling of the chief pollution officer (power decentralization) and the enhanced supervision of air quality officials' activities. Other modifications, such as the establishment of air pollution standards, were not put into effect until after 2007.

4. Theoretical model

I now develop a principal–agent model to explore the factors driving changes in the type of regulatory delegation in an economy. The goal is to determine when it is optimal for a society to limit the discretionary power of environmental inspectors.

The type of delegation that the consumer (principal) implements depends on the characteristics of the bureaucrat (agent) and the institutional context they operate within. The bureaucrat is driven by rent-seeking motivations, defined as the degree of preference misalignment between herself and the principal. She also captures a portion of the emissions compensation that flows from the producer to the consumer.

I find that full delegation, where the bureaucrat has discretionary power, is only optimal when the bureaucrat's rent-seeking motivation and capacity for appropriation are sufficiently low. As these parameters increase, the consumer shifts toward partial delegation, restricting the bureaucrat's discretionary power. My model further indicates that this restriction leads to a reduction in the expected perceived corruption by the producer.

4.1. The economy

Consider an economy consisting of a consumer, a producer, and a bureaucrat. The producer manufactures a product that generates a utility $G > 0$ for the consumer. The producer has the option to increase her revenue by elevating emissions $d \geq 0$. However, this increase in emissions requires the producer to pay an emissions compensation $t \geq 0$ to the consumer to offset the environmental impact.

The problem I present investigates how the consumer can optimally design a contract $\alpha = (t, d)$, and how this contract changes with changes in the discretionary power given to the bureaucrat.

The producer's net revenue function is,

$$R(\theta, d, t) = \pi + \theta d - t, \tag{1}$$

where $\pi > 0$ is a constant and θ is a coefficient that converts emissions into extra revenue.[11] θ is a random variable that can take two values, $\theta \in \{\underline{\theta}, \bar{\theta}\}$, with probability υ and $1 - \upsilon$, respectively. The consumer knows θ's probabilities, but not its realized value. I assume that the producer's type θ and choice of emissions intensity is observable and verifiable by the bureaucrat.[12]

[11] θ can be interpreted as the producer's ability to reduce costs by increasing emissions. Her revenue function can be decomposed into a fixed revenue component and a cost function: $cost = K - \theta d + t$ and $revenue = s$; $R(\theta, d, t) = s - K + \theta d - t = \pi + \theta d - t$. The coefficient K is the cost that comes from usual sources of production (e.g., labor or physical capital).

[12] In reality, environmental inspectors might not be able to perfectly observe firms' emissions. However, the main conclusions of the model would still hold if the bureaucrat had a sufficiently large informational advantage over the consumer on identifying a producer's type.

The consumer's utility function is,

$$U_c(t,d) = G - \frac{d^2}{2} + t(1-k), \tag{2}$$

She derives disutility from d but receives a compensation from the producer for emissions arising from production. The consumer designs a regulation contract $\alpha = (t,d)$ that determines this compensation and an emissions level. The bureaucrat, responsible for implementing this contract, is able to appropriate a portion $k \in (0,1)$ of the compensation t for herself.

There are two approaches through which the consumer can design the regulatory contract. Under partial delegation, the bureaucrat is not granted the authority to determine the values of the emission compensation the emission levels. Conversely, full delegation grants the bureaucrat the autonomy to select the specific terms of the contract. With this authority, the bureaucrat, who knows the producer's type, can implement a type-contingent regulatory policy. However, the bureaucrat has a vested interest in the emission compensation t.

The bureaucrat's utility function is,

$$U_b(\theta,t,d) = \beta k t + (1-\beta)U_c(t,d), \tag{3}$$

where $0 < \beta < 1$ measures the bureaucrat's rent-seeking motivation. The parameter β quantifies the degree of misalignment between the preferences of the consumer and the bureaucrat. A β value of 0 indicates perfect alignment of preferences. The coefficient k is interpreted as the bureaucrat's capacity of appropriation, which is seen as a function of the monitoring and control systems in place in this economy. Both β and k are exogenous parameters.

Under perfect information, the consumer implements a type-contingent contract: $d^{PI}(\theta) = \theta$ and $t^{PI}(\theta) = \pi + \theta^2$. Both emission levels and the size of the transfer are ultimately determined by the producer's type.[13]

4.2. Partial delegation

In the scenario where the consumer does not grant discretionary power to the bureaucrat to choose the regulatory contract, the bureaucrat implements the values of t and d as determined by the consumer. Due to the consumer's inability to observe the producer's type, she faces a classic problem of asymmetric information. To address this, she devises two distinct contracts aimed at maximizing her utility while ensuring that the producers participate (participation constraint) and accept the contract intended for their actual type (incentive compatibility constraint).

Given these assumptions, I can state the following result.

Optimal contract PD. Under partial delegation, the following contracts are implemented,

$$\bar{d} = (1-k)\bar{\theta} \quad \bar{t} = \pi + (1-k)\left(\bar{\theta}\underline{\theta} + \frac{(\bar{\theta}-\underline{\theta})^2}{v}\right) \tag{4}$$

$$\underline{d} = (1-k)\left(\underline{\theta} - \frac{1-v}{v}(\bar{\theta}-\underline{\theta})\right) \quad \underline{t} = \pi + (1-k)\left(\underline{\theta}^2 - \frac{1-v}{v}(\bar{\theta}-\underline{\theta})\underline{\theta}\right) \tag{5}$$

Proof. See Appendix A.

The variables $\underline{d}$, $\bar{d}$, $\underline{t}$ and $\bar{t}$ denote emissions and emissions compensation for the low and high types. Apart from the fraction appropriated k, there is no distortion on the amount of emissions of the high type; and the distortion at the bottom is a function of the relative likelihood of encountering the low type.

4.3. Full delegation

I now turn to the case in which the consumer gives discretionary power to the bureaucrat to choose the regulatory policy. The bureaucrat observes the producer's type and chooses t and d to maximize her utility function.

Optimal contract FD. Under full delegation, the bureaucrat implements the following contract,

$$d^{FD} = \theta H \quad t^{FD} = \pi + \theta^2 H, \tag{6}$$

where $H = \left(1 - k + \frac{\beta k}{1-\beta}\right)$.

Proof. See Appendix A.

H is interpreted as the degree of distortion generated by giving discretionary power to the bureaucrat. This analysis indicates that under full delegation, emission levels will invariably exceed those of the perfect information scenario if the bureaucrat's rent-seeking motivation is sufficiently high—that is, if $\beta > 1/2$ then $H > 1$ and the $d^{FD} > d^{PI}$. Unlike partial delegation, in which emission levels depend on firms' characteristics and the system they are in, environmental quality under full delegation depends on the characteristics of the bureaucrat.

[13] See Appendix A for the proof.

4.4. Equilibrium outcome

I now examine how the choice between these two types of delegation changes with the parameters β and k. The consumer chooses partial delegation whenever the following inequality holds,

$$E(U_c(t^{PD}, d^{PD})) > E(U_c(t^{FD}, d^{FD})), \tag{7}$$

where $E(.)$ is the expected value operator. By plugging into expression (7) the equilibrium values for emissions d and emissions compensation t, I derive the following proposition.

Proposition 1. The consumer favors partial delegation of regulation whenever $(\beta, k) > (\bar{\beta}, \bar{k})$.

Proof. See Appendix A.

The consumer withholds discretionary power from the bureaucrat when both the rent-seeking motivation and the capacity for rent appropriation exceed a specific threshold. If β and k are below this threshold, it is optimal for the consumer to give discretionary power to the bureaucrat. This happens because the consumer benefits from the bureaucrat's ability to see the producer's true type, even if their preferences are not fully aligned. Such benefits include reduced emission levels and higher compensation compared to what would be achieved under partial delegation. However, as β and k rise, these benefits dissipate and it becomes optimal to choose partial delegation.

4.5. Perceived corruption

To study what happens to perceived corruption in these two delegation regimes, I compare the amounts appropriated under full λ^{FD} and partial delegation λ^{PD}. I assume that the producer's perceived corruption μ is an increasing, linear function of the amount appropriated $\lambda = kt$ in the economy, plus a random error term with mean zero.

The producer's perceived corruption is:

$$\mu = a\lambda + \epsilon, \tag{8}$$

where $a > 0$ and $E(\epsilon) = 0$. I can now state my second proposition.

Proposition 2. There will be a reduction in expected perceived corruption when the economy goes from full to partial delegation of regulation if $\beta > \bar{\beta}'$.

Proof. See Appendix A.

Therefore, for a sufficient large β, a transition from full to partial delegation will reduce expected perceived corruption. An important indirect result here is that a change in the delegation regime that is solely generated by an increase in k will not be accompanied by a reduction in expected perceived corruption.

4.6. Discussion – the introduction of the AQA in South Africa

My model provides a framework to understand shifts in an economy's delegation regime. Proposition 1 states that the consumer restricts the bureaucrat's discretionary power in response to increased misalignment of preferences or enhanced capacity for rent appropriation—or both. I apply this theoretical insight to analyze the factors leading to the enactment of the Air Quality Act (AQA) in South Africa in 2005. My discussion is constrained to a theoretical examination due to the lack of empirical data to test the proposition.

I propose that the post-Apartheid expansion of local governments may have heightened the discrepancy in air quality preferences between the society (consumer) and air quality officials (bureaucrat), as well as augmented the officials' ability to appropriate rents. These dynamics likely contributed to the observed transition in the air quality regulation regime.

Local government expansion. Since transitioning to a non-racial democracy in 1994, South Africa has undertaken significant governmental reform. Communities that were previously neglected are now included in the national budget, with improvements in the provision of public goods such as water sanitation and electricity (Siddle and Koelble, 2017 and Naidoo, 2019). This inclusion required considerable investments in local governments, which saw increases in their decision-making authority, operational capabilities, and personnel.[14]

The extent of this expansion is particularly evident in the growth of local government employment. From 2001 to 2009, employment in local governments surged by 39%.[15] A notable aspect of this growth was the increase in managerial positions. According to the *Non-financial Census of Municipalities*, the number of employees at the management level in local governments grew from 3,926 in 2002 to 5,383 in 2005, reaching 12,268 by 2012 (Levy et al., 2021). This represents a 212% increase in the number of local managers over a decade.

[14] The public sector in South Africa comprises: (i) the public service (national and provincial departments), (ii) state-owned enterprises, (iii) local government, and (iv) other institutions, such as universities (Hassen and Altman, 2010). By 2009, local government accounted for 13% of total government employment.

[15] See Fig. 2 in Appendix B for detailed employment figures.

Misalignment of preferences. From 1994 to 2005, the period leading up to the introduction of the AQA, local governments were charged with implementing air quality regulations. As mentioned earlier, the chief air pollution officer was responsible for issuing licenses and setting emission guidelines for industries. Air quality officials at the municipal, metropolitan, and district levels executed these guidelines, often with minimal supervision from other government sectors and the chief officer himself. While specific employment figures for air quality officials from 1994 to 2005 are not available, interviews with air quality officials indicate a significant increase in employment following 1994, mirroring the rise in local managers' employment (Anonymous air quality official 3 and 4, personal communication, November, 2022). Given that both air quality officials and local managers are skilled workers with decision-making authority, the employment trends among local managers can serve as a proxy for understanding the growth in air quality officials' roles.

This rapid expansion likely exacerbated the misalignment between the air quality preferences of society and those of air quality officials. As two officials noted during interviews, a significant portion of the new hires were individuals who "had never worked with environmental quality before, were probably never concerned about it previously, and were not properly trained" (Anonymous air quality official 1 and 3, personal communication, November, 2022). It is reasonable to infer that these newcomers placed less emphasis on air quality compared to the more experienced inspectors.

Capacity for rent appropriation. Determining whether the capacity for rent appropriation among air quality officials increased following the end of Apartheid is challenging. Historians generally depict the pre-1994 Afrikaner bureaucracy as corrupt, though some believe that corruption levels did not change significantly after 1994 (Posel, 1999; Lodge, 1998; Hyslop, 2005). Nonetheless, it is widely acknowledged that the reform of the South African government gave rise to new forms of corruption and eliminated old ones (Shava and Chamisa, 2018). Furthermore, the rapid increase in local employment levels complicated the government's ability to monitor the actions of its newly appointed officials, potentially affecting the oversight of corruption and rent-seeking behaviors.

A potential proxy for measuring the capacity of rent appropriation is the number of cases of financial misconduct recorded in the South African public service.[16] Unfortunately, data for local governments are not available, but trends observed in national and provincial governments could provide insights into how rent appropriation may have varied at the local level. According to the *Public Service Commission Report*, cases of financial misconduct in South Africa increased by more than 160% from 2001 to 2014. This significant rise suggests that the capacity of air quality officials to appropriate rents may have also increased post-Apartheid, potentially influencing the shift in the delegation regime.[17]

Air quality preferences. The discussion thus far indicates that the conditions necessary for a shift in the delegation regime of air quality regulation may have been met in South Africa after 1994. However, an important underlying assumption of my model is that society's preferences regarding emissions remain stable as other variables change. Specifically, this assumption means that the value South Africans – and particularly South African legislators – place on air quality must remain relatively constant over time for Proposition 1 to have explanatory power. If the disutility associated with air pollution were to increase following the establishment of the non-racial democracy, this shift in societal values could also be a contributing factor to the observed changes in the delegation regime.

Unfortunately, there is no data to track the air quality preferences of South Africans over time. Public awareness of air pollution began in the 1950s (Halliday, 1958) and has increased since, but it is unclear whether this increase is due to more information, the accumulation of pollution, or an actual shift in preferences. One indicator that air quality preferences may have remained consistent after the end of Apartheid is the observed "continuity between the environmental management practices of the old and new regimes" (Steyn, 2005) during the initial years of the non-racial democracy. Environmental quality was not a primary concern for the new government, which focused more on addressing unemployment, poverty, and discrimination. Assuming the new government's priorities reflect the preferences of South African citizens, it appears that the importance placed on air quality did not undergo significant changes.

Foreign organizations. Foreign aid organizations such as the United Nations Environment Programme (UNEP), the World Bank, and the European Union (EU) played a key role in providing technical assistance and funding for South Africa's transition to NEMA and later the AQA (Glazewski, 2005 and Nel and du Plessis, 2001). These organizations offered expertise, capacity-building initiatives, and financial resources to help develop air quality management plans and align them with international standards. However, while their support was important, there is no substantial evidence that these organizations exerted direct pressure or initiated the move to change South Africa's air pollution legislation.

5. Empirical analysis

I now examine the impact of the introduction of the AQA on firms' perceptions. I focus on perceived corruption, but also discuss perceptions on licensing and permits, and on courts. I also briefly discuss the impact of the AQA on self-reported corruption. I begin by describing my data, I then outline my identification strategy, and I finish this section with the presentation of the results.

[16] Financial misconduct encompasses ethical, criminal, and financial management offenses, including corruption, fraud, financial mismanagement, and theft (Naidoo, 2017).

[17] See Fig. 3 in Appendix B for detailed statistics.

5.1. Data

Firms. I use data from the World Bank Enterprise Survey (WBES), conducted in South Africa in 2003 and 2007.[18] The WBES surveyed approximately 600 firms in 2003, and 1,000 firms in 2007, but only a fraction of these firms is present in both years. I work with this fraction, which gives me a balanced panel of 191 firms. The main industrial sectors in my sample are: food products, textiles, paper products, chemicals, metals, electrical machinery, transport equipment, and services.

Using a balanced panel aids in mitigating potential issues like sample selection and survival bias, which are significant in my case given the variability in firm participation across different survey waves. Additionally, a balanced panel enhances the consistency and comparability of my estimates by allowing comparisons of firms surveyed both before and after the change in air quality regulation. This approach is also important for using fixed effects, which account for unobserved, time-invariant characteristics, and are an important component of my identification strategy. However, this approach comes with drawbacks—a reduction in statistical power and, perhaps more critically, a limited generalizability of my findings.

My treated group are firms that belong to industries that are classified by the South African government as air polluting industries. The 2010 AQA.AEL lists these industries and the main industrial processes they perform. These are the industries that are affected by the introduction of the AQA. The treated group includes 74 firms.

My control group is composed of 25 firms that belong to non-manufacturer industries and manufacturer industries that emit negligible amounts of air pollution. These are firms that are not affected by the AQA due to the nature of their operations.[19]

Air quality act. The AQA was introduced in September 2005. As I mention above, it was not until 2009 and 2010 that the South African government established minimum air emission standards for industries and ambient air pollution standards, respectively. In this empirical analysis, the specific regulatory change I am examining is the reduction in the discretionary power of inspectors, which resulted from enhanced supervision of inspection activities (as detailed in Section 3); and the decentralization of licensing authority from the chief air pollution officer to local authorities.

Perceived corruption. My main outcome variable is firms' perceived corruption. There are at least two reasons to focus on perceived corruption. First, firms' investment and operational strategies are influenced as much by their perceptions of the business environment as by objective conditions. Perceived corruption can deter investment, increase operational costs, and disrupt fair competition, ultimately hampering economic growth (Mauro, 1995; Aidt et al., 2008, and Dutta and Sobel, 2016). Second, a significant body of literature indicates that perceptions of corruption can reflect actual corruption levels in developing countries (Svensson, 2003 and Olken, 2009). This link suggests that reducing perceived corruption could indicate reductions in actual corrupt practices.

During the period of my analysis, there is no clear trend in the perception of corruption in South Africa. The Corruption Perception Index by Transparency International improved slightly, moving from 4.4 (48th in the world out of 133 countries) to 5.1 (43rd out of 180 countries).[20] However, the World Bank's Control of Corruption index indicates a small deterioration in corruption control, declining from 0.27 to 0.19 between 2003 and 2007.[21]

5.2. Descriptive statistics

In my sample, firms have an average of 270 employees and report average annual sales of approximately 19 million USD (as of 2006), indicating that the sample consists predominantly of large firms. A significant majority, 81%, are privately owned, and on average approximately 6% of them export their products. These firms are distributed across a diverse range of sectors, from "Manufacturing of Food and Beverage" to "Computer Related Activities". They are situated in Cape Town, Durban, Johannesburg, and Port Elizabeth, which are among the most significant cities in South Africa. Table 6 in Appendix C details firms' characteristics and provides the descriptive statistics of my control variables—number of employees, changes in prices, and percentage of exports.

Table 1 displays the descriptive statistics of my dependent variables for the whole sample, treated and control groups.[22][23]

This table suggests an institutional improvement in the business climate over the studied period. First, the percentage of firms identifying corruption as an obstacle decreased by 10%, from 53% in 2003 to 49% in 2007 (columns 3 and 4). Second, there

[18] For more information on the data, see Appendix C. The data are publicly available at http://www.enterprisesurveys.org/data/exploreeconomies/2007/south-africa. The WBES is a firm-level survey of a representative sample of South Africa's private sector. The objective of the survey is to present a detailed picture of the business environment in the country. It interviews top managers and business owners in small, medium and large non-agricultural firms, and has information that ranges from legal status to sales' revenue.

[19] I also run regressions with two different control groups, non-manufacturers (14 firms) and non-manufacturers and manufacturers with very low air pollution levels (46 firms). These serve as robustness checks to my main regression and are presented in Table 2. For a detailed list of the industries that compose treatment and control groups, see Appendix C.

[20] See https://www.transparency.org/en/cpi/2007. Scores range from 0 (highly corrupt) to 10 (very clean).

[21] See https://data.worldbank.org/indicator/CC.EST?end=2022&locations=XO-ZA&start=2003. The index ranges from −2.5 to 2.5, with higher scores corresponding to better corruption control.

[22] I have a total of 191 firms for each year. The treated (74) and control (25) firms represent a subsample of this total. This is why the averages in the 'All' column in Table 1 do not match those of the treated and control groups.

[23] When top managers answer 'no' to the question, Is corruption an obstacle to your business?, it could mean either that there is no corruption or that bribing inspectors helps them overcome excessive bureaucracy. I assume the first interpretation is relevant for South Africa. This assumption is based on the negative connotation of the term 'corruption' in the country, and its association with harmful effects on society and business. This view has been reinforced by years of media exposure to corruption scandals involving government and private actors since the early 1990s.

Table 1
Descriptive statistics of main dependant variables.

		2003 (all)	2007	2003 (treated)	2007	2003 (control)	2007
Corruption is an obstacle?							
	No obstacle	47%	51%	53%	68%	52%	20%
	Minor obstacle	19%	21%	29%	8%	16%	4%
	Moderate obstacle	16%	15%	9%	14%	12%	40%
	Major obstacle	10%	12%	7%	6%	12%	36%
	Very severe obstacle	8%	1%	2%	4%	8%	0%
Licensing/permits are obstacles?							
	No obstacle	68%	82%	68%	73%	64%	76%
	Minor obstacle	12%	13%	8%	20%	12%	16%
	Moderate obstacle	14%	3%	14%	5%	20%	4%
	Major obstacle	4%	2%	6%	2%	4%	4%
	Very severe obstacle	2%	0%	4%	0%	0%	0%
Court is an obstacle?							
	No obstacle	55%	84%	64%	82%	60%	76%
	Minor obstacle	19%	9%	16%	11%	24%	8%
	Moderate obstacle	16%	4%	10%	7%	12%	4%
	Major obstacle	5%	2%	6%	0%	4%	12%
	Very severe obstacle	5%	1%	4%	0%	0%	0%
Days permit		9	144	3	181	6	60
Days license		6	10	14	10	2	.

The dataset consists of 191 firms in total '(all)'. Of these, 74 firms are classified as treated '(treated)', and 25 as control '(control)'. '.' refers to no observation. All figures are averages of the variables presented. 'Days permit' refers to the number of days required for a firm to obtain a permit. 'Days license' refers to the number of days required for a firm to obtain an operational license.

was a 44% reduction in firms reporting that licensing and/or permits were impediments to their business. In 2003, 32% firms mentioned that licenses and permits were an obstacle versus 18% in 2007. While this may indicate that the process for obtaining these documents has become easier for the average firm, it is important to note a decline in the number of firms applying for these documents coupled with an increase in the average waiting time.[24] Finally, about 45% of firms in the sample reported that courts were an obstacle to their business in 2003, compared to only 16% in 2007.

When focusing on perceived corruption, a difference emerges between treated and control firms. There was a significant improvement in the perceived corruption among treated firms from 2003 to 2007. In 2003, 53% of these firms reported that corruption was not an obstacle to their business, while by 2007, this figure had increased to 68%. In contrast, control firms experienced a deterioration in perceived corruption; in 2003, 52% reported that corruption was not an obstacle, but this percentage plummeted to 20% in 2007.[25]

5.3. Identification strategy

Proposition 2 of my theoretical model suggests that shifting from full to partial delegation of regulation could decrease the expected perceived corruption among producers, assuming all other factors remain constant. Inspired by this proposition, I aim to explore how changes in the delegation regime in South Africa have influenced firms' perceptions of corruption. I am interested in estimating the impact of the reduction in discretionary power of air quality officials, resulting from the implementation of the AQA, on firms' perceived corruption.

To estimate this impact, I use a difference-in-differences model, comparing treated firms to control firms. To causally identify the effect of interest, two conditions are necessary.[26]

First, the allocation of treatment must not be determined by the outcome variable. This means that, for clear identification, perceived corruption cannot be the motivating factor behind the introduction of the AQA. Historical records indicate that the AQA was not enacted in response to the perceived corruption among air-polluting firms. Rather, it was largely due to a broader societal belief that the APPA was ineffective at reducing air pollution. Moreover, as discussed in Section 4.6, the primary driver of the

[24] In 2003, 37 firms applied for a permit, compared to 21 firms in 2007; 49 firms applied for an operating license and/or permit in 2003, but only 1 firm did so in 2007.

[25] In Appendix C, I classify firms into categories of negligible, very low, low, and high air pollution. Table 7 demonstrates that perceived corruption among high air pollution firms decreased from 2003 to 2007, while it increased for all other categories of firms.

[26] In reality, two additional conditions are required for identification, which are not discussed here: (i) stable composition of control and treatment groups, and (ii) no spillovers between groups. I assume both conditions are met.

Table 2
Linear Prob. Model: AQA on perceived corruption.

	Baseline	Main	R1	R2
AQA x post, δ_i	−0.272***	−0.575***	−0.318**	−0.672***
	(0.010)	(0.141)	(0.133)	(0.157)
# of Employees	$0.22 \cdot 10^{-3}$***	$0.20 \cdot 10^{-3}$***	$0.20 \cdot 10^{-3}$***	$0.23 \cdot 10^{-3}$***
	$(0.41 \cdot 10^{-4})$	$(0.45 \cdot 10^{-4})$	$(0.49 \cdot 10^{-4})$	$(0.38 \cdot 10^{-4})$
% of exports	$-0.13 \cdot 10^{-2}$	$-2.2 \cdot 10^{-3}$	$-1.9 \cdot 10^{-3}$	$-2.3 \cdot 10^{-3}$**
	(0.0023)	(0.0031)	(0.0031)	(0.0040)
Change in prices	−0.104	−0.028	−0.045	0.0036
	(0.079)	(0.106)	(0.100)	(0.114)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Obs	374	188	224	168
R^2_{adj}	0.15	0.20	0.10	0.21

Standard errors are clustered at the firm level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
'Baseline' refers to the regression that includes all firms in my sample. 'Main' refers to my preferred specification, which includes firms regulated by the AQA as the treatment group and firms that emit negligible amounts of air pollution as the control group. 'R1' refers to the regression with treated firms and control firms that are non-manufacturers. 'R2' refers to the regression with treated firms and firms that are manufacturers with very low air pollution levels.

change in the delegation regime appears to be the post-Apartheid expansion of the South African government. Therefore, variations in perceived corruption are consequences of the changes in the delegation regime, not its causes.

In any case, to minimize potential omitted variable bias created by the influence of the outcome variable on the treatment allocation, I use firm-level fixed effects in all my regressions. These fixed effects help control for any observed or unobserved, time-invariant confounders. Additionally, I include control variables such as firm size, international exposure, and changes in prices in all regressions.

The second condition for my analysis is the parallel trends assumption, which requires that, without the treatment, differences in outcomes between the treatment and control groups would remain stable over time. Due to only having two periods in my panel, I cannot empirically verify the parallel trends before the treatment. However, indirect evidence suggests that from 1994 to 2005, the perceived corruption of air-polluting and non-air-polluting firms could have evolved in parallel. This is likely because the regulatory reforms implemented post-apartheid focused broadly on overarching issues, affecting all industries, rather than on specific industries (Hyslop, 2005 and Kuye, 2006). A good example of this is the NEMA, which, as mentioned above, is a framework rather than a specific regulation. Therefore, there is little reason to believe that any new regulation specifically altered the interaction between environmental inspectors and top managers in one industry over another, meaning the difference in perceived corruption between industries remained constant.

The econometric specification I use is the following linear probability model,

$$corrup_{it} = \gamma_i + \lambda_t + \delta \cdot (reg_i \cdot post_t) + X'_{it}\theta + \epsilon_{it}, \tag{9}$$

where $corrup_{it}$ is a binary response for the question *is corruption an obstacle?* of firm i at year t (this is the first variable of Table 1). This variable measures perceived corruption; it receives value 0 if the respondent chooses *No Obstacle*, and one otherwise. reg_i is a dummy that receives 1 if the firm is treated; and $post_t$ is a dummy that is equal to 0 before the AQA (2005) and 1 afterwards. X_{it} is a vector of three controls: variation in prices 2003–2007, percentage of direct exports and number of employees. I include two levels of fixed effects, γ_i and λ_t, firm and year, respectively. Standard errors are clustered at the firm level. The variable of interest is δ_i, which measures the effect of the introduction of the AQA on perceived corruption.[27]

5.4. Main results

Table 2 presents my main results.

The second column of the table presents estimates for my baseline regression, with every firm in my sample. The introduction of the AQA decreases the probability of reporting corruption as an obstacle by 27 percentage points. The column 'Main' presents my main estimate—the AQA generates a reduction of approximately 58 percentage points in the probability of listing corruption as a major issue. The columns 'R1' and 'R2' present the results for the regressions with a less and a more flexible control group, respectively. These estimates go in line with my main estimate.

[27] My perception variables refer to the general business environment in South Africa, not just environmental issues. Ideally, the main dependent variable would specifically address perceptions of environmental corruption. However, I believe my empirical results still capture the impact of the AQA on perceived corruption, licenses and permits, and courts for three reasons. First, my empirical strategy compares firms regulated by the AQA with those that are not, and the statistically significant results suggest an effect unique to the regulated firms. Second, the absence of significant findings for court perceptions and firm sales (robustness checks) indicates the impact is specific to the AQA. Lastly, no major regulatory changes affected air-polluting firms between 2003 and 2007 apart from the AQA.

Table 3
Linear Prob. Model: AQA on Licensing and Permits, and Courts.

	Licensing/permits		Courts	
	Baseline	Main	Baseline	Main
AQA x post, δ_i	−0.059	−0.052	−0.006	−0.142
	(0.092)	(0.154)	(0.091)	(0.128)
# of Employees	$-1.2 \cdot 10^{-4}$**	$-1.8 \cdot 10^{-4}$***	$0.76 \cdot 10^{-4}$	$0.24 \cdot 10^{-4}$
	$(0.41 \cdot 10^{-4})$	$(0.41 \cdot 10^{-4})$	$(26.5 \cdot 10^{-4})$	$(0.73 \cdot 10^{-4})$
% of exports	−0.001	−0.001	0.003	0.004*
	(0.002)	(0.004)	(0.002)	(0.002)
Change in prices	−0.092	−0.160	0.027	0.054
	(0.069)	(0.120)	(0.072)	(0.113)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Obs	362	188	362	188
R^2_{adj}	0.08	0.01	0.19	0.13

Standard errors are clustered at the firm level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
'Licensing/permits' refers to the regression with perceptions of licenses and permits as the dependent variable. 'courts' refers to the regression with perceptions of courts as the dependent variable. 'Main' refers to the regressions with my preferred econometric specification (see Table 2).

These results indicate that the introduction of the AQA leads to a reduction in firms' perceived corruption. Specifically, when the discretionary power of air quality officials is restricted through increased monitoring and supervision, the perceived corruption among affected firms decreases.

5.5. Auxiliary results

5.5.1. Licences, permits and courts

I now examine how the transition from the APPA to the AQA affects firms' perceptions of obtaining licenses and permits, as well as their perceptions on the operation of courts.

Firms that intend to conduct industrial processes involving emissions must apply for a license. As described in Section 3, before 2005, the APPA designated the chief air pollution officer and his team to grant these licenses. After the AQA was introduced, local authorities – usually provincial and district air quality officials – became responsible for issuing licenses.

Courts may be used by firms and the government when firms are penalized for non-compliance with emission guidelines, which are explicitly stated in the licenses. However, the use of courts is rare. Typically, air quality officials and firm managers reach an agreement on penalties before the case escalates to court. According to a senior air quality official I interviewed, this practice of seeking agreements has been in place since the 1960s and continues to this day (Anonymous air quality official 1, personal communication, November, 2022).

To investigate whether the introduction of the AQA changes perceptions on licenses and permits, as well as courts, I reran my econometric model with different dependent variables: "Are licenses and permits obstacles for your business?" and "Are courts an obstacle for your business?" Table 3 presents the results.

We see that the introduction of the AQA has no impact on whether managers state that courts are an obstacle for their business. This result aligns with the fact that the AQA does not substantially change the South African judiciary system, and that the vast majority of non-compliance cases do not culminate in legal disputes.[28] These results also increase my confidence that my main findings identify the impact of the AQA on perceived corruption, rather than other institutional changes.[29]

The results on licenses and permits are more interesting. Unlike perceived corruption, the channel through which the AQA might influence perceptions of obtaining licenses is the shift in responsibility from the national level (chief air pollution officer) to the local level (provincial and district air quality officials). Although provincial and district air quality officials, who rank higher than local air quality officials, often do not interact with industries daily, they are geographically closer to these industries than the chief officer was. This reduction in physical distance could improve the relationship between firms and the officials responsible for granting licenses—that is, decentralization may positively affect firms' perceptions.

[28] Another explanation is that there was not enough time to observe prosecutions related to the AQA at the time of the second survey in 2007. The AQA works slowly: first, offenders must be notified that they are in breach; second, they are asked to provide a document detailing their plan to rectify the issue; finally, if they are found in breach again, there must be a decision on whether to prosecute. Hence, if this explanation holds, affected firms would not have faced courts at the time of the survey.

[29] It is important to mention that, although South Africa embarked on extensive judiciary reforms post-Apartheid (Bosio, 2023), only one minor judiciary reform was implemented in 2005: the Intergovernmental Relations Framework Act 13 of 2005 (https://www.gov.za/documents/intergovernmental-relations-framework-act). This act mainly facilitated the settlement of intergovernmental disputes and should not have any direct effect on the firms in my sample.

Table 4
Actual corruption levels.

	2003 (all)	2007	2003 (control)	2007	2003 (treated)	2007
Average Bribe Given						
as a % of annual sales	5.7%	2.6%	0%	3.0%	5.0%	6.5%
Share of firms						
bribe to officials	1.7%	5.4%	0%	8.0%	1.4%	5.5%
bribe in gov't contract	1.0%	2.0%	0%	4.0%	2.0%	0%
bribe for permit	0%	0%	0%	0%	0%	0%
bribe for license	0%	0%	0%	0%	0%	0%

Figures are calculated conditional on a 'yes' or 'no' answer to the question of whether the top manager has given a bribe to an official in the last year. Missing values are not incorporated in the calculations.

The second and third columns of Table 3 show that the coefficient associated with this perception is statistically insignificant. This indicates that bringing the authority responsible for granting operational licenses closer to treated firms does not improve firms' perceptions of the licensing process. In other words, decentralization does not lead to any change in these perceptions.

From my interviews with air quality officials, it seems that the main reason for this result is that the process of granting licences is technical and impersonal (Anonymous air quality officials 1 and 2, personal communication, November, 2022). It is difficult for firms to influence the process in any meaningful way. Even though the AQA decentralizes responsibility and brings the process to the local level, not much changes from the perspective of an affected firm. Another explanation is that few firms in my sample applied for operational licenses between 2003 and 2007. Therefore, the statistically insignificant coefficients might also be due to the small number of firms experiencing the process.[30]

5.5.2. Actual corruption

I briefly discuss what happens to actual corruption. Due to the limited number of observations of self-reported corruption, I can only offer a descriptive discussion. Table 4 summarizes my findings.

As we see, very few firms report having given bribes to authorities. The number of firms that report specifically giving bribes to officials increases from three in 2003 to ten in 2007 (out of 191 firms). The bribe value is approximately 6% of total annual sales in 2003 and 3% in 2007. No firm reports giving bribes to authorities for obtaining permits or licenses, which is particularly relevant for industries with air-polluting processes.

This minor variation in the number of firms bribing authorities – and in the magnitude of these bribes – over the years and across treated and control firms does not allow us to derive a trend. Due to the self-reported nature of this data, firms lack incentives to disclose actual instances of corruption. Thus, from these results, my only conclusion is that the AQA does not change treated firms' incentives to report actual instances of corruption.

6. Robustness checks

I now demonstrate that my main empirical results are robust to different definitions of the dependent variable. I also conduct a falsification test to show that the AQA does not affect firm sales.

My main dependent variable, *is corruption an obstacle?*, is both ordinal and subjective. Respondents choose one of five possible answers based on their personal assessment of corruption and the scale presented to them (ranging from *No Obstacle* to *Very Severe Obstacle*). For my main regression, I transform this ordinal variable into a binary one, assuming that *No Obstacle* indicates no corruption ($corrup_{it} = 0$), and any other response indicates perceived corruption ($corrup_{it} = 1$).

I now redefine this variable to accommodate different perspectives on perceived corruption. I rerun my baseline regressions and my main regression using two different dependent variables. The first variable is assigned a value of 0 if the respondent selects *No Obstacle* or *Minor Obstacle*, and 1 otherwise. The second variable is assigned a value of 1 only if the respondent selects *Major Obstacle* or *Very Severe Obstacle*.

Results are presented in Table 5. They align with those presented in Section 5. The second and third columns of the table show the baseline specification results without and with control variables, respectively. The fourth column presents the results for my main regression. The coefficients are statistically insignificant for the baseline regression when I define $corrup_{it}$ as 1 only for *Major Obstacle* or *Very Severe Obstacle*. However, they become negative and statistically significant for my main specification. This suggests that my main results are not influenced by how I define my dependent variable.

In Table 5, I also present the results from an ordered logit model applied to my baseline and main regressions. This econometric model allows me to maintain the ordinal structure of my dependent variable, although it does not accommodate fixed effects. The results again align with my main findings. For instance, in the last column, we see that the introduction of the AQA is associated

[30] Top managers in my sample all report a perception of courts; however, few of them actually have any interaction with the judicial system. This means their perceptions are unlikely to change over time.

Table 5
Alternative dependent variables: AQA on perceived corruption. Linear Prob. Model and Ordered Logit.

	Baseline(NC)	Baseline	Main
Moderate Obstacle, Major Obstacle or Very Severe Obstacle			
AQA x post, δ_i	−0.242***	−0.224**	−0.690***
	(0.089)	(0.093)	(0.140)
Controls	No	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Obs	382	362	188
R^2_{adj}	0.11	0.10	0.25
Major Obstacle or Very Severe Obstacle			
AQA x post, δ_i	−0.025	−0.032	−0.241*
	(0.069)	(0.072)	(0.142)
Controls	No	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
Obs	382	362	188
R^2_{adj}	0.11	0.11	0.04
Ordered Logit (Average Marginal Effects)			
No Obstacle	0.138**	0.144**	0.260***
	(0.059)	(0.061)	(0.060)
Minor Obstacle	−0.020**	−0.021**	−0.023
	(0.009)	(0.010)	(0.014)
Moderate Obstacle	−0.046**	−0.048**	−0.090***
	(0.020)	(0.021)	(0.025)
Major Obstacle	−0.048**	−0.051**	−0.103***
	(0.022)	(0.023)	(0.031)
Very Severe Obstacle	−0.024**	−0.025**	−0.044**
	(0.012)	(0.012)	(0.019)
Controls	No	Yes	Yes
Obs	382	378	196

Standard errors are clustered by firm.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Dependent variable: perceived corruption.
'Baseline(NC)' refers to the regression with no controls that includes all firms in my sample. 'Baseline' refers to the regression that includes all firms in my sample. 'Main' refers to my preferred specification.

with a 26% increase in the likelihood of a respondent selecting *No Obstacle* and a 10% decrease in the likelihood of selecting *Major Obstacle*.

To conclude this section, I conduct a falsification test. I rerun my main econometric regressions using a dependent variable that is not directly related to the introduction of the AQA: firm sales. Although firm production might be correlated with the delegation of regulation – through reduced perceived corruption, increased stability, and higher investment – firm sales are largely determined by market dynamics beyond the control of any single firm. Therefore, this variable should not be correlated with the delegation change. Indeed, as Table 8 in Appendix C shows, the introduction of the AQA does not affect the sales of treated firms. This provides evidence that my main results are not driven by a spurious correlation.

7. Concluding remarks

In this paper, I develop a principal–agent model to determine when it is optimal for society to reduce the discretionary power of environmental inspectors, considering inspectors' characteristics and the system they operate in. I show that it is optimal to reduce inspectors' discretionary power when preference misalignment and when their capacity for rent appropriation are sufficiently large. My model provides a formal framework to examine the trade-off between information and the agency problem. While the model is informative for the issue at hand, it prioritizes tractability and abstracts from more complex dynamics that might better reflect real-world conditions.

I then use my theoretical model to discuss the potential drivers of the change in the air quality delegation regime that occurred in South Africa in 2005. The APPA, which granted considerable power to inspectors (air quality officials), was replaced by the AQA, which restricted their power through increased supervision. I suggest that this regulatory change may have been triggered by the rapid expansion of the South African government post-Apartheid. The hiring of many new air quality officials likely increased the gap between society's air quality preferences and those of the officials. Additionally, the expansion in employment appears to have made it more difficult for the government to monitor and control corrupt behavior. Combined, these factors may have prompted legislators to restrict officials' discretionary power.

Finally, I show that the introduction of the AQA reduced affected firms' perceived corruption. The reduction in the discretionary power of air quality officials decreased the likelihood of firms perceiving corruption as an obstacle to their business. However, the AQA did not change firms' perceptions regarding the process of obtaining licenses. This is important because the AQA decentralized the license-granting procedure from the national to the local level. While this empirical analysis does not directly test the predictions of my theoretical model, it is grounded in the theoretical framework the model provides.

These theoretical and empirical results contribute to the debate on the design and implementation of environmental regulation in developing countries. National governments in these countries often have limited resources to invest in environmental quality. Furthermore, the institutions in these countries, combined with low wages in the public sector, may lead to corrupt behavior by environmental inspectors. My work indicates that one potential solution to these problems, and to increase the efficacy of environmental regulation, is to invest in cheaper forms of monitoring and supervision and in the composition of the body of inspectors. By promoting activities that align inspectors' preferences with those of society, these governments might reduce potential corruption. Moreover, when designing environmental regulation, national governments in developing countries should consider the characteristics of the agents implementing it and the system they are embedded in. As the case of South Africa illustrates, this can be as important as the characteristics of the agents being regulated.

My work also demonstrates that reducing the discretionary power of environmental inspectors can benefit firms. Besides the intrinsic value of operating with reduced perceived corruption, firms may also operate more efficiently if they believe corruption is not a major obstacle. This could lead to increased investment in human and physical capital and technology, enhancing societal welfare. Future research could investigate the link between perceived corruption and firm dynamics in South Africa.

Finally, it is important to mention two limitations of this paper. First, the lack of microdata on the characteristics of air quality officials and their corrupt behavior limits my analysis. Future work could empirically test Proposition 1 by measuring the alignment of preferences between environmental inspectors and society, either through lab experiments or field experiments. Second, Proposition 2 could be empirically tested with more and better microdata. Unfortunately, my panel only has two time points. Future research could extend this analysis to other countries with better data availability.

CRediT authorship contribution statement

Pedro Naso: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

I declare no known conflict of interests.

Appendix A

Agents

Producer. The producer's payoff function is given by

$$R(\theta, t, d) = \pi + d\theta - t, \tag{10}$$

where $\pi > 0$ is a constant, $d > 0$ is the emissions level, $\theta \in [\underline{\theta}, \bar{\theta}]$ is the emissions coefficient, and t is the emission compensation.

Consumer. The consumer's utility function is

$$U_c(t, d) = G - \frac{d^2}{2} + t(1 - k), \tag{11}$$

where $G > 0$ is the utility generated by the good produced by the producer and k is the fraction of compensation appropriated by the bureaucrat. I assume that G is fixed and large enough to make $U_c(t, d) > 0$.

Bureaucrat. The bureaucrat's utility function is

$$U_b(t, d) = \beta k t + (1 - \beta) U_c(t, d), \tag{12}$$

where $\beta \in (0, 1)$ measures the bureaucrat's rent seeking motivation. $\lambda = kt$ is the total amount appropriated by the bureaucrat.

Perfect information

The consumer's preferred level of emissions when there is perfect information (bureaucrat is not used) is given by,

$$\begin{aligned} \max_{\alpha=(t,d)} \quad & G - \frac{d^2}{2} + t \\ \text{subject to} \quad & \pi + \theta d - t \geq 0 \end{aligned} \tag{13}$$

where $\pi + \theta d - t \geq 0$ is the producer's participation constraint. Because $U_c(t, d)$ increases with t, this constraint will always bind.

The equilibrium levels of d and t are:

$$d^{CI}(\theta) = \theta \quad t^{CI}(\theta) = \pi + \theta^2 \tag{14}$$

Partial delegation

Under partial delegation, the consumer solves the following maximization problem:

$$\begin{aligned} \max_{\underline{d},\bar{d},\underline{t},\bar{t}} \quad & (1-v)\left(G-\frac{\bar{d}^2}{2}+\bar{t}(1-k)\right)+v\left(G-\frac{\underline{d}^2}{2}+\underline{t}(1-k)\right) \\ \text{subject to} \quad & \pi+\theta\underline{d}-\underline{t}\geq 0 \\ & \pi+\bar{\theta}\bar{d}-\bar{t}\geq 0 \\ & \pi+\bar{\theta}\bar{d}-\bar{t}\geq \pi+\bar{\theta}\underline{d}-\underline{t} \\ & \pi+\theta\underline{d}-\underline{t}\geq \pi+\underline{\theta}\bar{d}-\bar{t} \end{aligned} \tag{15}$$

The participation constraint of the high type is redundant and the participation constraint of the low type must be binding. Moreover, the incentive compatibility constraint of the high type must bind. Finally, the incentive compatibility constraint of the low type becomes redundant.

We then have the following two expressions:

$$\underline{t}=\pi+\theta\underline{d} \tag{16}$$

$$\bar{t}=\pi+\bar{\theta}\bar{d}-\underline{d}(\bar{\theta}-\underline{\theta}) \tag{17}$$

The expressions we see in Eqs. (4) and (5) are obtained by rearranging the first order conditions of the new maximization problem.

Full delegation

The problem that the bureaucrat solves is given by,

$$\begin{aligned} \max_{\alpha=(d,t)} \quad & U_b(\theta,t,d)=\beta kt+(1-\beta)U_c(t,d) \\ \text{subject to} \quad & \pi+\theta d-t\geq 0 \end{aligned} \tag{18}$$

Again, the producer's participation constraint must be binding. By rearranging the first-order conditions, we have that,

$$d^{FD}=\theta H \quad t^{FD}=\pi+\theta^2 H, \tag{19}$$

where $H=\left(1-k+\frac{\beta k}{1-\beta}\right)$.

Proof of Proposition 1

To derive the equilibrium outcome, we need to work with the following inequality,

$$E(U_c(t^{PD},d^{PD}))>E(U_c(t^{FD},d^{FD})), \tag{20}$$

where $E(.)$ is the expected value operator, $U_c(t^{PD},d^{PD})$ is the consumer's utility under partial delegation and $U_c(t^{FD},d^{FD})$ is the consumer's utility under full delegation of regulation.

After some manipulation, this inequality becomes:

$$\frac{(1-v)(\underline{\theta}-\bar{\theta})^2+v\underline{\theta}^2+\frac{1-v}{v}\bar{\theta}}{E(\theta^2)}>1-\frac{\beta^2k^2}{(1-\beta)^2(1-k)^2}, \tag{21}$$

Note that the left-hand side of this expression is always positive. I define $g(\beta,k)=1-\frac{\beta^2k^2}{(1-\beta)^2(1-k)^2}$ and $h(v,\underline{\theta},\bar{\theta})=\frac{(1-v)(\underline{\theta}-\bar{\theta})^2+v\underline{\theta}^2+\frac{1-v}{v}\bar{\theta}}{E(\theta^2)}$. Recall that $0<\beta,k,v<1$.

Let us first analyze the dynamics of $h(v,\underline{\theta},\bar{\theta})$, which is always positive.

Assuming that $2\underline{\theta}<\bar{\theta}+1/v^2$, we have that $\frac{\partial h(v,\underline{\theta},\bar{\theta})}{\partial v}<0$. This means that the expected utility of the partial delegation regime decreases with the probability of encountering a low emission type. This result makes sense—in an economy with a large number of low emission types, the distortion that the bureaucrat generates is not large enough for the consumer to restrict her discretionary power. We also know that: $h(1,\underline{\theta},\bar{\theta})=0$ and $\lim_{v\to 0}h(v,\underline{\theta},\bar{\theta})=\infty$.

Let us now analyze the dynamics of $g(\beta,k)$.

We have that the maximum value of $g(\beta,k)$ is 1, attained when either β or k is equal to zero. We have that $\frac{\partial g(\beta,k)}{\partial k},\frac{\partial g(\beta,k)}{\partial \beta}<0$. That is, as these two variables increase – misalignment between preferences increases and the capacity of appropriation of rents also increases – $g(\beta,k)$ decreases and it becomes optimal to restrict the bureaucrat's discretionary power.

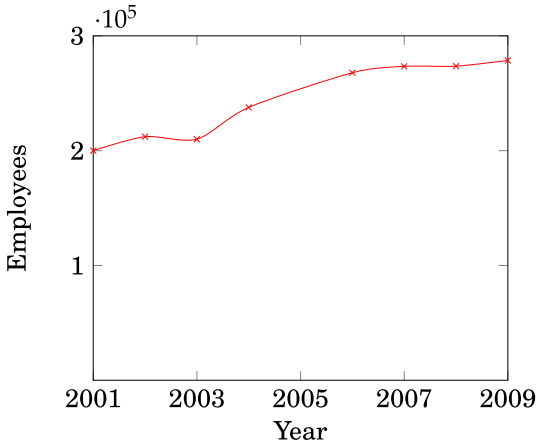


Fig. 2. Local government employment 2001–2009. *Source:* Naidoo (2008), Hassen and Altman (2010), Non-financial Census of Municipalities (Statistics South Africa, 2003, 2004 and Statistics South Africa, 2007) and Intergovernmental Fiscal Review (National Treasury, Republic of South Africa, 2009)

Consider a situation in which the economy is under the full delegation regime. This situation is feasible since $g(\beta, k)$ can be larger than $h(v, \underline{\theta}, \bar{\theta})$ for combination of values of v_1, k_1, β_1. As k_1, β_1 increase, given the continuity of $g(\beta, k)$, there must be a non-empty set of values $\bar{\beta}, \bar{k}$, for which $h(v_1, \underline{\theta}, \bar{\theta}) \geq g(\bar{\beta}, \bar{k})$ and the consumer favors partial delegation over full delegation of regulation.

Proof of Proposition 2

To prove Proposition 2, we need to compare expected perceived corruption under partial delegation and under full delegation. Assume that k_1 is the fraction appropriated under full delegation and that $k_2 = k_1 + \gamma$, where $\gamma > 0$ is the fraction appropriated under partial delegation (after a transition). Then, we have that $E(\mu^{PD}) = a(\pi k_2 + \frac{(1-k_2)k_2}{v}\left((\bar{\theta} - \underline{\theta})^2 + v\bar{\theta}(2\underline{\theta} - \bar{\theta})\right))$ and $E(\mu^{FD}) = a(\pi k_1 + H k_1 E(\theta^2))$. There is a transition from full to partial delegation of regulation. Does this transition reduce perceived corruption? That is, when is $E(\mu^{PD}) < E(\mu^{FD})$ true?

This expression is equivalent to:

$$\pi(k_2 - k_1) + \frac{(1-k_2)k_2}{v}\left((\bar{\theta} - \underline{\theta})^2 + v\bar{\theta}(2\underline{\theta} - \bar{\theta})\right) - \left(1 - k_1 + \frac{\beta k_1}{1-\beta}\right) k_1 E(\theta^2) < 0 \tag{22}$$

Note that the first two terms are positive and the third term is negative. Moreover, the third term is increasing in β and approaches infinity when β tends to 1 (complete misalignment). Therefore, there must exist a value $\beta > \bar{\beta}'$ for which the expression above is true.

The expression on the right hand side above increases with γ for $\gamma < 1/2$. Recall that $0 < \gamma, k < 1$. Hence, it is unlikely that there will be a reduction in expected perceived reduction when the economy goes from full to partial delegation if this change is brought about because of an increased k.

Appendix B

See Figs. 2 and 3.

Appendix C

The data used in this paper come from the World Bank Enterprise Survey (WBES) for South Africa (2003 and 2007). The WBES targeted establishments located in Johannesburg, Cape Town, Port Elizabeth and Durban. The sample is composed by the following categories of industries:

1. Manufacturing: Food and Beverages, Machinery and Equipment, Electrical Machinery and Equipment, Textiles, Garment, Leather and Footwear, Paper and Paper Products, Printing and Publishing, Non-Metallic Mineral Products, Basic Metals, Fabricated Metal products, Wood and Wood Products, Furniture, Refined Petroleum Products, Chemical Products, Rubber and Plastics, and Other Manufacturing;
2. Retail Trade;

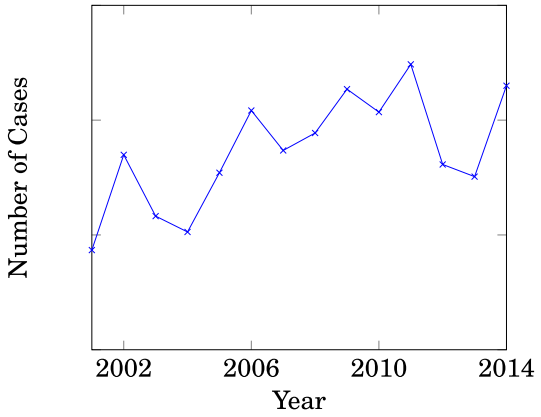


Fig. 3. Financial misconduct cases – National and provincial government. *Source:* Public Service Commission Reports (Public Service Commission, 2014, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004 and Public Service Commission, 2003)

Table 6
Summary of firm characteristics.

	Obs	Mean	St. Dev.	Min	Max
Employees (2006)	379	268.88	597.63	5	5697
Annual Sales (Rand)	371	$3.09 \cdot 10^8$	$1.55 \cdot 10^9$	10054	$2.56 \cdot 10^{10}$
Privately Owned (%)	382	81.38	36.98	0	100
Change in Prices	376	0.32	0.52	−1	1
Percentage of Exports	380	5.73	14.05	0	100

Table 7
Perceived corruption and Pollution intensity – Averages.

	2003	2007
High Air Pollution	0.64	0.43
Low Air Pollution	0.48	0.59
Very Low Air Pollution	0.48	0.80
Negligible Air Pollution	0.36	0.79

Perceived corruption is a binary variable that receives 1 if corruption is a major obstacle to a firm and 0 otherwise. In the Table, I present averages for each group of industries and year.

3. Construction;
4. Wholesale trade;
5. Hotels, bars and restaurants;
6. Transportation, storage and communications;
7. Computer related activities.

Firms are identified by their 4-digit ISIC 3.1 code in the panel I have.[31] In total, there are 191 firms surveyed in both periods, belonging to 88 different industries.

Table 6 summarizes the main characteristics of these firms.

Perceived corruption of firms and pollution intensity

Table 7 groups firms according to their air pollution intensity and relates that to perceived corruption. Emission intensive ('High Air Pollution') firms experience a reduction in perceived corruption over time; whereas, all other groups of firms increase their perceived corruption from 2003 to 2007.

[31] Detailed explanation on the ISIC rev. 3.1, and codes for every industry can be found in https://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=17.

Table 8
DID model: AQA on firm sales.

	Baseline	Main
AQA x post, δ_i	$-2.99 \cdot 10^8$	$-3.70 \cdot 10^8$
	$(4.24 \cdot 10^8)$	$(3.88 \cdot 10^8)$
# of Employees	$22.8 \cdot 10^{-4}$	$24.3 \cdot 10^{-4}$**
	$(41.8 \cdot 10^{-4})$	$(11.3 \cdot 10^{-4})$
% of exports	$40.8 \cdot 10^{-5}$	$63.7 \cdot 10^{-5}$
	$(45.4 \cdot 10^{-5})$	$(82.9 \cdot 10^{-5})$
Change in prices	$-1.19 \cdot 10^8$	$-3.28 \cdot 10^8$
	$(1.56 \cdot 10^8)$	$(2.91 \cdot 10^8)$
Year FE	Yes	Yes
Firm FE	Yes	Yes
Obs	344	174
R^2_{adj}	0.53	0.53

Standard errors are clustered at the firm level.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
'Baseline' refers to the regression that includes all firms in my sample. 'Main' refers to my preferred specification.

Treatment group

The following list shows all industries that are regulated by the AQA.AEL and that are present in my sample (the numbers in parentheses are their ISIC codes). These are my treated industries:

- Manufacture of other fabricated metal products (2899);
- Treatment and coating of metals; general mechanical engineering (2892);
- Forging, pressing, stamping and roll-forming of metal; powder metallurgy (2891);
- Manufacture of other non-metallic mineral products (2692, 2694, 2695 and 2610);
- Other mining and quarrying (1410 and 1420);
- Manufacture of chemicals and chemical products (2411, 2412, 2413, 2421, 2422, 2423, 2424, 2429 and 2430);
- Manufacture of paper and paper products (2101, 2102 and 2109);
- Production, processing and preserving of meat products (1511, 1512, 1513 and 1514).

Out of 191 firms, 74 belong to these industries and form my treatment group.

Control groups

These are the three control groups I use in the regressions of Table 2. The control group of my main regression is the second one. The other two control groups serve as robustness checks to the main regression. The numbers in parentheses are the industries ISIC codes.

1. 14 firms, **non-manufacturers**: Publishing, printing and reproduction of recorded media (22); Wholesale trade and commission trade (51); Retail Trade (52); Hotels and Restaurants (55); Other business activities (74); Sewage and refuse disposal (90);
2. 25 firms, **non-manufacturers plus manufacturers with very low air pollution levels**: Publishing, printing and reproduction of recorded media (22); Wholesale trade and commission trade (51); Retail Trade (52); Hotels and Restaurants (55); Other business activities (74); Sewage and refuse disposal (90); Spinning, weaving and finishing of textiles (171); Tanning and dressing of leather (19); Manufacture of wood and products of wood (20); Manufacture of medical, precision and optical instruments (33);
3. 46 firms, **non-manufacturers plus manufacturers with very low and low air pollution levels**: Publishing, printing and reproduction of recorded media (22); Wholesale trade and commission trade (51); Retail Trade (52); Hotels and Restaurants (55); Other business activities (74); Sewage and refuse disposal (90); Spinning, weaving and finishing of textiles (171); Tanning and dressing of leather (19); Manufacture of wood and products of wood (20); Manufacture of medical, precision and optical instruments (33); Manufacture of wearing apparel (18); Manufacture of office, accounting and computing (30); Manufacture of radio, television and communication equipment (32); Manufacture of furniture (36).

AQA on firm sales

See Table 8.

Data availability

Data will be made available on request.

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