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Economics and Political Economy of Natural Resources in Developing Countries: Essays on the Private Sector, Environmental Policies and Deforestation

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Dédicace

Au Burkina Faso, qui traverse la pire crise de son histoire;
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Executive Summary

Natural resources bring both the hope and despair of resource-based development. Some countries, such as Botswana, have relied on these resources to build their economic prosperity over the last fifty years, while others, such as Venezuela and Sierra Leone, have stagnated or even fallen into cycles of violence following the discovery of the resources. This puzzle labeled the "resource curse" has been extensively studied in development economics. However, little attention has been paid to the impact of natural resources on the private sector, insofar as most of the rent from these resources accrues to the government. Yet, the adverse effects of the natural resource discovery, such as Dutch disease, rampant corruption and rent-seeking behavior directly affect the private sector, the engine of growth. In addition, the context of climate change is pushing countries to adopt energy transition policies, which are increasing demand for the mineral resources, essential for green energy production. Caught in the trap between attracting investors and protecting the environment, developing countries are competing for investment in their mining sector. Like climate change, to which African countries will suffer the consequences despite an insignificant contribution to global emissions, the energy transition could come at the cost of an environmental disaster if regulation is lacking in mineral-rich countries. This thesis, dedicated to this issue, focuses firstly on the private sector and secondly on environmental policies and deforestation.

Chapter 1 analyzes the effect of natural resources' dependence on manufacturing firms' productivity. Using data from the World Bank's Enterprise Survey, it shows that dependence on natural resources is detrimental to firms' productivity. The mechanism operates through real effective exchange rate volatility and corruption. Resource-dependent countries should: consider reforms that: (i) create backward and forward linkages between domestic companies and the extractive sector, in order to limit enclave economies; (ii) combat corruption; and (iii) implement macroeconomic policies that limit shocks on the real effective exchange rate.

Chapter 2 examines the relationship between extractive resources and public capital in developing countries. We use the IMF's new public capital database, which distinguishes between "full public provision" capital and public-private partnership capital, to assess the effect of extractive resources. The results show that extractive resources exert a positive effect on public capital in public-private partnership, while their effect on public capital in "full public provision" is negative. These results highlight the fact that rent-seeking behavior (political or economic) can motivate public investment spending in resource-rich countries.

Chapter 3) borrows from the literature on inter-states fiscal competition and regulation. It examines whether mining-dependent African countries engage in strategic interaction in their environmental commitment using two measures: a *de jure* environmental policy and a *de facto* environmental policy. Our results confirm that countries behave strategically in response to their neighbors' environmental policies. We show that this strategic behavior leads to an increase in regulation (race to the top) for *de jure* environmental policy and a decrease in regulation (race to the bottom) for *de facto* environmental policy.

Chapter 4 investigates the link between mining and deforestation in Africa using a spatial econometric framework. The results suggest that mining increases deforestation, while environmental policy helps to reduce deforestation in mineral-rich countries. An increase in mining rents of one percentage point of GDP results in a forest loss of around 50 km2. Furthermore, regional economic communities have heterogeneous effects on deforestation.

Resumé Exécutif

Les ressources naturelles portent à la fois l'espoir et le désespoir d'un développement basé sur celles-ci. Certains pays comme le Botswana se sont basés sur ces ressources pour bâtir leur prospérité économique ces cinquante dernières années alors que d'autres comme le Venezuela ou la Sierra Leone ont stagné ou même basculé dans des cycles de violence après la découverte de ces ressources. Ce paradoxe appelé malédiction des ressources naturelles a fait l'objet d'importante recherche en économie du développement. Cependant, l'impact des ressources naturelles sur le secteur privé a fait l'objet de peu d'intérêt dans la mesure où la rente tirée de ces ressources reviennent en grande partie à l'Etat. Pourtant, les effets adverses de la découverte des ressources naturelles comme le syndrome hollandais, la corruption et le comportement de captation de la rente affectent directement le secteur privé, moteur de la croissance. Par ailleurs, le contexte de changement climatique pousse les pays à adopter des politiques de transition énergétique. Ces politiques accroissent la demande des ressources minérales essentielles à la production d'énergie verte. Piégés entre attrait des investisseurs et protection de l'environnement, les pays en développement se font la concurrence. Tout comme le changement climatique pour lequel les pays africains souffriront des conséquences malgré une contribution insignifiante aux émissions mondiales, la transition énergétique pourrait se faire au prix d'un désastre environnemental si la régulation fait défaut. Cette thèse, dédiée à cette problématique, s'intéresse dans une première partie au secteur privé et dans une deuxième partie à l'environnement et aux politiques environnementales.

Le chapitre 1 analyse l'effet de la dépendance aux ressources naturelles sur la productivité des entreprises manufacturières. Il montre que la dépendance aux ressources naturelles a un effet négatif sur la productivité des entreprises. Le mécanisme passe par la volatilité du taux de change effectif réel et la corruption. Les pays dépendants des ressources naturelles devraient : (i) envisager des réformes qui créent des liens en amont et en aval entre les entreprises domestiques et le secteur extractif; (ii) combattre la corruption ; et (iii) mettre limiter les effets des chocs sur le taux de change effectif réel.

Le chapitre 2 étudie la relation entre les ressources extractives et le capital public dans les pays en développement. Les résultats montrent que les ressources extractives exercent un effet positif sur le capital public en partenariat public-privé tandis que leur effet sur le capital public de "pleine fourniture publique" est négatif. Ces résultats mettent en lumière le fait qu'un comportement de recherche de rente peut motiver les dépenses d'investissement public dans les pays riches en ressources.

Le chapitre 3 emprunte la littérature sur la concurrence fiscale et la régulation. Il examine si les pays africains dépendant des ressources minières sont engagés dans une interaction stratégique dans leur engagement environnementaux en utilisant deux mesures : une politique de jure et une politique de facto. Nos résultats confirment que les pays adoptent un comportement stratégique en réponse à la politique environnementale de leurs voisins. Ce comportement stratégique conduit à une augmentation de la régulation environnementale de jure (race to the top) et à une baisse de la régulation de facto (race to the bottom).

Le chapitre 4 étudie le lien entre l'exploitation minière et la déforestation en Afrique en utilisant un cadre d'économétrie spatiale. Les résultats suggèrent que l'exploitation minière augmente la déforestation tandis que la politique environnementale contribue à réduire la déforestation. Une augmentation de la rente minière d'un point de pourcentage du PIB entraîne une perte de forêt d'environ 50 km^2. En outre, la communauté économique régionale a des effets hétérogènes sur la déforestation.

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General Introduction

"All in all, I wish we had discovered water."
Sheik Ahmed Yamani, former Oil Minister of Saudi Arabia

"Ten years from now, twenty years from now, you will see, oil will bring us ruin... It is the devil's excrement."
Juan Pablo Perez Alfonzo, former Venezuelan Oil Minister and OPEC co-founder

"Even without oil, we are doing so well... With oil as a shot in the arm, we're going to fly."
John Kufuor, former president of Ghana

0.1 Context and motivations

Natural resources and development: Between hope and despair

The discovery of natural resources carries both the hope and despair of development based on these resources. The success stories of natural resource-based development are scant, while obvious failures are legion. For every success story, there is a less glowing one, making it difficult to predict a country's development trajectory based on its natural resource potential, even under conditions of favorable prices. Countries such as Botswana, Chile, Malaysia and Norway have been able to harness their natural resources for development. GDP per capita at purchasing power parity (PPP) in Botswana has increased 142-fold in sixty years, from $277 in 1960 to $39,316 in 2019 thanks to the discovery of the world's largest diamond deposits in the 1960s, good policies and strong institutions. The human capital index in the country has tripled over the same period.[1] Diamonds account for 80% of Botswana's current export revenue and over 35% of government revenues (Sebudubudu and Mooketsane, 2016). GDP per capita at PPP in Chile increased by more than 10-fold over the same time period rising from $43303 in 1960 to $447187 in 2019. In Malaysia, the GDP per capita at PPP in 2019 was more than 36 times its level in 1960. Norway's GDP per capita at PPP multiplied by 7 between 1960 and 2019.

In contrast, examples such as Venezuela, the Democratic Republic of Congo, and Angola among others exhibit the hardness to convert natural resource wealth into shared prosperity. Venezuela's GDP per capita (at PPP) was divided by more than 8 between 1960 and 2019. The Democratic Republic of Congo took almost 60 years to double its GDP per capita. Examples of growth disappointment after natural resources discovery are plenty across developing countries (Cust and Mihalyi, 2017).

The contrasting success stories and patent failure show that the discovery of natural resources is, in itself, neither a blessing nor a curse. Having the preconditions for good resource management seems to be the blessing. Indeed, the transition from a predominantly agricultural to an extractive economy poses enormous challenges. First of all, since extractive resources are capital-intensive, the wealth created is concentrated in the hands of a few individuals, some of them expatriates, leaving the vast majority of the population behind. In the absence of an appropriate policy, inequalities and the sense of injustice increase (Lessmann and Steinkraus, 2019; Berman et al., 2023). Secondly, the massive influx of foreign currency, un-

[1] Source: Penn World Table, PWT100.01, January 23, 2023.

related to the economy's productive capacity, can quickly pose serious problems for macroeconomic management. The national currency appreciates and external competitiveness deteriorates (The Economist, 1977; Harberger, 1983; Edwards and Aoki, 1983), public (consumption and wasteful) spending increases faster than revenue growth (Bhattacharyya and Collier, 2013), public debt explodes in the event of unfavorable economic conditions (sudden drop in prices, resource depletion), tax effort is relaxed in favor of rents (Bornhorst et al., 2009), the other sectors become neglected (Cockx and Francken, 2014, 2016), and so on. Thirdly, the environmental costs of exploiting natural resources can be considerable, particularly in conditions where regulation is weak. Developing countries often suffer not only from weak regulatory capacity, but also from regulatory capture, that despite having the means to regulate resource exploitation, prefer not to do so. Fourthly, the discovery of natural resources, particularly when they can be looted, generates conflicts (Berman et al., 2017) and political instability (Bjorvatn and Farzanegan, 2015). Lastly, the discovery of natural resources deter governance, in particular it generates rampant corruption (Bhattacharyya and Hodler, 2010; Arezki and Brückner, 2011; Knutsen et al., 2017), authoritarians tilt of political regimes (Jensen and Wantchekon, 2004; Caselli and Tesei, 2016) and predatory behavior of the ruling elite, which has access to resources without having to resort to tax collection (Bornhorst et al., 2009). These challenges explain the dominance of the "resource curse" in developing countries. However, several stories across developed and developing countries show that these challenges are not insurmountable.

Two major events fuelled the hope of development based on natural resources over the last three decades: the upturn in the price of extractive raw materials (non-renewable resources) and the increase in discoveries. The African Union (2009) put African mining sector at the core of African economic growth and socioeconomic development. Figure 1 shows the evolution of the price index for base metals, precious metals and energy. Despite moments of decline in line with crises in economic activity as was the case in 2008, 2015 and 2020, the overall trend remains upward over the entire period. The base metal price index has increased by a factor of 4.5 from 37.41 in 1992 to 169.88 in 2022. That of precious metals has multiplied by 5.4 over the same period from 27.28 to 146.66. And that of energy increased from 47.94 to 299.51 or multiplied by 6.2 over the same period. Figures 2 and 3 displays the number of mineral discovery by size and by commodity respectively in Africa from 1990 to 2019. African countries experienced a commodity boom over the years 2000s and 2010s. Gold is the major resource discovered over these decades. Moreover, the price of gold increased in the same period. However, African countries did not experience spectacular economic over these decades. In fact, between 2004 and 2014, GDP per capita growth was 2.5% in African resource-rich countries against 4% for the rest of the world resource-rich countries and 2% in Africa non resource-rich countries.[2] According to Cust and Zeufack (2023) consider that this as a "missed opportunity" for Africa. This hope coupled with the disillusion that follows the discoveries of natural resources has been a concern for both academics and policymakers.

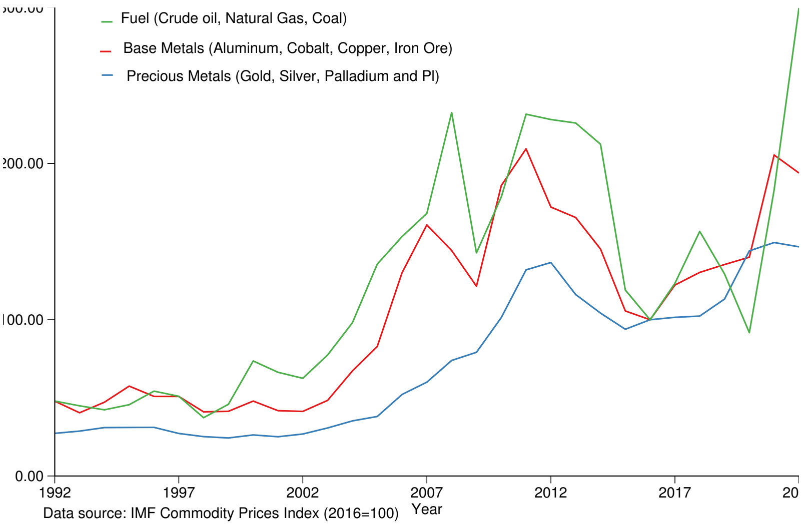


Figure 1: Evolution of commodity price indices

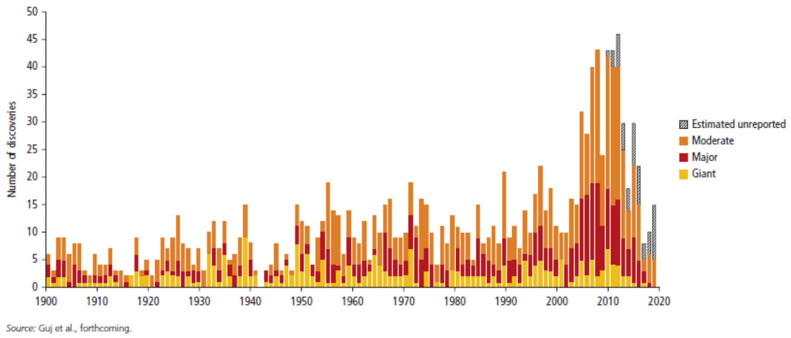


Figure 2: Number of African Mineral Discoveries, by Size of Deposit, 1900–2019

The natural resource curse hypothesis has been one of the prolific research areas in development economics over the last three decades. Since the seminal work by Sachs and Warner (1995), the literature on the "resource curse" thesis rapidly expanded to a broad set of economic, political and social outcomes including institutions, governance, public spending, tax revenue, political stability, environmental

[2] A country is considered to be resource-rich if it draws at least 20 percent of exports or 20 percent of government revenues from resources.

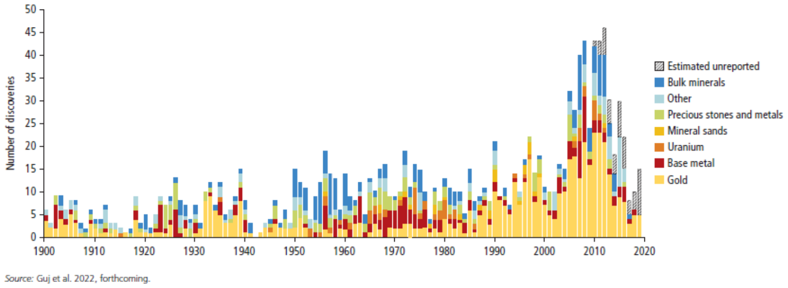
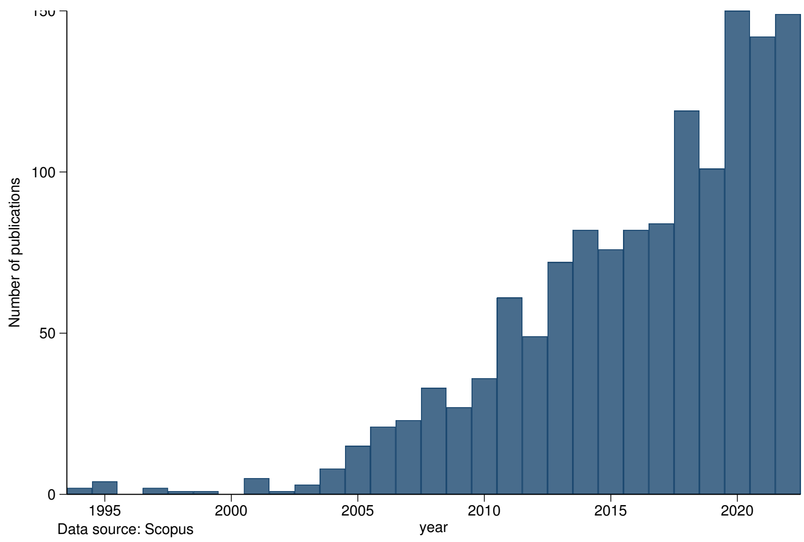


Figure 3: Number of African Mineral Discoveries, by Commodity, 1900–2019

quality and conflicts (Bornhorst et al., 2009; Ross, 2004; Brollo et al., 2013; Berman et al., 2017).

Figure 4 shows the evolution of the number of publications related to the resource curse literature per year in scientific journals. The papers were identified using a combination of keywords in the Scopus database and restricting the subject of Economics, Econometrics and Finance, Social Sciences, Environmental Sciences, Energy, Business, Management and Accounting. We found a total number of 1411 papers as of November 12, 2022. Through screening in the title and the abstracts, we excluded 62 irrelevant papers to the resource curse literature which reduced the sample to 1349 papers published papers in 505 journals. From less than 10 publications per year in 2000, the number of publications on natural resources and development reached 150 in 2020.



Notes: Keywords: ("resource curse" OR "paradox of plenty" OR "the curse of natural resources" OR "natural resources: a curse" OR "resource-curse hypothesis" OR "mining discovery and conflicts" OR "oil and conflict" OR "mining on conflict" OR "mining and conflict" OR "oil on violence" OR "oil on war" OR "natural resources and Dutch disease" OR "oil discoveries" OR "gas discoveries")

Figure 4: Evolution of the number of papers published per year

Yet, this extensive literature pays little attention to the role of the private sector and the interdependence between economies in natural resource regulation. The core of “resource curse” literature, which focuses on natural resources and GDP growth, has been extend to public spending (Cockx and Francken, 2016, 2014; Bhattacharyya and Collier, 2013; Arezki and Brückner, 2011), conflicts and political stability (Berman et al., 2023, 2017; Caselli and Tesei, 2016; Bjorvatn and Farzanegan, 2015), governance and institutions (Torvik, 2002; Bhattacharyya and Hodler, 2010; Cabrales and Hauk, 2011; Mehlum et al., 2006b) and other socioeconomic outcomes.

Mineral resources, environment and environmental policies in the context of climate change

Recent years have been marked by a growing awareness of climate change and the stakes for the survival of humanity (Calculli et al., 2021). This climate awareness is fuelling energy transition policies which put mineral resources at the heart of the transition. Mineral resources are involved in the production of various green energy sources, from solar and wind power to electric vehicles, as well as participating in several steps in the value chain, from production to storage. Lithium, nickel, cobalt, manganese and graphite are essential to producing batteries. Rare earth elements are necessary for permanent magnets, which are vital for wind turbines and electric motors. Aluminum and copper are crucial for electricity-related technologies (IEA, 2021). The construction of green energy sources such as solar photovoltaic power plants, wind farms and electric vehicles is more intensive in mineral resources than fossil fuels (IEA, 2021). A typical electric car requires six times more mineral resources than a conventional car. A wind power plant requires nine times more mineral resources than a gas-fired power plant of the same capacity (see Figure 5).

Since 2010, the quantity of mineral resources required to install a power generation unit has increased by 50% (IEA, 2021). The International Energy Agency (IEA) estimates that to meet the objectives of the Paris Climate Agreement, the share of clean energies in global demand should increase by over 40% for copper and rare earth, 60-70% for nickel and cobalt, and almost 90% for lithium over the next two decades. According to BloombergNEF (BNEF), building solar panels with 1 GW [gigawatt] capacity requires 10,252 tons of aluminum, 3,380 tons of polysilicon and 18.5 tons of silver to manufacture. The global installed solar capacity is expected to reach 3 000 GW by 2030. 154,352 tons of steel, 2,866 tons of copper and 387 tons of aluminum would be needed to construct wind turbines and infrastructure with a power capacity of one gigawatt. By 2030, the installed wind capacity will reach

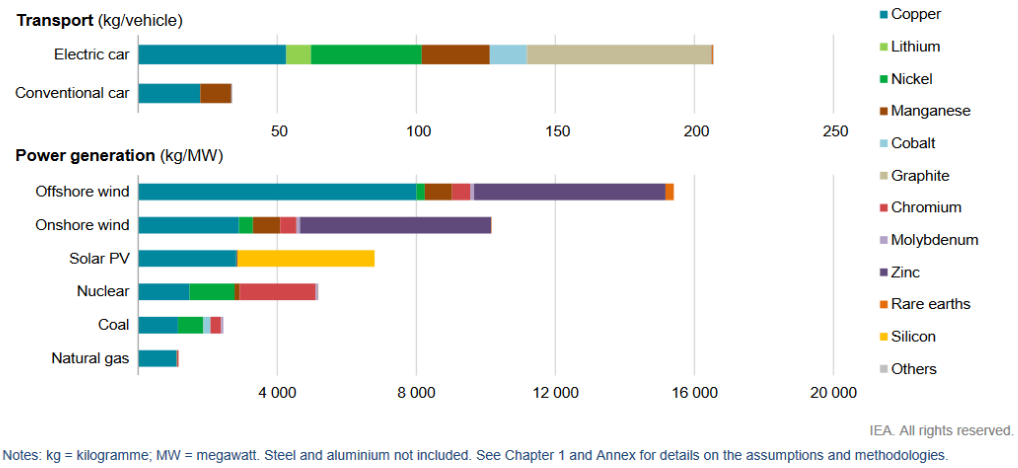


Figure 5: Minerals used in selected clean energy technologies

2,110 GW according to the Global Wind Energy Outlook (GWEO). Manufacturing 1 GWh Lithium-ion batteries would take 1,731 tons of copper, 1,202 tons of aluminum, and 729 tons of lithium. Twenty-five (25) kilograms of copper are needed for a single, typical, fast electric vehicle charging station.[3] According to Mining Watch Canada:"[Three] billion tons of mined metals and minerals will be needed to power the energy transition".

In all, the demand for mineral resources is set to triple by 2040. This explosion in demand for mineral resources over the coming decades, largely fuelled by energy transition policies, has serious consequences for the environment and the environmental policies of the countries that produce these resources. As far as environmental policies are concerned, the rise in demand and hence in prices may lead countries either to cooperate and jointly strengthen their environmental policies (race to the top) or to compete with each other to attract investment and lower environmental standards (race to the bottom). The implication of these two equilibria is either sustainable exploitation of mining resources with less environmental impact or resources' exploitation with unbearable environmental costs for present and future generations. Unfortunately, most developing countries where the minerals needed for the energy transition are (and will continue to be) extracted, often lack institutional capacity for strong regulation.

Africa is one of the regions in the world that has contributed least to climate change and will pay the highest cost, because it is vulnerable to climate shocks and it lacks of adaptation capacity (IPCC, 2014). Similarly, Africa is likely to pay the highest cost for the energy transition if mineral resources are exploited at the expense of the environment. Indeed, Africa remains the region of the world where

[3] https://liquidity-provider.com/news/metals-will-be-the-oil-of-the-future/

the energy transition remains slow, despite its green energy potential. The share of renewable sources in electricity consumption is 23%, compared with a global average of 30%, 29% in North America, 36% in Europe, and 61% in Latin America and the Caribbean.[4]

0.2 Theoretical foundations

This thesis draws on several theoretical families. Firstly, the market-based and political economy arguments of the resource curse literature. Secondly, it borrows from the literature on taxation and environmental regulation.

The Dutch disease theory

The term "Dutch disease" was first used in 1977 by the British newspaper, *The Economist*, to describe the economic situation in the Netherlands following the discovery of gas fields in the North Ocean in 1959. The Economist (1977) notes that the Netherlands has been particularly hard hit by the recession affecting OPEC member countries compared to its European peers. Industrial production has not increased since 1974, investment has fallen by 15%, unemployment is 5.4% compared with 1.1% in 1970, and employment in the manufacturing sector has dropped by 16%. Paradoxically, the Dutch economy appears strong to the outside world, with the guilder one of the world's strongest currencies, accounting for 16.4% of world trade. The Economist explains that this contrast between the external health of the economy and its lack of internal health is a symptom of "Dutch disease".

The Economist explains that Dutch disease has three causes, two of which are internal and only one external. These are: a currency that is too strong, rising production costs for industry, and revenue that is spent and not invested. The first is currency appreciation. In anticipation of abundant and secure nuclear energy in the future, and against a backdrop of cheaper oil, the Dutch authorities over-exploited their gas fields. The current account improved through two mechanisms: the high proportion of gas in domestic energy consumption (58%) reduced import and export revenues increased due to gas exports. The result is an excessive appreciation of the guilder.

The second cause is the increase in factors of production. Guilder appreciation per se is not the problem as domestic and import prices adjust. However, in the case of Holland, input costs, particularly wages, have remained high, in contrast to import prices. Without a policy of increasing labor productivity or reducing the wage costs borne by companies, they become less competitive. Despite the

[4] https://ourworldindata.org/low-carbon-electricity-by-country

government's determination to reduce production costs, the policies implemented have contributed to increasing production costs.

The third cause is the use of gas revenues: resources spent rather than invested. Increased gas revenues have led to higher public spending. However, this increase came at the expense of investment. Between 1973-75, public spending was around 50% of GDP, of which around 3% was investment spending, compared with over 40% for consumption and transfers.

Economists were quick to seize on the phenomenon, making it the subject of extensive research. This interest can be explained, in part, by the apparent paradox that the phenomenon arouses in the scientific community and the interest for policymakers in developing countries. The theoretical seminal work began in the late 1970s and early 1980s (references). Corden and Neary (1982) propose a systematic analysis of the Dutch disease, applicable in situations where the booming sector is not necessarily the extractive sector. The authors take as their starting point Salter's (1952) model of a small open economy producing two tradable goods (energy and manufacturing) and one non-tradable good (services). They are therefore interested in the effect of a boom in the energy sector on the manufacturing sector. Corden and Neary (1982) show that a boom in the energy sector leads to two phenomena: "the resources movement effect" and "the spending effect". The boom in the energy sector raises the marginal productivity of the mobile factors of production employed in this sector, attracting factors of production from other sectors. The "resource movement effect" is less pronounced in the absence of competition between the boom sector and other sectors for the same factors of production. The "spending effect" arises from the increase in income in the boom sector, which will increase demand in the other sectors. Prices rise and competitiveness deteriorates. Both effects lead to a compression of the industrial sector (deindustrialization) when only the labor factor is mobile between sectors. In the same vein, Harberger (1983)'s model predicts that an increase in the price of oil leads to an appreciation of the exchange rate, and consequently to a loss of competitiveness in the non-oil tradable sector. Edwards and Aoki (1983) analyze how a boom in one sector in a small open economy with a fixed exchange rate affects the rest of the economy. The authors conclude that the Dutch disease is not a disease in any clear sense. The authors demonstrate that in a non-monetary economy. This theoretical work has served as the basis for several empirical studies in the literature on the link between natural resources and development.

Rent-seeking and the resource curse

The second family of models on which this thesis is based concerns rent-seeking theory (political or economic): the voracity model developed by Tornell and Lane (1999) and Tornell (1999), rent-seeking and entrepreneurial talent misallocation highlighted by Torvik (2002), and rent-seeking and institutional quality degradation (Mehlum et al., 2006a,b).

Tornell and Lane (1999) consider an economic and political environment characterized by powerful interest groups struggling to monopolize resources and weak institutions. Under these conditions, a windfall leads to a more than proportional increase in public spending to the benefit of interest groups. As a result, the public deficit widens and economic growth slows. Tornell (1999) reaches the same conclusions as Tornell and Lane (1999) when considering a discrete-time model. In the voracity model, the windfall from either the discovery of a natural resource or the terms of trade is captured by interest groups through unproductive investment. The current account deteriorates, as does the public deficit, while the quality of investment declines.

Torvik (2002)'s model explains that natural resources lead to a detour of entrepreneurial talent from productive activities to rent-seeking activities. The result is a misallocation of talent throughout the economy and a consequent decline in well-being.

Mehlum et al. (2006b,a) explain that the discovery of natural resources can constitute a double curse for countries with already poor-quality institutions, as it deteriorates the quality of institutions in addition to having negative effects on economic growth. The authors note that the abundance of natural resources has produced both winners and losers in terms of growth; the losers are generally countries with poor-quality institutions (grabber-friendly institutions). Extreme cases of this double curse concern the occurrence of conflicts in resource-rich countries (Van der Ploeg and Rohner, 2012).

Borrowing from taxation and regulation literature

The literature on natural resources and development, particularly the resource curse literature (Sachs and Warner, 1995, 2001; Torvik, 2009; Venables, 2016), has hitherto considered independence among states. However, the regulation of natural resources, which is crucial for maximizing their benefits within a country, can be influenced by the policies of neighboring countries. While the literature on regulation is extensive on this matter, the literature on the resource curse has traditionally considered what happens within each country independently. In an extension of the resource curse thesis, we consider interdependence among states by drawing upon the literature on regulation.

Economic theory predicts that competition among jurisdictions can lead to two outcomes: a sub-optimal equilibrium known as the "race to the bottom" or an optimal equilibrium labeled as the "race to the top". The idea that competition among jurisdictions to attract mobile capital leads to a better allocation of resources was formalized by Tiebout (1956). Tiebout (1956)'s model shows that, just as in the private sector, competition among local governments leads to a more efficient allocation of resources, thus achieving an optimal equilibrium. Similarly, Brennan and Buchanan (1980) argues that when the workforce is mobile, competition among jurisdictions can result in optimal tax rates, by reducing the taxation power of jurisdictions, and improve public goods provision. These predictions are based on neoclassical analysis, which considers that competition leads to the efficient use of resources (Engel, 1997).

However, neoclassical theory fails to explain the full story. In a situation of strategic interactions with information asymmetry, competition or the pursuit of individual interests can lead to a sub-optimal situation, the "race to the bottom". The idea that the strategic behavior of jurisdictions to attract mobile capital by manipulating regulation can lead to a sub-optimal equilibrium dates back to the 1930s with Berle and Means (1932) and formalized by Cary (1974). The debate on the consequences of globalization in the 1990s (Davies and Vadlamannati, 2013; Kim and Wilson, 1997; Oates, 1999, 2002) revives the interest in the subject. Game theory provides a framework for analyzing these interactions and the resulting equilibrium. The typical case is the prisoner's dilemma, a situation in which the pursuit of individual interest leaves every participant worse off. Hardin (1968) apply the prisoner's dilemma in his analysis of the "tragedy of the commons".

0.3 Value Added and main findings

This thesis contributes to the debate on natural resources and development, in particular on two aspects still little explored in the literature: within countries, the private sector, and between countries, the environment and environmental policies. Studies of the natural resource curse have paid less attention to the private sector, given that much of the rent is captured by the state. Government behavior is therefore decisive in determining whether the resource becomes a curse or a blessing. However, the various mechanisms by which the link between resources and the economy as a whole operates, such as price volatility, rent-seeking behavior, Dutch disease and the deterioration of institutions, show that the private sector, which is at the heart of economic activity, can be impacted or can help to limit the adverse effects. The first part of the thesis is dedicated to this issue. The first chapter (Chapter

2) examines the effect of natural resource dependence on the productivity of manufacturing firms in developing countries. To my knowledge, this is the first work to investigate the effect of natural resources on the productivity of manufacturing firms in developing countries despite the flourishing literature on firm productivity (Javorcik, 2004; Arnold et al., 2008; Dong and Zhang, 2009; Van Biesebroeck, 2005; Crowley and McCann, 2018; Kouamé and Tapsoba, 2019; Islam et al., 2019; Fang et al., 2022). Existing work focuses on the effect of natural resources on banking firms (Beck and Poelhekke, 2023; Adetutu et al., 2020; Ma et al., 2021). Using World Bank company survey data covering 100 developing countries over the period 2008-2019 and a multilevel model, Chapter 1 shows that dependence on natural resources undermines firm's productivity. The effect is driven by oil and gas rents as opposed to mineral rents. The mechanism operates through real effective exchange rate volatility and corruption. GDP growth volatility and political instability are not mediating the relationship between oil and gas dependence and firm productivity. Resource-dependent countries should consider reforms that create backward and forward linkages between domestic companies and the extractive sector, in order to limit enclave economies.

Chapter 2 examines the relationship between extractive resources and public capital in public-private partnerships in developing countries. We use the IMF's new public capital database, which distinguishes between "full public provision" capital and public-private partnership capital, to assess the effect of extractive resources. The results show that extractive resources exert a positive effect on public capital in public-private partnership, while their effect on public capital in public provision is negative. These results highlight the fact that rent-seeking behavior (political or economic) can motivate public investment spending in resource-rich countries. Tying the hands" between the private and public sectors in investment projects helps to limit rent-seeking behavior.

The second part of the thesis is based on the perspective of interdependence of states in the relationship between mineral resources and the environment, and environmental policies. Previous work on the curse of natural resources assumes that a country's choice has no influence on that of its neighbor. However, the literature on taxation and environmental regulation is well-documented on the subject. To attract investors, countries may engage in a pollution heaven hypothesis of deregulation. In the context of climate change, a country's environmental reputation is a competitive and even diplomatic factor. In the interests of a good reputation, countries can mimic each other in adopting environmentally-friendly policies. In the first chapter of this section (Chapter 3), we study the strategic interaction of

African countries in their environmental policies and the resulting balances. Given this complexity, we use two measures of environmental policy: *de jure* environmental policy and *de facto* environmental policy. Our results confirm that countries behave strategically in response to their neighbors' environmental policies. A 1% increase in the environmental commitment of its neighbors increases its own environmental commitment by by 0.3% and 0.8% for *de jure* and *de facto* respectively. We show that this strategic behavior leads to an increase in regulation (race to the top) for *de jure* environmental policy and a decrease in regulation (race to the bottom) for *de facto* environmental policy.

The final chapter (Chapter 4) follows on from the previous one. It studies the effect of mining rents on deforestation by considering spatial dependence in deforestation. The underlying hypothesis is that unobserved factors influence deforestation in countries that share geographical similarities. The results show that mining increases deforestation, while environmental policy helps to reduce deforestation in mineral-rich countries. An increase in mining rents of one percentage point of GDP results in a forest loss of around 50 km^2. Furthermore, regional economic communities have heterogeneous effects on deforestation. Economic communities such as the Economic Community of West African States (ECOWAS) and the West African Economic and Monetary Union (UEMOA) are associated with lower deforestation, while the Economic Community of Central African States (ECCAS) and the Southern African Development Community (SADC) are associated with higher deforestation.

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Part I

Natural Resources and the Private Sector

Chapter 1

Natural Resources and Productivity in Developing Countries: Evidence from Firm-level Data

> "Productivity isn't everything, but in the long run it is almost everything."
>
> Krugman (1997)

1.1 Introduction

The negative association between natural resource endowment and economic performance coined as the 'resource curse' (Gelb, 1988; Auty, 1994; Sachs and Warner, 1995) remains puzzling and controversial despite three decades of extensive research (van der Ploeg, 2011; Ross, 2015; Venables, 2016; Papyrakis, 2017). While the most popular trend is that natural resource wealth is a curse (Gelb, 1988; Sachs and Warner, 1995, 1999, 2001), an increasing move in the literature argues that the natural resource curse phenomena remains a statistical mirage (Brunnschweiler and Bulte, 2008; Brunnschweiler, 2008; James, 2015; Smith, 2015). Conducting a meta-analysis based on 43 studies, Havranek et al. (2016) argue that there is no consensus in the debate: "40% of empirical papers finding a negative effect, 40% finding no effect, and 20% finding a positive effect" of natural resources on economic growth. Dauvin and Guerreiro (2017) undertake the same exercise based on 69 empirical studies totaling 1,419 estimates and point out that the way natural resources are considered and the role of institutional quality are crucial to understanding the heterogeneous results in the literature. This chapter aims to contribute to this debate by investigating the effect of natural resource dependence on manufacturing firm productivity in developing countries. Productivity is a key engine to economic growth (Easterly and Levine, 2001; Krugman, 1997; Solow, 1994). According to McGowan et al. (2015), productivity "reflects our ability to produce more output by better combining inputs, owing to new ideas, technological innovations and business models." In fact, the difference in productivity explains a large share of the difference in income per capita across countries (McGowan et al., 2015). Surprisingly, the resource curse literature on economic growth payed little attention to productivity (Farhadi et al., 2015).

Both market-based and political economy arguments provide solid frameworks for explaining the relationship between natural resource dependence and firm's productivity. From the market-based perspective, the idea that natural resource dependence affects manufacturing firm productivity is, at least, as old as the "Dutch Disease thesis"[1], coined by The Economist (1977) and formalized by Corden and Neary (1982). According to the Dutch disease thesis, a boom in natural resource sector crowd out the manufacturing sector through two mechanisms: (i) "spending effects" that result in appreciation of the exchange rate and (ii) resource-movements effect that draw out labor from the manufacturing sector to the extractive sector. Another market based mechanism through which natural resources may harm firm

[1]See Mien and Goujon (2021) for survey of Dutch disease literature.

productivity is related to commodity price volatility that increase uncertainty (e.g. real exchange rate fluctuations) leading to inefficient allocation of resources (Van der Ploeg and Poelhekke, 2009).

From the political economy perspective, several arguments support the fact that natural resource dependence may hinder firm productivity. First, by altering institutional quality (Robinson et al., 2006; Mehlum et al., 2006; Bhattacharyya and Hodler, 2010), natural resource dependence set up disabling business environment which hamper firm productivity. The literature documents that, on the one hand, natural resources deter institutional quality (Arezki and Brückner, 2011; Knutsen et al., 2017) and, on the other hand, whether resource windfall becomes a curse or blessing is conditional to the institutional environment (van der Ploeg, 2011). Natural resources fuels conflicts Berman et al. (2017); Lessmann and Steinkraus (2019), increase regimes duration and political instability, increase corruption (Arezki and Brückner, 2011; Bjorvatn and Farzanegan, 2015; Knutsen et al., 2017). Second, rent-seeking behavior is prevalent in resource-rich context. Torvik (2002) taking a political economy approach, proposes a theoretical model which infer that "a greater amount of natural resources increases the number of entrepreneurs engaged in rent-seeking and reduces the number of entrepreneurs running productive firms." The implication is straight forward: as the incentive to resource appropriation increase, the number of entrepreneurs engaged in resources-grabbing activities increase more than those engaged in wealth-producing activities. As a result, the productivity in the manufacturing sector decreases. Third, natural resource dependent countries are deem to invest less in education and health (Stijns, 2006; Behbudi et al., 2010; Cockx and Francken, 2014, 2016; Sun et al., 2018) and public capital (Bhattacharyya and Collier, 2013). In fact, resource windfall enhance government autonomy to tax revenue and increases volatility, which lead to neglecting investment in human capital (Cockx and Francken, 2014). By crowding out investment in human capital and public capital, natural resources wealth prevents resources-rich countries from providing the manufacturing sector with adequately qualified workforce and quality infrastructure, crucial for competitiveness.

Nevertheless, the effect of natural resources on firm performance is not trivial. First, natural resources such energy and raw material are crucial for production. Having access to abundant and cheaper inputs can result in cost savings, which can favor firm productivity and competitiveness. Second, resource discoveries encourage investment in infrastructure, such as transportation and communication networks, essential for firms to operate efficiently (Zeng et al., 2022). Governments in resource-rich countries often invest in infrastructure to facilitate the extraction and transportation of natural resources. This infrastructure can benefit firms by reducing transportation costs, improving access to markets and suppliers, and increasing the reliability of supply chains (Wan and Zhang, 2018). Third, well designed local content policies can favor local industries that on the one hand supply inputs or services to the extractive sector and on the other hand process the raw material from the extractive sector. Forward and backward linkages can generate clusters of firms that benefit from knowledge spillovers and economies of scale, which can improve their productivity (Emmanuel et al., 2016; Geenen, 2019). These virtuous effects although possible require sound policies that create synergy between the manufacturing sector and the extractive sector and managing well the resource windfall.

Against this theoretical background, the empirical literature remains silent about the effect of resource dependence on firm productivity. Since the pioneer works (Gelb, 1988; Auty, 1994; Sachs and Warner, 1995), the resource curse thesis has been extended in many directions including public capital (Bhattacharyya and Collier, 2013), human capital (Behbudi et al., 2010; Cockx and Francken, 2014, 2016; Stijns, 2006), institutions (Ross, 2001). These extensive works payed little attention to the private sector, in part because the rent accrues to the State (Bhattacharyya and Collier, 2013). Evidence of resource dependence on firm's performance remains scant. This chapter fills this gap in the literature by studying the effect of natural resource dependence on the productivity of manufacturing firms in developing countries.

The chapter contributes to two strands of the literature. First, it contributes to the literature on the determinant of firm's productivity. Thanks to the World Bank Enterprise Surveys (WBES) database, a large and comprehensive data harmonized across countries, the literature on the determinants of firm productivity is flourishing (Javorcik, 2004; Arnold et al., 2008; Dong and Zhang, 2009; Van Biesebroeck, 2005; Crowley and McCann, 2018; Kouamé and Tapsoba, 2019; Islam et al., 2019; Fang et al., 2022). This literature focuses more on individual firm characteristics, while ignoring country dependence to natural resource dependence. The studies on natural resources and firm performance are limited to the banking sector (Beck and Poelhekke, 2023; Adetutu et al., 2020; Ma et al., 2021). Beck and Poelhekke (2023) using a sample of 6,237 banks in 105 countries between 1991 and 2011 find that oil price shock reduce bank deposits. Adetutu et al. (2020) find that oil boom decrease bank productivity. Ma et al. (2021) argue that oil boom increase stock returns risk of Chinese banks. The second strand of the literature is on the resource curse thesis. To our knowledge, this chapter is the first to analyze the effect of natural resource dependence on manufacturing firm productivity. Herrera and Kouame (2017) study the determinants of the productivity of non-oil sector in Nigeria but did not consider the effect of oil. Second, the chapter contributes to the resource curse thesis which focuses primarily on country economic growth. As a result, the literature not only neglect the effect of natural resources on productivity but it also oversights the private sector. To the best of our knowledge, this is the first paper to test the resource curse hypothesis on manufacturing firms.

This chapter relies on a sample representative firms in 100 developing countries over the period 2008-2019 and using a multilevel model approach. The multi-level mixed model allows better dealing with issues related to the structure of the data and endogeneity stemming from omitted variables (Kouamé and Tapsoba, 2019). I find that natural resource dependence has a negative effect on firm productivity. This negative effect is observed for oil and gas dependence rather than for mineral resources, whose effect is not significant. The analysis by firm size shows that both small and large firms are negatively affected, although the impact is different: the negative effect of resource rents on total factor productivity is greater for small firms. Following the age, older firms are more affected than younger firms. The chapter further identifies the underlying mechanisms through which resource dependence affects firm productivity: inadequately educated work force, political instability and corruption are mediating factors. The results are robust to other alternative measures of productivity and to different specifications.

The remaining of the chapter is organized as follows. Section 1.2 presents the theoretical framework of the link between natural resources and firm productivity. The data and descriptive analysis follow in Section 3.3. Section 1.4 presents the empirical strategy. Section 1.5 presents the results. Section 1.7 undertakes robustness checks. Section 1.9 concludes the paper.

1.2 Natural resources and productivity: theoretical background

This section discusses the theoretical bases of the relationship between natural resources and firm productivity. Market-based and political economy arguments are both relevant to explain the relationship between natural resources and firm's productivity.

1.2.1 Market-based arguments on the link between natural resources and firm's productivity

The main market-based argument stem from the Dutch disease hypothesis[2] coined by The Economist (1977) and formalized by Corden and Neary (1982). It is the idea that the boom in the resource sector crowd out the other (productive) sectors of the economy. Originally coined to describe the contrast between the external strength of the Netherlands economy, materialized by strong guilder and a current account surplus, and domestic ailments characterized by stagnant industrial production, decreasing corporate investment and employment in manufacturing industry and rising unemployment. After the discovery of gas reserves, Netherlands economy benefit from a surge in foreign currency inflows from gas revenue. This inflow of foreign currency appreciates the guilder and deteriorate the completeness of the other sectors of Netherlands economy. Three sectors are typically considering when modeling the Dutch disease: the resource sector or the booming sector,[3] the non-resource tradable sector (agriculture or manufacturing sector) and the non-tradable sector (usually the services' sector). Prices in the resource and non resource tradable sector are set in the world market while those in the non-tradable sector are determined domestically. The Dutch disease occurs through two mechanisms. The first channel is the "resource movement effect" that drives out resources (capital and labor) away from the manufacturing sector. The boom in the extractive sector drive up the wages in this sector which attract more skilled workers. The consequences are: (i) a decrease in the workforce available for the manufacturing sector and an increase in the wages as result of the relative labor scarcity; (ii) a decrease in the production in the manufacturing sector which lead to an unbalance between the supply and the demand of manufactured goods; (iii) a rise in import causing appreciation of the real exchange rate. If the extractive sector is operating as an "enclave economy" – as is the case in most developing countries – then the resource movement effect is reduced.

The second mechanism, known as the "spending effect", suggests that the resource windfall can lead to an increase in aggregate demand from both public and private spending. As the demand increases, *ceteris paribus*, prices in the non-tradable sectors also increase which causes an appreciation of the real exchange rate. Since the supply of manufactured goods cannot increase in the short-run, prices increase

[2] I focus here on natural resource driven Dutch disease although other resource windfalls such as foreign aid, remittances and tourism can generate the Dutch disease.

[3] Corden and Neary (1982) employ the booming sector because it can refer to another set of activities outside the extractive sector such as the "technologically more advanced activities."

at the expense for the competitiveness of the domestic goods. As a result, the manufacturing sector declines.

Commodity prices' volatility is the second market-based argument that explain the relationship between natural resources and firm productivity. Sound macroeconomic environment is key to firm productivity (Kouamé and Tapsoba, 2019). However, commodity price volatility challenges macroeconomic stability. Instability such as exchange rate volatility, inflation, debt overhang and growth volatility are prevalent in developing resource-rich countries (Wang et al., 2023; Raveh and Tsur, 2020; Melina et al., 2016; Van der Ploeg and Poelhekke, 2009; Manzano and Rigobon, 2001). According to Van der Ploeg and Poelhekke (2009) countries that specialize in commodities with substantial price volatility experience more volatility in their terms of trade than those specialized in commodities or industrial goods with more stable prices. Aghion et al. (2009) shows that firms are more exposed to liquidity constraint in an environment characterized by macroeconomic volatility driven by nominal exchange rate movements. Wang et al. (2023) argue that due to financial constraints, natural resources countries use resource deposit as collateral that exposes them to price fluctuations which lead to debt overhang. Coupled with lacking capacity to manage commodity prices boom and bust, resource rich countries are often trapped in debt. Manzano and Rigobon (2001) support the same argument pointing out that the 1980's debt crisis is driven by excessive borrowing and the belief of continuous rising path of oil prices. In the same vein, Raveh and Tsur (2020) argue that even in democracy natural resource wealth encourage further borrowing. Summing up, macroeconomic stemming from commodity prices' volatility constitutes a significant cost for companies in terms of risk management, which is detrimental to their productivity. Ma et al. (2021) provide evidence that oil-shocks, especially supply shock increases bank risk. Conversely, companies operating in healthy macroeconomic environments characterized by moderate inflation, debt control and low exchange rate volatility can be more productive through greater risk and cost control.

1.2.2 Political economy arguments on the link between natural resources and firm's productivity

Several political economy arguments support potential links between natural resources and firm productivity. Although interconnected, I articulate these argument into rent-seeking behavior, corruption and political instability and the quality bureaucracy. First, Torvik (2002) proposes a simple model similar to Tornell and Lane

(1999) and Baland and Francois (2000) made of four sectors: the natural resource sector, a backward sector producing with constant returns to scale, a modern sector producing with increasing returns to scale and the public sector. In the model, entrepreneurs can engage in political competition, through rent-seeking or corruption, to redistribute income in their own interests. Torvik (2002) concludes that "a greater amount of natural resources increases the number of entrepreneurs engaged in rent-seeking and reduces the number of entrepreneurs running productive firms."

Second, resource-dependent economies are often plagued by rampant corruption (Bhattacharyya and Hodler, 2010; Zhan, 2017), political instability (Caselli and Tesei, 2016) and conflict (Berman et al., 2017; Janus, 2012). This environment is not conducive to the emergence of virtuous entrepreneurs, innovation and investment in research and development, which can increase productivity.

Third, bureaucracy plays a key role in both decision and execution of legislation (Alesina and Tabellini, 2007). Bureaucracy refers to a system of rules, procedures, and regulations that govern the operations of organizations. While bureaucracy is often associated with inefficiency and red tape, a well-designed bureaucratic system can provide several benefits to firms, while a poorly designed one can lead to negative consequences. A good quality bureaucracy promotes consistency and reliability in decision-making, accountability and transparency, which is invaluable for enable business environment.

1.3 Data

The paper combines firm-level and country-level variables to assess the effect of natural resource dependence on firm productivity. The selection of the variables follows the rich literature on firm productivity and the variable of interest of the study (Javorcik, 2004; Arnold et al., 2008; Van Biesebroeck, 2005; Crowley and McCann, 2018; Kouamé and Tapsoba, 2019; Herrera and Kouame, 2017; Islam et al., 2019; Léon, 2020; Fang et al., 2022; Léon and Dosso, 2022). The firm-level data are from the World Bank Enterprise Survey (WBES).

The WBES data are rounds of surveys conducted at the firm level in developing countries and emerging markets.[4] Most countries have more than one rounds (see Table 1.A1) but firms are not surveyed over time justifying the pseudo panel structure of the data. This study focuses on a manufacturing sector which covers a wide range of industries such as food, chemicals products, fabricated metal, machinery and equipment products, textiles and garments, Information and com-

[4]Over the last years, the dataset is covering some developed countries.

munication technology (ICT), construction, non-metallic mineral products, rubber and plastics products, etc. The baseline estimate include 28 871 firms. However, due to missing data for some variables, the number of firms decreases following the regressions. The WBES dataset is built upon a representative sample, mainly from the private sector, and covers a broad range of business environments such as access to finance, corruption burden, infrastructure, and firm performance measures such as sales, profits, employment, productivity, participation to the foreign market, etc. The dataset also include firms' characteristics such as their ownership structure, age, size, and industry. It uses a standardized questionnaire and sampling methodology which is valuable for cross-country analysis.

The country-level data are the country's traditional determinants of productivity including variables that capture enabling business environment, macroeconomic variables and our variable of interest extractive resources resource rents. The data are from the World Governance Indicators (WDI) and the World Development Indicators (WGI).

1.3.1 Firm's level variables

Firm productivity: firm productivity is the dependent variable. Total Factor Productivity (TFP) is the primary dependent variable of focus in this study. The WBES survey compute two types of TFP: a valued added based and a production based TFP. The production based TFP estimates the residuals from industry-specific production function with the total output as dependent variable. The computation of the value added based TFP proceeds the same way using the value added as the dependent variable. This former is preferred because value added account for the value of the inputs used in the production process. Appendix 1.9 describes in details the methodology of computing both TFP. The average TFP based on the value added in the sample is 1.48 with a minimum and a maximum of -6.3 and 7.9 respectively. The use of total factor productivity as a measure of firm productivity (TFP) is common in the literature (Javorcik, 2004; Arnold et al., 2008; Van Biesebroeck, 2005; Crowley and McCann, 2018; Fang et al., 2022). Javorcik (2004) uses TFP to investigate the spillover effects of foreign direct investment on firm performance in Lithuania. Likewise, Arnold et al. (2008) use TFP when investigating the relationship between access to services inputs and firm productivity in Africa. Unlike labor productivity, TFP takes into account the differences in non-labor inputs and therefore provide a better measure of efficiency (Fang et al., 2022). For robustness checks, I use a production-based TFP, the value added and labor productivity as alternative measures of firm's productivity. Figure 3.1 displays the distribution of

Total Factor Productivity and Labor productivity following firms' size. The average total factor productivity based on production is 2.0 with minimum and maximum -5.4 and 12.2 respectively. The value added is bounded between 4.1 and and 20.5 with an average of 12.9. Labor productivity has an average of 9.3 with a minimum of 1.1 and a maximum of 15.9.

Firm's ownership: the ownership variable is the share of working capital owned by the government, the domestic private sector and foreign entities.[5] We include in our regression the government and foreign share of the working capital. As a result, the reference group is the domestic private share of the working capital. Fang et al. (2022) find that the foreign ownership increases firm's productivity. However, they did not account for the government share. Cull et al. (2015) argue that firm's connection to the government reduces their financial constraints.

Firm's size: firm size is the number of employees in the last fiscal year. Firm size is important for their productivity. Finding the optimal size can help firms benefit from economies of scale. Larger firms are to some extent more productive than smaller ones. However, as firm size increase and poses management challenges it may start to deter productivity. Several studies control for firm size in their estimate of productivity (Aw et al., 2007; Kouamé and Tapsoba, 2019; Fang et al., 2022).

Firm's age: firm's age is calculated using the difference between the year of the survey and the year of the establishment. To some extent, it is reasonable to expect older firms to be more productive than younger ones. However, for some sectors (i.e technology), younger firms have shown exponential growth. Kouamé and Tapsoba (2019) find that mature firm (6–15 years old) are less productive than the older firm (more than 15 years old).

Credit constraint: firm are asked the following question. " How much of an obstacle: Access to finance?" The responses are ordinal with six modalities spanning from 0 to 5: (0) 'no obstacle', (1) 'minor obstacle', (2) 'moderate obstacle', (3) 'major obstacle', (4) 'severe obstacle' and (5) 'very severe obstacle'. Because the observations for very severe obstacle is fewer (less than 10%) compared to the other modalities, I grouped severe and very severe in the same group. The financial constraint variable now takes the value of 0 to 4. The reference group in the regression is 'no obstacle'. Financial constraint is one of the major constraints to business operation in developing countries (Asiedu et al., 2021). Li et al. (2018) find that access to internal and external finance promote firm productivity in China. I expect

[5] Firm ownership may refer to different type of classification such as family and non-family ownership (Barbera and Moores, 2013). In this study, I focus on foreign, government and domestic private classification regarding the information in the dataset.

credit constraints to hinder firm productivity.

Electricity constraint: the Electricity constraint variable is similar to the credit constraint variable. Firms identify electricity as one of their top obstacles in developing countries (Asiedu et al., 2021).

Top manager gender: the literature on the determinant of firm performance often point out the gender gap (Jain, 2022). We control the gender of the top manager. The reference group is female. Following the literature, firms that have male top managers are expected to be more productive. Fang et al. (2022) find that for manufacturing sector, gender matters for firms' productivity.

Top manager experience in the industry: this variable is the number of years of experience the top manager has in the same industry. Experienced managers may manage to be more productive than non-experienced ones.

Share of direct export: the share of direct exports measures firm access to the international market. With the international market being more competitive than the domestic one, export is expected to foster productivity. Several works in the literature support the idea that export participation increase firm productivity (Delgado et al., 2002; Aw et al., 2007).

1.3.2 Country-level variables

Natural resource rents: natural resource dependence is measured by the share of total natural resource rents as a percentage of GDP. Resource rents are "the difference between the value of production for a stock of minerals at world prices and their total costs of production" (World Bank, 2020). the resource rent as a share of GDP is preferred to the other measures since resource dependence is pointed out as originating the resource curse. I further distinguish mineral resource rents from oil and gas resource rents to check whether the type of resources matters. Minerals are gold, tin, lead, iron, zinc, copper, silver, nickel, bauxite, and phosphate. Oil and gas rents are the difference between the value of crude oil natural gas production at regional prices and the production costs.

GDP per capita: the country-level income per capita is a proxy of the level of development. Firms evolving in countries where per capita GDP are higher is likely to benefit from higher demand. I expect an increase in GDP per capita to positively affect firm productivity. GDP per capita data are from the the World Bank (World Development Indicators, WDI).

Inflation: inflation measures both macroeconomic stability (case of hyperinflation) and the relative cost of inputs. The inflation variable is the consumer price index and the data are taken from the World Bank (WDI) dataset. Increase inflation drives up the cost of inputs such as capital (including financial capital) and labor (through wages) which in turn hinder firm productivity.

GDP growth: GDP growth is a measure of economic dynamism. A flourishing economic environment is characterized by sustained economic growth which boosts firm productivity by increasing demand. GDP growth data are from the World Bank (WDI) dataset.

Rule of law: rule of law is a common measure of enabling business environment. It reflects people's perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. It is a continuous variable taking the values spanning from -2.5 to +2.5 where the higher value implies a better quality of the rule of law. The data are from the World Governance Indicators (WGI) dataset (Kaufmann et al., 2011).

Regulatory quality: as an alternative measure of enabling business environment I resort to Regulatory quality. It reflects people's perceptions of "the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development". It is a continuous variable taking the values spanning from -2.5 to +2.5 where the higher value implies better quality in regulation. The data for this variable are also taken from the World Governance Indicators (WGI) dataset (Kaufmann et al., 2011).

Real effective exchange rate (REER): The REER measures "the development of the price (or cost) level adjusted value of a country's currency against a basket of the country's trading partners" (Darvas, 2021). The standard deviation of the real effective exchange rate for a window of five years before the survey year captures its volatility. Table 1.1 provides the descriptive statistics for both the country-level and firm-level variables.

Table 1.1: Descriptive statistics

	(1)	(2)	(3)	(4)	(5)
	N	mean	sd	min	max
Total factor productivity (VA)	28,871	1.478	1.513	-6.309	7.929
Total factor productivity (production)	28,871	2.198	2.030	-5.442	12.22
Value Added (log)	28,871	12.87	2.180	4.084	20.54
Labor productivity (VA per worker)	28,780	9.287	1.470	1.138	15.93
Firm's size (log of employees)	28,858	3.702	1.334	0.693	9.405
Export (log)	28,803	0.947	1.624	0	4.615
Foreign ownership (log)	28,456	0.457	1.318	0	4.615
Government share (log)	28,465	0.0560	0.455	0	4.605
Firm's age (log)	28,871	2.897	0.790	0	7.615
Top manager experience log)	28,563	2.831	0.655	0	4.263
Credit constraint	28,473	1.435	1.279	0	4
Political instability constraint	28,176	1.569	1.438	0	4
Corruption constraint	27,873	1.616	1.465	0	4
Inadequately educated workforce	28,604	1.443	1.269	0	4
Electricity constraint	28,561	1.675	1.479	0	4
GDP growth	28,869	4.418	3.525	-14.84	11.65
GDP per capita (log)	28,871	8.291	0.992	5.729	10.82
Inflation	28,072	4.639	3.690	-2.410	36.91
Regulatory quality	28,871	-0.115	0.647	-1.685	1.805
Rule of law	28,871	-0.283	0.635	-1.903	1.975
Mineral resource rents % of GDP (log)	28,871	2.202	2.521	1	16.83
Oil and Gas rents % of GDP (log)	28,871	0.823	0.836	0	4.415
Natural resource rents % of GDP (log)	28,871	1.460	0.848	0	4.418
Exchange rate (log)	28,871	3.715	2.864	-1.539	9.959
Cumulative discoveries	28,871	1.004	5.122	0	28
Discoveries count	28,871	1.189	6.038	0	33
Discoveries estimated value (log)	28,871	0.270	1.280	0	7.171
Commulative value of discoveries	28,871	0.432	2.056	0	10.62

Number of countries: 100; Number of firms: 28 871. Period: 2008-2019.

1.4 Empirical strategy

Estimating the effect of natural resource dependence on firm productivity raises two challenges: the structure of the data and potential endogeneity. First, firms in the same country share the same geographic, economic, political and institutional environment. Ignoring this cluster effect by using a standard econometric method may be misleading. For instance, using aggregated data and interpreting country-level relationships (between effects) as pertaining on firm level relationships (within effects) leads to an *'ecological fallacy'* whereas the reverse leads to an *'atomistic fallacy'* (Rabe-Hesketh and Skrondal, 2008).[6] Second, although, I do not expect firm performance to affect country resource dependence, endogeneity originating from omitted variable bias may still be an issue.

To address these issues, I resort to a multilevel mixed model which captures country-level heterogeneity by accounting for the clustering effects and allowing the intercept to vary across countries. Furthermore, the multilevel mixed model allows including simultaneously country-level variables and, country and time-fixed effects which control for the difference in demand conditions, survey waves, and time-invariant omitted variables Kouamé and Tapsoba (2019). Hence, I specify a multilevel mixed model based on two levels model where the firm is the first and the country the second level.

The firm-level equation specifies as follows:

$$Prod_{ijt} = \alpha_{0jt} + \beta ER_{jt} + Z_{it}\gamma + X_{jt}\lambda + \epsilon_{ijt}, \quad \epsilon_{ijt} \sim N(0, \sigma^2) \tag{1.1}$$

where: $Prod_{ijt}$ is the productivity of firm i in country j at the year t. I consider total factor productivity (TFP). ER_{it} is our variable of interest, the measure of natural dependence. I expect a negative association between natural resource dependence and firm productivity.

Z_{it} is a vector of variables accounting for firm-level characteristics. I control for firm characteristics such as size, age, ownership, top manager characteristics, financial access and the connection to the foreign market. I follow the rich literature on firm performance to identify these variables (Darko et al., 2021; Fang et al., 2022; Konte and Tetteh, 2023; Kouamé and Tapsoba, 2019).

X_{jt} is a vector of country-level variables that may affect firm productivity. These variables include GDP growth, inflation and institutional quality variables. GDP growth captures change in the economic environment while the inflation rate controls

[6] See Rabe-Hesketh and Skrondal (2008) and Hox et al. (2017) for extensive discussion on the subject.

prices' stability. Institutional quality is measured by the rule of law and regulatory quality.

The country-level equation specifies as follows:

$$\alpha_{0jt} = \alpha_{00t} + \nu_{jt}, \quad \nu_{jt} \sim N(0, \delta^2), \quad \nu_{jt} \perp \epsilon_{ijt} \tag{1.2}$$

The baseline model is obtained by combining equations 2.1 and 2.2 as follows:

$$Prod_{ijt} = \alpha_{00t} + \beta ER_{jt} + Z_{it}\gamma + X_{jt}\lambda + \nu_{jt} + \epsilon_{ijt} \tag{1.3}$$

$\nu_{jt} + \epsilon_{ijt}$ is the random part of the model with ν_{jt} the country-specific error term. The main advantage of the multilevel mixed model is that by capturing both between and within-country effects of natural resource dependence, it accounts for potential bias stemming from the *'ecological fallacy'*.

1.5 Estimations results and discussion

1.5.1 Baseline results

Table 1.2 displays the baseline results. I start by estimating a naive equation (column 1) where I include only my variable of interest, natural resource rents as a share of GDP, and control for region and year fixed effects. I then follow by adding the other variables of control sequentially from column (2) to (7). In column (2), I added the size and ownership. In column 3, I add the firm's age, credit constraint, and access to the international market measured by the share of direct export. In column (4), the top manager characteristics (gender and experience) were included. In column (5) I add macroeconomic conditions (GDP per capita) and inflation while variables related to the business environment (rule of law and regulatory quality) are alternatively added in columns (6) and (7).

Natural resource dependence, measured by the share of resources rent to GDP, exerts a negative effect firm's total factor productivity. The coefficient is statistically significant at a 1% level in all the regression and its size is even stronger in column (7) where I include all the control variables. This result is consistent with our hypothesis that resource dependence hamper firm productivity. Although the idea that natural resources crowd out entrepreneurship is not new (Torvik, 2002), this is the first empirical evidence of the adverse effect of natural resource dependence and firm productivity.

Firm size affects positively their productivity. The fact that larger firms are more productive than smaller ones is intuitive and expected. As opposed to small firms, larger firms benefit from economies of scale, specialization (dedicate a team for research and development for instance), and easier access to resources and reputations. Conversely, firm age is negatively associated with its productivity: older firms tend to be less productive.

The coefficient associated with the government share in the capital is positive and significant while the foreign share is not significant. This result is unexpected because previous works find foreign ownership to be associated with firm performance (Kouamé and Tapsoba, 2019). However, government firms may benefit from contentedness to several services including finances (Cull et al., 2015) which in return positively their productivity.

Credit constraints negatively affect firm productivity as expected. Firms that declare credit constraint to be a very severe to their business operation are 18.2 percentage points lower productivity compared to those that did not find access to credit as a constraint to their business. The coefficients associated with top manager gender and experience are statistically not significant.

The coefficients associated with the macroeconomic variables have the expected signs and are statistically significant. An increase in GDP per capita is associated with an improvement of firm productivity. An increase in per capita GDP, ceteris paribus, fosters consumer demand and may positively affect firm productivity. As expected inflation affects negatively firm productivity. In fact, inflation increases macroeconomic uncertainty and the costs of inputs (wages, capital and other services) including the cost of credit (through higher interest rates; the so-called Fisher effects (Mishkin, 1992)).

The controls for business the environment have unexpected signs. The coefficient associated with the rule of law is not statistically significant while the one for regulatory quality is significant. Higher regulatory quality is expected to provide a better competitive environment. However, it can adversely increase the compliance cost when the regulation is poorly designed.

1.5.2 Does the resource type matter?

The literature on natural resource curse shows that the type of the resources matters (Badeeb et al., 2017; Frankel, 2010; Vahabi, 2018; Boschini et al., 2007). For instance, Azomahou et al. (2021) show that governance is more challenging for African oil-exporting countries compared to others. Tables 1.3 and 1.4, present the estimates for respectively oil and gas resources to mineral resource dependence. In accordance with previous literature, oil and gas dependence exert negative effects on firm pro-

Table 1.2: Estimates of total resource rents on TFP

	Dependent variable: Total Factor Productivity (TPF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural resource rents (log)	**-0.135*****	**-0.139*****	**-0.134*****	**-0.134*****	**-0.128*****	**-0.115****	**-0.212*****
	(0.0419)	**(0.0419)**	**(0.0414)**	**(0.0418)**	**(0.0422)**	**(0.0459)**	**(0.0520)**
Ownership							
Government share (log)		0.0458**	0.0471***	0.0476**	0.0426**	0.0502***	0.0485**
		(0.0181)	(0.0182)	(0.0186)	(0.0187)	(0.0190)	(0.0190)
Foreign share (log)		0.0198***	0.0167**	0.00449	-0.000296	0.00214	0.00173
		(0.00646)	(0.00651)	(0.00694)	(0.00706)	(0.00721)	(0.00720)
Credit constraint							
Minor constraint			-0.0613***	-0.0612***	-0.0621***	-0.0551**	-0.0573**
			(0.0235)	(0.0236)	(0.0240)	(0.0242)	(0.0242)
Moderate constraint			-0.0778***	-0.0757***	-0.0775***	-0.0767***	-0.0781***
			(0.0231)	(0.0232)	(0.0235)	(0.0239)	(0.0239)
Major constraint			-0.0859***	-0.0807***	-0.0801***	-0.0636**	-0.0666**
			(0.0268)	(0.0270)	(0.0273)	(0.0279)	(0.0279)
(Very) severe constraint			-0.222***	-0.218***	-0.231***	-0.223***	-0.222***
			(0.0352)	(0.0354)	(0.0359)	(0.0365)	(0.0364)
Other firm characteristics							
Firm's size				0.0249***	0.0271***	0.0288***	0.0283***
				(0.00748)	(0.00760)	(0.00773)	(0.00772)
Firm's age (log)				-0.0421***	-0.0452***	-0.0474***	-0.0482***
				(0.0134)	(0.0145)	(0.0148)	(0.0148)
Share of direct export (log)				0.0172***	0.0173***	0.0163**	0.0178***
				(0.00614)	(0.00624)	(0.00635)	(0.00635)
Management							
Top manager gender					0.00216	0.0115	0.00762
					(0.0305)	(0.0308)	(0.0308)
Top manager experience					0.00149	0.00483	0.00538
					(0.0148)	(0.0151)	(0.0151)
Macroeconomic and institutions							
GDP per capita (log)						0.0345	0.294***
						(0.0766)	(0.0763)
Inflation						-0.0119**	-0.0117*
						(0.00584)	(0.00603)
Rule of law						0.0418	
						(0.0865)	
Regulatory quality							-0.493***
							(0.0874)
Constant	0.934***	0.915***	0.995***	0.988***	0.948***	0.888	-1.044*
	(0.184)	(0.184)	(0.184)	(0.190)	(0.196)	(0.623)	(0.631)
# Observations	27,418	27,004	26,648	26,378	25,409	24,663	24,663
Number of countries	100	100	100	100	100	99	99
Log likelihood	-47088	-46453	-45803	-45312	-43525	-42246	-42232
chi2	5418	5200	5221	5218	5168	5090	5137
Chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the effect of oil and gas resource dependence on total factor productivity. Standard errors in parentheses. The multi-level nature of the model account for country fixed effects. * Indicates significance at 10% level, **significance at 5% level, and ***significance at 1% level.

ductivity. The results from the control variables remain similar to those from Table 1.2. Although the coefficient associated with mineral dependence is not statistically significant, the fact that mineral resources do not have a significant effect itself is unfortunate because the mining sector is expected to create backward and forward linkages with domestic firms to avoid enclave economies. Local content policies intend to create these linkages.

Table 1.3: Estimates of oil and rents on TFP

	Dependent variable: Total Factor Productivity (TPF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Oil and Gas rents (log)	**-0.122*****	**-0.129*****	**-0.124*****	**-0.127*****	**-0.118*****	**-0.123****	**-0.281*****
	(0.0431)	**(0.0431)**	**(0.0425)**	**(0.0429)**	**(0.0431)**	**(0.0511)**	**(0.0572)**
Ownership							
Government share (log)		0.0460**	0.0473***	0.0478**	0.0427**	0.0502***	0.0490***
		(0.0181)	(0.0182)	(0.0186)	(0.0187)	(0.0190)	(0.0190)
Foreign share (log)		0.0197***	0.0166**	0.00449	-0.000303	0.00210	0.00158
		(0.00646)	(0.00651)	(0.00694)	(0.00706)	(0.00721)	(0.00720)
Credit constraint							
Minor constraint			-0.0607***	-0.0604**	-0.0615**	-0.0547**	-0.0565**
			(0.0235)	(0.0236)	(0.0240)	(0.0242)	(0.0242)
Moderate constraint			-0.0768***	-0.0746***	-0.0765***	-0.0760***	-0.0765***
			(0.0231)	(0.0232)	(0.0235)	(0.0239)	(0.0239)
Major constraint			-0.0846***	-0.0793***	-0.0789***	-0.0626**	-0.0649**
			(0.0268)	(0.0270)	(0.0273)	(0.0279)	(0.0279)
(Very) severe constraint			-0.220***	-0.216***	-0.230***	-0.221***	-0.220***
			(0.0352)	(0.0354)	(0.0359)	(0.0365)	(0.0364)
Other firm characteristics							
Firm's size				0.0249***	0.0271***	0.0289***	0.0282***
				(0.00748)	(0.00760)	(0.00773)	(0.00772)
Firm's age (log)				-0.0418***	-0.0449***	-0.0476***	-0.0485***
				(0.0134)	(0.0145)	(0.0148)	(0.0148)
Share of direct export (log)				0.0170***	0.0171***	0.0161**	0.0175***
				(0.00614)	(0.00624)	(0.00635)	(0.00635)
Management							
Top manager gender					0.00310	0.0124	0.00874
					(0.0305)	(0.0308)	(0.0308)
Top manager experience					0.00143	0.00456	0.00474
					(0.0148)	(0.0151)	(0.0151)
Macroeconomic and institutions							
GDP per capita (log)						0.111	0.401***
						(0.0802)	(0.0783)
Inflation						-0.0119**	-0.0113*
						(0.00583)	(0.00604)
Rule of law						-0.0292	
						(0.0951)	
Regulatory quality							-0.587***
							(0.0922)
Constant	0.695***	0.675***	0.760***	0.757***	0.721***	0.109	-2.199***
	(0.153)	(0.153)	(0.153)	(0.159)	(0.166)	(0.625)	(0.622)
Observations	27,418	27,004	26,648	26,378	25,409	24,663	24,663
Number of countries	100	100	100	100	100	99	99
Log likelihood	-47090	-46454	-45804	-45312	-43526	-42247	-42229
chi2	5415	5197	5219	5216	5166	5089	5147
Chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the effect of oil and gas resource dependence on total factor productivity. Standard errors in parentheses. The multi-level nature of the model account for country fixed effects. * Indicates significance at 10% level, **significance at 5% level, and ***significance at 1% level.

Table 1.4: Estimates of mineral rents on TFP

	Dependent variable: Total Factor Productivity (TPF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mineral rents (log)	**0.00266**	**0.00355**	**0.00226**	**0.00465**	**0.00469**	**0.00948**	**0.0101**
	(0.0110)	**(0.0110)**	**(0.0110)**	**(0.0111)**	**(0.0112)**	**(0.0128)**	**(0.0137)**
Ownership							
Government share (log)		0.0447**	0.0461**	0.0466**	0.0416**	0.0497***	0.0479**
		(0.0181)	(0.0182)	(0.0186)	(0.0187)	(0.0190)	(0.0190)
Foreign share (log)		0.0197***	0.0166**	0.00445	-0.000315	0.00217	0.00189
		(0.00646)	(0.00651)	(0.00694)	(0.00706)	(0.00721)	(0.00720)
Credit constraint							
Minor constraint			-0.0612***	-0.0608**	-0.0618***	-0.0544**	-0.0559**
			(0.0235)	(0.0236)	(0.0240)	(0.0242)	(0.0242)
Moderate constraint			-0.0779***	-0.0756***	-0.0774***	-0.0757***	-0.0765***
			(0.0231)	(0.0232)	(0.0235)	(0.0239)	(0.0239)
Major constraint			-0.0856***	-0.0801***	-0.0795***	-0.0621**	-0.0637**
			(0.0268)	(0.0270)	(0.0274)	(0.0279)	(0.0279)
(Very) severe constraint			-0.221***	-0.216***	-0.230***	-0.221***	-0.219***
			(0.0352)	(0.0354)	(0.0359)	(0.0365)	(0.0365)
Other firm characteristics							
Firm's size				0.0250***	0.0272***	0.0290***	0.0288***
				(0.00748)	(0.00761)	(0.00773)	(0.00772)
Firm's age (log)				-0.0414***	-0.0448***	-0.0468***	-0.0474***
				(0.0134)	(0.0145)	(0.0148)	(0.0148)
Share of direct export (log)				0.0170***	0.0172***	0.0160**	0.0169***
				(0.00614)	(0.00624)	(0.00635)	(0.00635)
Management							
Top manager gender					0.00232	0.0124	0.00970
					(0.0305)	(0.0308)	(0.0308)
Top manager experience					0.00210	0.00520	0.00558
					(0.0148)	(0.0151)	(0.0151)
Macroeconomic and institutions							
GDP per capita (log)						0.0518	0.294***
						(0.0749)	(0.0724)
Inflation						-0.0122**	-0.0123**
						(0.00579)	(0.00596)
Rule of law						0.0661	
						(0.0842)	
Regulatory quality							-0.379***
							(0.0824)
Constant	0.566***	0.536***	0.631***	0.617***	0.590***	-1.541***	0.451
	(0.149)	(0.149)	(0.150)	(0.156)	(0.163)	(0.587)	(0.601)
Observations	27,418	27,004	26,648	26,378	25,409	24,663	24,663
Number of countries	100	100	100	100	100	99	99
Log likelihood	-47094	-46458	-45808	-45317	-43529	-42249	-42240
chi2	5405	5186	5208	5205	5157	5082	5112
Chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the effect of mineral resource dependence on total factor productivity. Standard errors in parentheses. The multi-level nature of the model account for country fixed effects. * Indicates significance at 10% level, **significance at 5% level, and ***significance at 1% level.

1.6 Transmission channels

In this section, I conduct a mediation analysis to gain a deeper understanding of the underlying mechanisms through which oil and gas dependence deters firm productivity. Both market-based and political economy arguments provide solid ground for the mediation analysis. From the market-based perspective, potential transmission channels include the real exchange rate (as highlighted in the Dutch Disease literature), growth volatility, and resource constraints such as availability of an educated workforce, access to electricity, telecommunication, and transportation. From the political economy perspective, potential channels include political instability, corruption, and institutional quality, such as trade regulation and the court system, which may pose obstacles to business operations.

Various methods have been employed to identify mediation mechanisms (Memon et al., 2018; Rungtusanatham et al., 2014). Baron and Kenny (1986)'s approach is one of the earliest and most well-known methods. It involves conducting a series of regression analyses to test for the presence of mediation mechanism. This approach requires demonstrating that the independent variable significantly predicts the mediator, the mediator significantly predicts the dependent variable while controlling for the independent variable, and the effect of the independent variable on the dependent variable decreases when the mediator is included in the analysis (Baron and Kenny, 1986). However, the recent literature strongly discourage researchers using Baron and Kenny (1986)'s approach (Memon et al., 2018; Aguinis et al., 2017; Rungtusanatham et al., 2014). According to Rungtusanatham et al. (2014), Baron and Kenny (1986)'s approach suffers from low statistical power and cannot provide a direct quantification of a specific indirect effect nor test its significance.

This paper employs Structural Equation Modeling (SEM) framework to analyze the mechanisms through which oil and natural gas dependence deters firm's productivity. As a more comprehensive approach to mediation analysis, SEM allows for the examination of multiple mediators and complex relationships between variables (Mehmetoglu, 2018). It combines factor analysis and path analysis to estimate both the direct and indirect effects in a mediation model. In SEM, the relationships among variables are represented by a series of structural equations. These equations specify the direct and indirect paths between the variables of interest. In the context of this study, the indirect effect represents the mediation effect, which captures the influence of the oil and gas dependence on firm's productivity through the mediator(s). The total effect is the sum of the direct and indirect effects. SEM utilizes the Maximum Likelihood Estimation (MLE) method to estimate the parameters of the model.

In Table 1.5, I investigate the channels through which, oil and gas dependence may affect firm productivity. As potential channels, I use real effective exchange rate volatility, GDP growth volatility, political stability and absence of violence, control of corruption as mediating factors.

Table 1.5 presents the results of the transmission channel analysis. Real effective exchange rate (REER) volatility and corruption are the transmission channels of the effect of oil and gas resource dependence on business productivity. The effect of REER volatility accounts for 25% of the total effect, while the effect of corruption accounts for 18%. Growth volatility and political instability are not significant channels. Hence, both political economy and market-based arguments explain the mechanisms through which oil and gas dependence hinder firms' productivity. This result is informative for policymaker seeking to curb the adverse effect of natural resource dependence on their manufacturing sector.

Table 1.5: Transmission channels

	Market-based channels					
Mediating variables	REER volatility			GDP growth volatility		
Estimates	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo
Indirect effect	-0.015	-0.015	-0.015	-0.000	-0.000	-0.000
Std. Err.	0.003	0.003	0.003	0.000	0.000	0.000
Z-value	-5.69	-5.69	-5.69	-1.723	-1.723	-1.653
P-value	0.000	0.000	0.000	0.085	0.085	0.98
Conf. Interva	[-0.021 , -0.010]			[-0.001 , -0.000]		
RIT	0.25			–		
	Political economy channels					
Mediating variables	Political instability			Corruption		
Estimates	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo
Indirect effect	0.000	0.000	0.000	0.012	0.012	0.012
Std. Err.	0.002	0.002	0.002	0.004	0.004	0.004
Z-value	0.012	0.012	0.011	3.490	3.490	3.485
P-value	0.990	0.990	0.991	0.000	0.000	0.000
Conf. Interva	[-0.004 , 0.004]			[0.005 , 0.019]		
RIT	–			0.18		

Note: RIT= (Indirect effect/Total effect)

In Table 1.6, I conduct a placebo test to assess for the absence of alternative mechanisms. These variables are linked to physical and institutional infrastructures quality, often called into question in oil and gas dependent countries. The World Bank Enterprises Survey questionnaire contains question such as "How Much Of An Obstacle: Electricity?"; "How Much Of An Obstacle: Inadequately Educated Workforce?" and "How Much Of An Obstacle: Transport?"; "How Much Of An Obstacle: Trade regulation?"; "How Much Of An Obstacle: court system?"; "How Much Of An Obstacle: Access to finance?". The answers are multi-modal outcomes coded from 0 to 5 where 0: no obstacle; 1: minor obstacle; 2: moderate obstacle; 3: major obstacle; 4: severe obstacle; 5: very severe obstacle. We use the variables as proxy of our potential channels. It turns out that constraints linked to inadequate education of the workforce, access to electricity, transport, trade regulation, the court system and access to credit are not mediating channels. The mediating effects of these variables is close to zero: 1% for electricity and trade regulation, 1.2% for transport and 1.6% for credit. Moreover, zero is a bound of the confidence interval for all these results.

Table 1.6: Transmission channels: Placebo

Mediating variables	Education			Electricity			Transport		
Estimates	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo
Indirect effect	-0.000	-0.000	-0.000	0.001	0.001	0.001	0.001	0.001	0.001
Std. Err.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Z-value	-1.597	-1.597	-1.517	2.143	2.143	2.104	2.573	2.573	2.532
P-value	0.110	0.110	0.129	0.032	0.032	0.035	0.010	0.010	0.011
Conf. Interva	[-0.001 , 0.000]			[0.000 , 0.001]			[0.000 , 0.002]		
RIT	–			0.01			0.012		

Mediating variables	Trade regulation			Court system			Credit		
Estimates	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo	Delta	Sobel	Monte Carlo
Indirect effect	-0.001	-0.001	-0.001	0.000	0.000	0.000	-0.001	-0.001	-0.001
Std. Err.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Z-value	-2.563	-2.563	-2.516	1.181	1.181	1.089	-2.778	-2.778	-2.727
P-value	0.010	0.010	0.012	0.238	0.238	0.276	0.005	0.005	0.006
Conf. Interva	[-0.002 , -0.000]			[-0.000 , 0.001]			[-0.002 , -0.000]		
RIT	0.01			–			0.016		

Note: RIT= (Indirect effect/Total effect)

1.7 Robustness checks

This section undertakes several robustness tests to make sure that the results are robust to alternative measures of productivity and natural resources and other additional control variables.

1.7.1 Alternative measure of productivity: Production based TFP

In the baseline estimates, the total factor productivity is based on value added. For a robustness purpose, I use here the output based productivity. The difference between the value added based and the output based is that the later does not account for the value of the inputs used in the production process (see Appendix 1.9 for details.). Table 1.7 presents the results. The results from the output based total factor productivity are similar to the baseline results except the fact that the size of the coefficients are lower compared to Table 1.3.

Table 1.7: Robustness: Estimates of oil and gas rents on TFP (output based)

	Dependent variable: Total Factor Productivity (output based)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Oil and Gas rents (log)	**-0.111****	**-0.121****	**-0.120****	**-0.125*****	**-0.122****	**-0.166*****	**-0.199*****
	(0.0490)	**(0.0485)**	**(0.0485)**	**(0.0484)**	**(0.0493)**	**(0.0541)**	**(0.0544)**
Firm's size (log)		0.00437	0.0130	0.0128	0.0102	0.0100	0.00994
		(0.00966)	(0.0107)	(0.0108)	(0.0110)	(0.0110)	(0.0110)
Ownership							
Government share (log)		0.0488*	0.0453*	0.0478*	0.0584**	0.0576**	0.0566**
		(0.0268)	(0.0271)	(0.0274)	(0.0279)	(0.0279)	(0.0279)
Foreign share (log)		0.0152	0.0181*	0.0175*	0.0203**	0.0206**	0.0201*
		(0.00966)	(0.00994)	(0.0101)	(0.0103)	(0.0103)	(0.0103)
Firm's age (log)			-0.000703	0.00971	0.00483	0.00446	0.00435
			(0.0165)	(0.0177)	(0.0181)	(0.0181)	(0.0181)
Credit constraint							
Minor constraint			-0.0507	-0.0544	-0.0461	-0.0468	-0.0476
			(0.0338)	(0.0341)	(0.0345)	(0.0345)	(0.0345)
Moderate constraint			-0.0209	-0.0240	-0.0195	-0.0203	-0.0202
			(0.0333)	(0.0336)	(0.0342)	(0.0342)	(0.0341)
Major constraint			-0.0448	-0.0499	-0.0366	-0.0374	-0.0384
			(0.0389)	(0.0393)	(0.0401)	(0.0401)	(0.0401)
(Very) severe constraint			-0.241***	-0.243***	-0.238***	-0.238***	-0.238***
			(0.0515)	(0.0521)	(0.0530)	(0.0530)	(0.0530)
Share of direct export (log)			-0.0233***	-0.0233***	-0.0224**	-0.0221**	-0.0216**
			(0.00868)	(0.00877)	(0.00892)	(0.00892)	(0.00892)
Top manager gender (male)				-0.0380	-0.0377	-0.0381	-0.0390
				(0.0361)	(0.0364)	(0.0364)	(0.0364)
Top manager experience (log)				-0.0504**	-0.0437**	-0.0441**	-0.0435**
				(0.0208)	(0.0212)	(0.0212)	(0.0212)
Macroeconomic controls							
GDP per capita (log)					0.0649	0.186**	0.237***
					(0.0542)	(0.0829)	(0.0742)
Inflation					-0.00970	-0.00956	-0.0103
					(0.00782)	(0.00779)	(0.00784)
Rule of law						-0.191*	
						(0.0997)	
Regulatory quality							-0.333***
							(0.0968)
Region Fixed effects	YES	YES	YES	YES	YES	YES	YES
Year Fixed effects	YES	YES	YES	YES	YES	YES	YES
Constant	2.526***	2.508***	2.552***	2.706***	2.377***	1.443**	1.000*
	(0.161)	(0.164)	(0.171)	(0.179)	(0.453)	(0.660)	(0.607)
Observations	28,871	28,440	28,014	27,599	26,814	26,814	26,814
Number of groups	106	106	106	106	105	105	105
Log likelihood	-61003	-60108	-59194	-58330	-56725	-56723	-56719
chi2	44.15	51.37	81.25	89.06	91.84	95.99	103.3
chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.7.2 Alternative measure of productivity: valued added

Here, I resort to the firm's total valued added as a proxy of firm's productivity. The value added is the difference between the value of the outputs (sales) and the inputs (purchase of intermediary goods and services). The results are in Table 1.8. Again, oil and gas rents exert negative effect on firm productivity. The coefficients are negative and significant with a greater size. Most of the control variables remain significant with the expected signs.

Table 1.8: Estimates of Oil and Gas on Value Added

	Dependent variable: Log of Value Added						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Oil and Gas rents (log)	**-0.335*** **	**-0.469*** **	**-0.447*** **	**-0.444*** **	**-0.500*** **	**-0.470*** **	**-0.564*** **
	(0.0829)	**(0.0629)**	**(0.0620)**	**(0.0623)**	**(0.0657)**	**(0.0719)**	**(0.0632)**
Firm's size (log)		1.150***	1.117***	1.114***	1.114***	1.114***	1.113***
		(0.00486)	(0.00530)	(0.00535)	(0.00547)	(0.00547)	(0.00547)
Ownership							
Government share (log)		0.0125	0.00496	0.00703	0.00738	0.00777	0.00581
		(0.0138)	(0.0138)	(0.0140)	(0.0142)	(0.0142)	(0.0142)
Foreign share (log)		0.102***	0.0906***	0.0910***	0.0890***	0.0890***	0.0886***
		(0.00504)	(0.00516)	(0.00524)	(0.00538)	(0.00538)	(0.00538)
Firm's age (log)			0.0684***	0.0623***	0.0623***	0.0624***	0.0623***
			(0.00816)	(0.00877)	(0.00900)	(0.00900)	(0.00899)
Credit constraint							
Minor constraint			-0.123***	-0.115***	-0.118***	-0.118***	-0.120***
			(0.0169)	(0.0170)	(0.0173)	(0.0173)	(0.0173)
Moderate constraint			-0.145***	-0.139***	-0.144***	-0.144***	-0.145***
			(0.0169)	(0.0170)	(0.0174)	(0.0174)	(0.0174)
Major constraint			-0.205***	-0.202***	-0.194***	-0.194***	-0.194***
			(0.0200)	(0.0201)	(0.0206)	(0.0206)	(0.0206)
(Very) severe constraint			-0.271***	-0.274***	-0.265***	-0.265***	-0.263***
			(0.0264)	(0.0266)	(0.0271)	(0.0271)	(0.0271)
Share of direct export (log)			0.0485***	0.0501***	0.0490***	0.0490***	0.0499***
			(0.00443)	(0.00446)	(0.00456)	(0.00456)	(0.00456)
Top manager gender (male)				0.154***	0.156***	0.156***	0.155***
				(0.0184)	(0.0187)	(0.0187)	(0.0187)
Top manager experience (log)				0.0274***	0.0311***	0.0312***	0.0311***
				(0.0103)	(0.0106)	(0.0106)	(0.0106)
Macroeconomic controls							
GDP per capita (log)					0.704***	0.618***	0.925***
					(0.0801)	(0.102)	(0.0822)
Inflation					-0.0183***	-0.0186***	-0.0152***
					(0.00453)	(0.00454)	(0.00452)
Rule of law						0.156	
						(0.105)	
Regulatory quality							-0.550***
							(0.0798)
Region Fixed effects	YES	YES	YES	YES	YES	YES	YES
Year Fixed effects	YES	YES	YES	YES	YES	YES	YES
Constant	12.27***	8.196***	8.229***	8.022***	3.735***	4.419***	1.715***
	(0.237)	(0.191)	(0.188)	(0.191)	(0.593)	(0.768)	(0.631)
Observations	39,292	38,752	38,100	37,420	36,243	36,243	36,243
Log likelihood	-82003	-61821	-60542	-59340	-57667	-57666	-57644
chi2	229.8	65162	65145	64357	61379	61385	61508
chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.7.3 Alternative measure of productivity: labor productivity

I use the value added per worker as a measure of labor productivity. The results on the mechanisms through oil and gas dependence adversely affect firm productivity show that inadequately educated workforce is the major channels. Labor productivity hence, is a good alternative candidate to perform the robustness of the results. The results are in Table 1.9. They are similar to the baselines estimates. The coefficients of oil and gas rents are negative and statistically significant. Moreover, the control variables are mostly significant with the expected sign.

1.7.4 Resource abundance vs. Resource wealth

It is often argued that resource dependence leads to the resource curse while resource abundance fosters economic growth (James, 2015; Brunnschweiler and Bulte, 2008; Brunnschweiler, 2008). I test this assumption using giants oil and gas discoveries instead of the resource rents.

The results are in Table 1.10. The variable of interest in columns 1 and 2 is cumulative oil and gas discoveries. In the column 1, I only control for region and year fixed effects. In column 2, I include all the control variables as in the baselines. I replicate the same exercise for the yearly numbers of discoveries in columns 3 and 4, the estimated value of discoveries in columns 5 and 6, and the cumulative value of discoveries in columns 7 and 8. I did not find any statistically significant effect oil discovery on firm productivity. Although less dramatic, the lack of a significant effect on firm productivity following natural resource discoveries is a signal that resource-rich countries have failed to establish backward and forward linkages between the extractive sector and the manufacturing sector.

Fortunately, well designed local content policies could influence the share of local or national spending in the total extractive industry spending (Östensson, 2017). Oil and gas rich countries should design and implement local content policies that create a synergy between the extractive sector and the manufacturing one. In this regard, the cases of Chile and Malaysia are insightful (Lebdioui, 2020). In Malaysia, local content policies promote protection and capacity building which contribute to emerging competitive suppliers. In contrast, market failures and low public incentives for innovation and learning by doing hindered the emergence of competitive local suppliers (Lebdioui, 2020).

Table 1.9: Estimates of Oil and Gas rents on Labor Productivity

	Dependent variable: Labor productivity						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Oil and Gas rents (log)	**-0.387*** **	**-0.434*** **	**-0.412*** **	**-0.408*** **	**-0.458*** **	**-0.441*** **	**-0.529*** **
	(0.0637)	**(0.0628)**	**(0.0622)**	**(0.0625)**	**(0.0665)**	**(0.0723)**	**(0.0638)**
	(0.0637)	(0.0628)	(0.0622)	(0.0625)	(0.0665)	(0.0723)	(0.0638)
Firm's size (log)		0.134***	0.102***	0.100***	0.100***	0.100***	0.0998***
		(0.00494)	(0.00538)	(0.00542)	(0.00555)	(0.00555)	(0.00555)
Ownership							
Government share (log)		0.00307	-0.00279	-0.00160	-0.00135	-0.00112	-0.00293
		(0.0138)	(0.0139)	(0.0140)	(0.0143)	(0.0143)	(0.0143)
Foreign share (log)		0.102***	0.0905***	0.0911***	0.0891***	0.0891***	0.0887***
		(0.00504)	(0.00517)	(0.00525)	(0.00539)	(0.00539)	(0.00539)
Firm's age (log)			0.0576***	0.0533***	0.0536***	0.0536***	0.0536***
			(0.00814)	(0.00875)	(0.00898)	(0.00898)	(0.00897)
Credit constraint							
Minor constraint			-0.120***	-0.114***	-0.116***	-0.116***	-0.118***
			(0.0169)	(0.0170)	(0.0173)	(0.0173)	(0.0173)
Moderate constraint			-0.143***	-0.137***	-0.141***	-0.141***	-0.142***
			(0.0169)	(0.0170)	(0.0174)	(0.0174)	(0.0174)
Major constraint			-0.193***	-0.190***	-0.181***	-0.181***	-0.181***
			(0.0200)	(0.0201)	(0.0206)	(0.0206)	(0.0206)
(Very) severe constraint			-0.263***	-0.267***	-0.257***	-0.257***	-0.256***
			(0.0264)	(0.0266)	(0.0271)	(0.0271)	(0.0271)
Share of direct export (log)			0.0489***	0.0503***	0.0487***	0.0487***	0.0496***
			(0.00443)	(0.00447)	(0.00456)	(0.00456)	(0.00456)
Top manager gender (male)				0.154***	0.156***	0.156***	0.155***
				(0.0184)	(0.0187)	(0.0187)	(0.0187)
Top manager experience (log)				0.0225**	0.0263**	0.0263**	0.0262**
				(0.0103)	(0.0106)	(0.0106)	(0.0106)
Macroeconomic controls							
GDP per capita (log)					0.704***	0.654***	0.941***
					(0.0814)	(0.102)	(0.0830)
Inflation					-0.0167***	-0.0169***	-0.0132***
					(0.00453)	(0.00454)	(0.00452)
Rule of law						0.0903	
						(0.105)	
Regulatory quality							-0.591***
							(0.0800)
Region Fixed effects	YES	YES	YES	YES	YES	YES	YES
Year Fixed effects	YES	YES	YES	YES	YES	YES	YES
Constant	8.995***	8.443***	8.501***	8.301***	3.984***	4.381***	1.812***
	(0.192)	(0.191)	(0.189)	(0.192)	(0.602)	(0.772)	(0.637)
Observations	39,330	38,827	38,169	37,484	36,309	36,309	36,309
Log likelihood	-63737	-61981	-60695	-59485	-57806	-57806	-57780
chi2	569.1	2171	2481	2533	2511	2511	2585
chi2 p-value	0	0	0	0	0	0	0

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 1.10: Resource dependence vs. Resource wealth

	Dependent variable: Total Factor Productivity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Oil and Gas discovery (cum.)	0.0156	0.00844						
	(0.0137)	(0.0134)						
Oil and Gas discovery (count)			0.0126	0.00620				
			(0.0115)	(0.0113)				
Estimated value of discovery (log)					0.00738	-0.0156		
					(0.0317)	(0.0307)		
Cumulative estimated value of discovery (log)							0.0127	-0.00508
							(0.0238)	(0.0231)
Main control variables	No	Yes	No	Yes	No	Yes	No	Yes
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.682***	0.718	1.683***	0.714	1.702***	0.685	1.693***	0.686
	(0.130)	(0.565)	(0.130)	(0.565)	(0.131)	(0.564)	(0.131)	(0.565)
Observations	28,871	26,814	28,871	26,814	28,871	26,814	28,871	26,814
Log likelihood	-52064	-48345	-52064	-48345	-52064	-48345	-52064	-48345
chi2	57.71	155.3	57.60	155.2	56.29	155.1	56.55	154.8
Chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.8 Sensitivity analysis

1.8.1 Sensitivity analysis: firm's size

Table 1.11 presents the sensitivity of the results following firms' size. Small firm are firms with less than 20 employees, medium firs are those that have 20 to 99 employees and large firms those with 100 or greater employees as classified in the WBES dataset. Regardless of the size of the firm oil and gas rents exert a negative effect on productivity. However, a closer look shows that for total factor productivity, smaller firm are more likely to suffer from resource dependence than the larger ones. The coefficient decreases in absolute term from small to large firms. Also, the coefficient for large firms is significant only at 10% threshold while for small firms it is significant at 1%. For labor productivity, the coefficient remain strongly significant at 1% across firms' size. The coefficient size increases from small to large firms, indicating that the results for labor productivity are opposite to those for total factor productivity. This finding suggests that when capital is not taken into account, large firms are more likely to suffer from the resource dependence compare to the smaller ones.

1.8.2 Sensitivity analysis: firm's age

Table 1.12 shows the sensitivity of the results following the age of the firms. The classification of firms into young, mature and old follows Kouamé and Tapsoba (2019). Young firms are those of less or equal to 5 years, mature firm have from 6

Table 1.11: Sensitivity: over the firm's size

	Total Factor Productivity			Labor productivity		
	Small	Medium	Large	Small	Medium	Large
	(1)	(2)	(3)	(1)	(2)	(3)
Oil and Gas rents	-0.160***	-0.114**	-0.110*	-0.206***	-0.329***	-0.571***
	(0.0553)	(0.0574)	(0.0649)	(0.0733)	(0.0730)	(0.0983)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,468	10,474	6,884	12,662	14,222	9,425
Log likelihood	-16771	-19101	-12480	-19523	-22330	-15503
chi2	83.57	66.44	101.8	618.7	794.8	632.4
chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

to 15 years and the old ones are those that have more than 15 years. Regardless of the age of the firm oil and gas dependence exerts a negative effect on productivity. The magnitude of the coefficient is larger for labor productivity compared to total factor productivity. Older firms are more likely to suffer from resource dependence compared to the younger ones.

Table 1.12: Sensitivity: firm's age

	Total Factor Productivity			Labor productivity		
	Young	Mature	Old	Young	Mature	Old
	(1)	(2)	(3)	(1)	(2)	(3)
Oil and Gas rents	-0.175*	-0.239*	-0.257**	-0.452***	-0.478***	-0.485***
	(0.103)	(0.135)	(0.122)	(0.145)	(0.133)	(0.138)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed effects	YES	Yes	Yes	Yes	Yes	Yes
Constant	0.0188	-1.613	-1.355	4.586**	4.775***	4.970***
	(1.330)	(1.515)	(1.410)	(1.806)	(1.505)	(1.564)
Observations	933	4,184	6,648	1,296	5,687	8,773
Log likelihood	-1248	-5655	-9318	-2076	-9151	-13636
chi2	82.40	340.5	270.1	284.9	538.1	1079
chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

1.9 Conclusion

It is argued that natural resource dependence is a curse to economic growth Auty and Warhurst (1993). Surprisingly, while firms are engine to economic growth, the empirical literature on natural resource dependence on firm performance remain scant. Based on a theoretical model, Torvik (2002) conclude that "a greater amount of natural resources increases the number of entrepreneurs engaged in rent seeking and reduces the number of entrepreneurs running productive firm". I test this theoretical prediction using a larger and representative sample of firms in developing and emerging countries. I document an empirical evidence of this theoretical prediction by investigating the relationship between natural resource dependence and firm productivity.

Using the World Bank Enterprise Survey (WBES) data for 28 871 firms over 106 countries surveyed from 2008 to 2019 and relying on multilevel mixed model estimation method, I find four key results. First, natural resource dependence exerts a negative effect on firm total factor productivity. The effect is driven by oil and gas rents as opposed to mineral rents. Second, this negative effect mediates through real effective exchange rate volatility and corruption. GDP growth volatility and political instability are not mediating the relationship between oil and gas dependence and firm productivity. The results are robust to alternative measure of firm's productivity, additional controls and controlling for industry fixed effects.

Several policy implications emerge from these findings. First, natural resource dependent countries should undertake local content policies to strengthen the ties between the extractive sector and the other sectors. Second, REER volatility and corruption are the main channels through which the rent deter firm performance. Resource dependent government need to pay careful consideration to institutional reforms that promote good governance and fight against corruption. Third, natural resource dependent countries often suffer from sound macroeconomic mismanagement. They need to design sound macroeconomic policies including exchange rate management.

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Table 1.A1: List of countries

SSA	EAP	ECA	LAC	MNA	SAR
Angola	Cambodia	Albania	Barbados	Djibouti	Afghanistan
Benin	China	Armenia	Bolivia	Iraq	Bangladesh
Botswana	Indonesia	Azerbaijan	Brazil	Israel	Bhutan
Burkina Faso	Malaysia	Belarus	Chile	Jordan	India
Burundi	Mongolia	Bosnia and Herzegovina	Colombia	Lebanon	Nepal
Cameroon	Myanmar	Bulgaria	Dominican Republic	Malta	Pakistan
Chad	Philippines	Croatia	Ecuador	Morocco	
Eswatini		Cyprus	El Salvador	Tunisia	
Ethiopia	Thailand	Estonia	Guatemala		
Ghana	Timor-Leste	Georgia	Guyana		
Guinea	Vietnam		Honduras		
Kenya		Hungary	Jamaica		
Lesotho			Mexico		
Madagascar		Kazakhstan	Nicaragua		
Malawi		Kosovo	Panama		
Mali		Kyrgyz Republic	Paraguay		
Mauritania		Latvia	Peru		
Mauritius		Lithuania	Suriname		
Mozambique		Moldova			
Namibia		Montenegro	Uruguay		
Niger		North Macedonia			
Nigeria		Poland			
Rwanda					
Senegal		Romania			
Sudan		Serbia			
Tanzania		Slovenia			
Togo					
Uganda		Tajikistan			
Zambia		Ukraine			
Zimbabwe		Uzbekistan			

Table 1.A2: Robustness: Estimates of total resource rents on TFP with industry fixed effects

	Dependent variable: Total Factor Productivity (TPF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Natural resource rents (log)	**-0.443*****	**-0.450*****	**-0.467*****	**-0.478*****	**-0.392*****	**-0.402*****	**-0.430*****
	(0.0903)	**(0.0904)**	**(0.0908)**	**(0.0908)**	**(0.0990)**	**(0.100)**	**(0.103)**
Firm's size (log)		0.0213***	0.00637	0.00696	0.00755	0.00756	0.00762
		(0.00678)	(0.00750)	(0.00758)	(0.00780)	(0.00780)	(0.00780)
Ownership							
Government share (log)		0.0607***	0.0603***	0.0639***	0.0646***	0.0643***	0.0641***
		(0.0208)	(0.0208)	(0.0209)	(0.0211)	(0.0211)	(0.0211)
Foreign share (log)		0.0192***	0.0138*	0.0135*	0.0136*	0.0136*	0.0135*
		(0.00726)	(0.00744)	(0.00755)	(0.00780)	(0.00780)	(0.00780)
Firm's age (log)			0.0194*	0.0198	0.0216*	0.0216*	0.0217*
			(0.0117)	(0.0124)	(0.0128)	(0.0128)	(0.0128)
Credit constraint							
Minor constraint			-0.0603**	-0.0566**	-0.0562**	-0.0564**	-0.0559**
			(0.0239)	(0.0240)	(0.0245)	(0.0245)	(0.0245)
Moderate constraint			-0.0965***	-0.0934***	-0.0939***	-0.0940***	-0.0937***
			(0.0236)	(0.0238)	(0.0244)	(0.0244)	(0.0244)
Major constraint			-0.137***	-0.134***	-0.122***	-0.122***	-0.122***
			(0.0282)	(0.0284)	(0.0294)	(0.0294)	(0.0294)
(Very) severe constraint			-0.218***	-0.215***	-0.196***	-0.196***	-0.195***
			(0.0382)	(0.0385)	(0.0398)	(0.0398)	(0.0398)
Share of direct export (log)			0.0199***	0.0191***	0.0219***	0.0219***	0.0220***
			(0.00628)	(0.00633)	(0.00652)	(0.00652)	(0.00652)
Top manager gender (male)				-0.00172	-0.00495	-0.00513	-0.00502
				(0.0256)	(0.0261)	(0.0261)	(0.0261)
Top manager experience (log)				-0.0129	-0.0157	-0.0157	-0.0161
				(0.0152)	(0.0157)	(0.0157)	(0.0157)
Macroeconomic controls							
GDP per capita (log)					0.196	0.271	0.314**
					(0.124)	(0.166)	(0.150)
Inflation					-0.0257**	-0.0250**	-0.0207*
					(0.0104)	(0.0105)	(0.0110)
Rule of law						-0.115	
						(0.168)	
Regulatory quality							-0.234
							(0.166)
Region Fixed effects	YES	YES	YES	YES	YES	YES	YES
Industry Fixed effects	YES	YES	YES	YES	YES	YES	YES
Year Fixed effects	YES	YES	YES	YES	YES	YES	YES
Constant	2.198***	2.141***	2.262***	2.346***	1.408	0.833	0.373
	(0.330)	(0.331)	(0.334)	(0.338)	(1.133)	(1.422)	(1.353)
# Observations	12,821	12,597	12,444	12,271	11,765	11,765	11,765
Log likelihood	-17670	-17341	-17088	-16836	-16212	-16212	-16211
chi2	562.1	575.9	646.5	648.9	572.6	572.9	574.6
chi2 p-value	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 1.A3: Robustness: Estimates of mineral rents on TFP with industry fixed effects

	Dependent variable: Total Factor Productivity (TPF)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mineral resource rents (log)	**0.000203**	**0.00204**	**0.000912**	**0.00286**	**-0.0145**	**-0.0145**	**-0.0135**
	(0.0214)	**(0.0214)**	**(0.0214)**	**(0.0215)**	**(0.0221)**	**(0.0221)**	**(0.0226)**
Firm's size (log)		0.0212***	0.00651	0.00707	0.00769	0.00770	0.00770
		(0.00678)	(0.00751)	(0.00759)	(0.00781)	(0.00781)	(0.00781)
Ownership							
Government share (log)		0.0605***	0.0600***	0.0636***	0.0646***	0.0646***	0.0646***
		(0.0208)	(0.0209)	(0.0210)	(0.0211)	(0.0211)	(0.0211)
Foreign share (log)		0.0191***	0.0139*	0.0136*	0.0135*	0.0136*	0.0135*
		(0.00727)	(0.00745)	(0.00755)	(0.00780)	(0.00780)	(0.00780)
Firm's age (log)			0.0205*	0.0208*	0.0223*	0.0223*	0.0223*
			(0.0117)	(0.0124)	(0.0128)	(0.0128)	(0.0128)
Credit constraint							
Minor constraint			-0.0598**	-0.0563**	-0.0556**	-0.0557**	-0.0556**
			(0.0239)	(0.0241)	(0.0245)	(0.0245)	(0.0245)
Moderate constraint			-0.0960***	-0.0929***	-0.0932***	-0.0933***	-0.0932***
			(0.0236)	(0.0238)	(0.0244)	(0.0244)	(0.0244)
Major constraint			-0.135***	-0.132***	-0.120***	-0.120***	-0.120***
			(0.0282)	(0.0284)	(0.0294)	(0.0294)	(0.0294)
(Very) severe constraint			-0.215***	-0.212***	-0.195***	-0.194***	-0.194***
			(0.0382)	(0.0386)	(0.0398)	(0.0398)	(0.0398)
Share of direct export (log)			0.0192***	0.0184***	0.0215***	0.0215***	0.0215***
			(0.00629)	(0.00634)	(0.00652)	(0.00652)	(0.00652)
Top manager gender (male)				-0.000683	-0.00360	-0.00363	-0.00360
				(0.0257)	(0.0261)	(0.0261)	(0.0261)
Top manager experience (log)				-0.0119	-0.0157	-0.0157	-0.0157
				(0.0152)	(0.0157)	(0.0157)	(0.0157)
Macroeconomic controls							
GDP per capita (log)					0.389***	0.407**	0.410***
					(0.113)	(0.160)	(0.149)
Inflation					-0.0243**	-0.0241**	-0.0235**
					(0.0104)	(0.0105)	(0.0111)
Rule of law						-0.0266	
						(0.164)	
Regulatory quality							-0.0346
							(0.162)
Region Fixed effects	YES	YES	YES	YES	YES	YES	YES
Industry Fixed effects	YES	YES	YES	YES	YES	YES	YES
Year Fixed effects	YES	YES	YES	YES	YES	YES	YES
Constant	0.949***	0.865***	0.941***	0.976***	-1.043	-1.192	-1.243
	(0.235)	(0.237)	(0.239)	(0.245)	(0.937)	(1.308)	(1.324)
Observations	12,821	12,597	12,444	12,271	11,765	11,765	11,765
Log likelihood	-17682	-17353	-17102	-16849	-16220	-16220	-16220
chi2	536.6	549.5	618.3	619.4	557.2	557.2	557.2
Chi2 p-value	0	0.000	0.000	0.000	0.000	0.000	0.000

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Computing Total Factor Productivity

I summarize here the methodology of computing the Total Factor Productivity as laid out by the the World Bank Enterprises Survey Analysis Unit "World Bank Group (2020). The World Bank Enterprises Survey Analysis Unit computes the two measures of total factor productivity (TFP) using the following methodology. TFP is the portion of output that is not explained by the amount of inputs utilized.

The estimation uses a Cobb-Douglas production function in the following form:

$$VA_i = A_i K_i^{\alpha_k} L_i^{\alpha_l} \tag{1.4}$$

where VA_i is firm-level value-added which is a function of inputs of capital (K_I), and labor (L_i). A_i measures production efficiency at firm level, the share of output that cannot be directly attributed to the utilized inputs. The regression equation is obtained by applying the natural logarithm on both sides of Equation 1.4. To second-order Taylor polynomial around the Cobb-Douglas is used to allow more flexible functional form, when this translog specification fits the data better. The regression functions are estimated separately for each country, c for respective value added based (Equation 1.5) and production based (Equation 1.6) as follows:

$$\begin{aligned}\ln(VA_{sci}) &= c_{VAKL} + \alpha_1 \ln(K_{sci}) + \alpha_2 \ln(L_{sci}) + \alpha_3 \ln(K_{sci}) \times I_c \\ &+ \alpha_4 \ln(L_{sci}) \times I_c + \frac{1}{2}\alpha_5[\ln(K_{scti})]^2 + \frac{1}{2}\alpha_6[\ln(L_{scti})]^2 \\ &+ \alpha_7 \ln(K_{scti}) \times \ln(L_{scti}) + FE_i + FE_c + FE_t + u_{sci}^{VAKL}\end{aligned} \tag{1.5}$$

$$\begin{aligned}\ln(Y_{cti}) &= c_{YKLM} + \beta_1 \ln(K_{sci}) + \beta_2 \ln(L_{sci}) + \beta_3 \ln(M_{sci}) + \beta_4 \ln(K_{sci}) \times I_c \\ &+ \beta_5 \ln(L_{sci}) \times I_c + \beta_6 \ln(M_{sci}) \times I_c + \frac{1}{2}\beta_7[\ln(K_{scti})]^2 + \frac{1}{2}\beta_8[\ln(L_{scti})]^2 \\ &+ \frac{1}{2}\beta_9[\ln(M_{scti})]^2 + \beta_{10} \ln(K_{cti}) \times \ln(L_{cti}) + \beta_{11} \ln(K_{cti}) \times \ln(M_{cti}) \\ &+ \beta_{12} \ln(L_{cti}) \times \ln(M_{cti}) + \beta_{13} \ln(K_{cti}) \times \ln(L_{cti}) \times \ln(M_{cti}) \\ &+ FE_i + FE_c + FE_t + u_{sci}^{YKLM}\end{aligned} \tag{1.6}$$

where:
s, c, t and i denote respectively country, year and firm
I_c denotes a dummy variable for income group of the economy.
c_{VAKL}, and c_{YKLM} are constants
FE_i, FE_c and FE_t are income level, economy, and year fixed effects.

The Total Factor Productivity (TFP) is estimated as:

$$T\hat{F}P_{ctif} = \hat{u}_{ctif} + \hat{c}_f + F\hat{E}_{if} + F\hat{F}_{cf} + F\hat{E}_{tf}; \qquad f \in \{VA, KLM\} \tag{1.7}$$

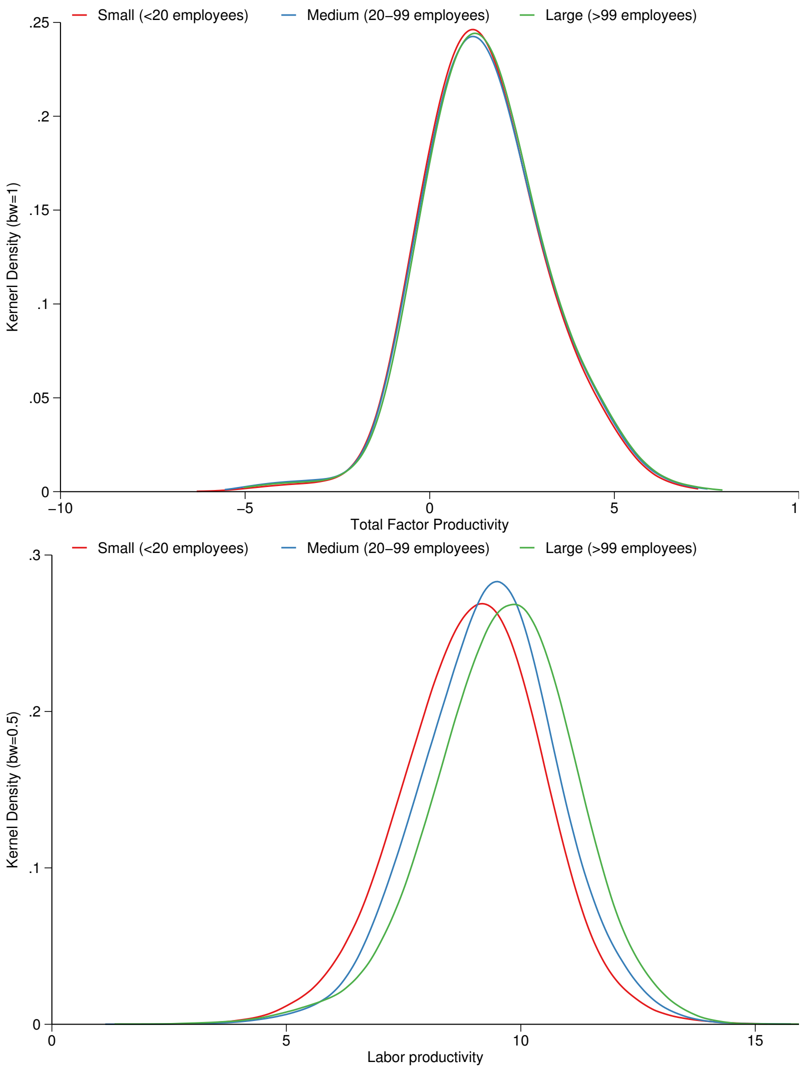


Figure 1.A1: Kernel Density of Productivity following firms' size

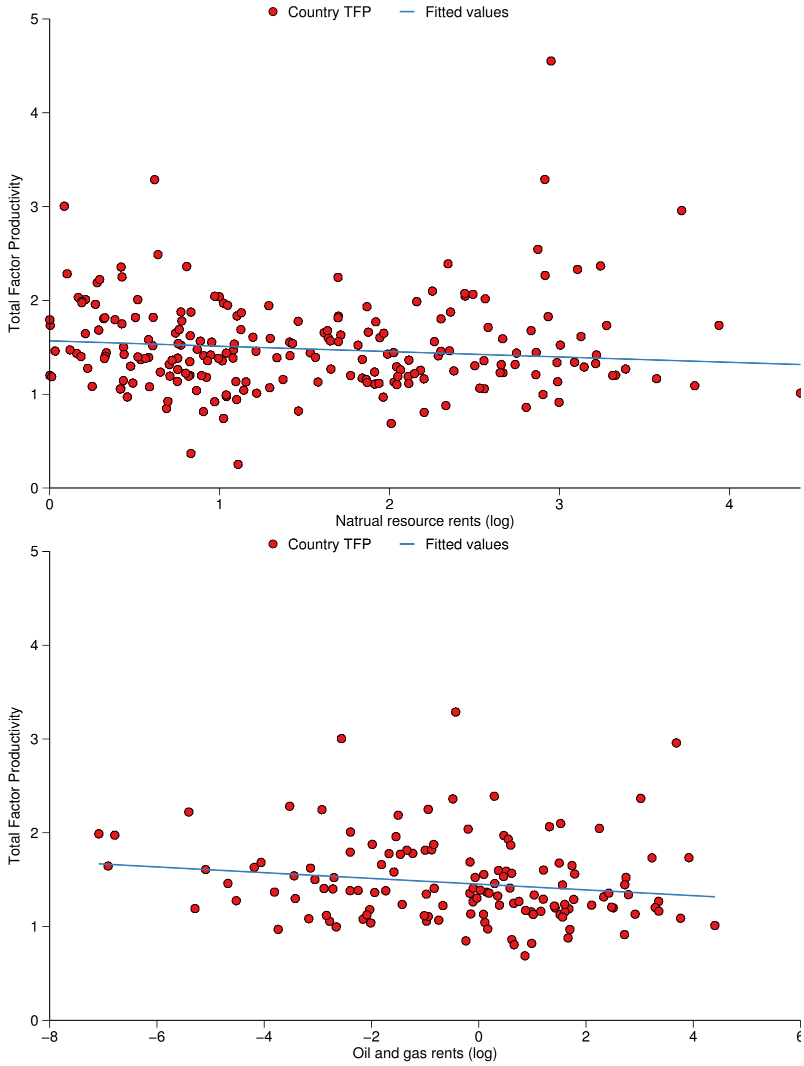


Figure 1.A2: Correlation between Productivity and natural resource rents

Chapter 2

Extractive Resources and Public Capital in Developing Countries: Does Public-Private Partnership matter?

2.1 Introduction

The management of natural resources, in developing countries, has received much attention within and beyond academia over the last two decades. For instance, in October 2000, the World Bank joined a consortium[1] to support and finance the Chad-Cameroon Oil Pipeline Project subject to the conditions that "a large part of the oil revenue goes to a Future Generations Fund, health, education and other development projects".[2] However, over the years, the Chadian government has failed to comply with the requirements of the agreement, and in 2008 the World Bank left the consortium.[3]

Within academia, the issue surrounding natural resources management has received a growing interest both theoretically and empirically since the pioneer works by Auty (1994) and Sachs and Warner (1995). This growing and ongoing literature has identified three main mechanisms through which resource wealth can be a curse: the "Dutch disease", the crowding-out effect on human and physical capital and the deterioration of institution quality (Gylfason, 2002). It turns out that these mechanisms are linked to the way the revenues drawn from natural resources are managed. Government spending is one of the closest ways to scrutinize how the "resource curse" operates and how it can be avoided (Bhattacharyya and Collier, 2013).

The empirical studies on the effect of natural resources on public expenditures yield mixed results. On the one side, Cockx and Francken (2014, 2016) support a negative relationship between natural resources wealth and public spending on education and public health, leaving a broad consensus that natural resources are detrimental for government spending on human capital (health and education)[4]. On the other side, Bhattacharyya and Collier (2013) and Karimu et al. (2017) analyzed the effect of the natural resource on public investment. While Bhattacharyya and Collier (2013), on a global sample of 45 countries[5] over the period 1970-2005, found a negative effect of the natural resources on public capital, Karimu et al. (2017) on a sample of 39 Sub-Saharan African countries, claimed that natural resource increases public investment. Besides this discrepancy in the result, Bhattacharyya and Collier (2013) add that good economic and political institutions reduce the adverse effect

[1]With ExxonMobil, Petronas Malaysia, and Chevron

[2]https://dietmartemps.com/travel-blog/the-white-elephant-the-trouble-with-foreign-aid-in-africa_384/

[3]Some observers said that Chad government use the oil revenue to buy arms (source:www.dietmartemps.com)

[4]For further discussion on some nuances see Stijns (2006)

[5]Including three Sub-Saharan African countries: Kenya, Senegal, and South Africa

of the natural resources rents on public capital" whereas Karimu et al. (2017) argue that "the aggregate effect of resource rent on public investment is larger for countries with relatively poor political institutions than countries with stronger institutions" in developing countries. Considering these two contradictory conclusions, a further investigation of the relationship between government investment behavior and natural resources wealth, particularly in developing countries, is required.

Several aspects remain uninvestigated in the current state of the literature on the relationship between natural resources and public investment. First, Karimu et al. (2017) found that the aggregate effect of natural resources is stronger in Sub-Saharan African countries with weaker political institutions. Why would governments in resource-rich countries with weaker institutions invest more than those with stronger institutions Sub-Saharan Africa? Two plausible views[6] might explain this result. The first view is that public investment is higher in resource-rich countries with weak institutions as a result of *ex ante* limited managerial capacity in terms of projects appraisal, selection, implementation, and evaluation in these countries. The volume of public investment is, therefore, higher owing to investment mismanagement in these countries compared to those with higher institutional quality which benefit from their relative effectiveness. Dabla-Norris et al. (2012) provide evidence that Public Investment Management Index (PIMI) is lower in oil-rich countries. The other view is that the high public investment might be resulting from rent-seeking behavior (whether it is political or economic rent). In resource-rich countries, when institutions are poor and hence the control on executives is weak, governments can deliberately choose to increase public investment but in inefficient projects with "negative social surplus" (Robinson and Torvik, 2005). In both cases, the scaling-up effect of public investment claimed in the recent literature on natural resources management in developing countries can be misleading. The increase of public investment might not lead to an effective increase in public capital stock and the volume of money invested can end up being wasted.

Second, the previous studies on public capital assume a full translation of public investment into an increase in public capital stock. However, Keefer and Knack (2007) hypothesize that rent-seeking behavior leads to an increase in public investment in countries with the low institutional quality and warn against the effort to estimate "the growth effects of productive public investment using only observed measures of public investment". Additionally, Gelb (1988) quoted by Torvik (2009)

[6]The authors explain that institutions being correlated with economic development, the marginal effect of an increase in resource rents have less impact on public investment in countries with other alternative sources of financing public investment than those who rely on natural resources. But such a story implies that the endogeneity of institutions is not fully addressed.

documented that "about half of the windfall gains from the OPEC shocks in the 1970s were invested domestically". While any growth model would predict a strong economic growth following the increase in public investment, growth was not only weak, but it was negative in the OPEC countries (Torvik, 2009). Furthermore, Krueger (1974) identifies public investment as one of the major sources of rent-seeking. Investment efficiency is therefore crucial when investigating the effect of natural resources on public investment.

Third, Bhattacharyya and Collier (2013) and Karimu et al. (2017) aggregate natural resources rents although natural "resource curse" literature emphasizes that the type of resource matters. Bhattacharyya and Collier (2013) only distinguished point resource from forest and agricultural resources. However, heterogeneity might still exist when it comes to public capital because of the difference in terms of infrastructure required for resource exploitation. Unlike these previous studies (Bhattacharyya and Collier, 2013; Karimu et al., 2017), we focus on extractive resources[7] and a sample of developing countries. The interest of focusing on extractive resources and developing countries is twofold. Firstly, as extractive resources are nonrenewable (and therefore exhaustible) their management is more challenging in developing countries where the institutions are poor. A mismanagement of these resources fuels social injustice and can lead to internal conflicts (Besley and Persson, 2008; Collier et al., 2004; Dube and Vargas, 2013; Ross, 2004). Secondly, while the policy recommendation for resources management in developed countries is straight forward to establish Sovereign Wealth Funds (SWF); it is recently argued that developing countries should invest resource windfall domestically in order to scale-up their infrastructure gap and sustain their economic development (Van der Ploeg and Venables, 2011; Venables, 2016). A good understanding of the mechanisms that underpin government investment behavior in developing resource-rich countries is imperative to address those challenges.

Finally, extractive resources entail investment in public infrastructures such as railways, roads, and social infrastructures which implicate the private sector in the form of Public-Private Partnership (PPP)[8] investment. Public-private partnership limit rent-seeking behavior and politically motivated investment as compared to full public provision investment. Indeed, private sector participation improves the decision-making process by performing as accountability mechanisms (Takano,

[7]Extractive resources refer to nonrenewable natural resource extracted from the ground such as oil, gas, coal and minerals.

[8]PPP investments "cover spending on various infrastructure services, including energy, water, transport, and telecoms." It relies on data for total PPP projects commitments taken from the European Investment Bank for European countries and the World Bank Private Participation in Infrastructure database for low- and middle-income countries. (IMF, 2017)

2017). Moreover, PPPs scheme are deemed to bring more efficiency in terms of financing and management for public infrastructure delivery (Ke, 2014; Miraftab, 2004).

The paper bridges two ongoing literature on public investment in developing countries. The first strand of the literature examines public investment efficiency and its implication on economic growth without an interest in natural resources endowment (Barhoumi et al., 2018; Dabla-Norris et al., 2012; Gupta et al., 2014; Pritchett, 2000). The second strand, dedicated to natural resource management in developing countries, analyses the effect of natural resource wealth on public investment but pays little attention to its efficiency (Bhattacharyya and Hodler, 2014; Karimu et al., 2017). Since rent-seeking behavior can motivate public investment in developing countries, considering solely the volume of government spending can be misleading. Indeed, the increase in public investment expenditures does not necessarily lead to an increase in public capital, at least not in the same proportions. Our main contributions to the literature are the followings: (*i*) we distinguish the effect of extractive resources on public capital provided by full public provision and public-private-partnership public capital; (*ii*) our measure of public capital consider a partial translation of public investment into public capital which is more realistic, owing to public investment inefficiency; and (*iii*) we use more disaggregated extractive resources (specifically into oil, coal, natural gas mining) to capture their specificity. As infrastructure required for resource extraction differs according to the resource, it is plausible to expect the government to have different attitudes toward public investment depending on the type of the resource at their disposal.

Using a sample of 95 developing countries over the period 1996-2015 and instrumental variables techniques, our results show two keys findings. On the one hand, extractive resource exerts a negative effect on full public provision capital in developing countries. The size of the effect is varies following the type of resources. The negative effect of mineral resources is lower compared to energy resources (gas, coal and oil). On the other hand, extractive resources are associated with an increase in public-private partnership capital.

The rest of the paper is organized as follow: the second section reviews the literature; the third one describes the data; the fourth section presents the identification strategy; the fifth section presents the results and the last section concludes.

2.2 Literature review

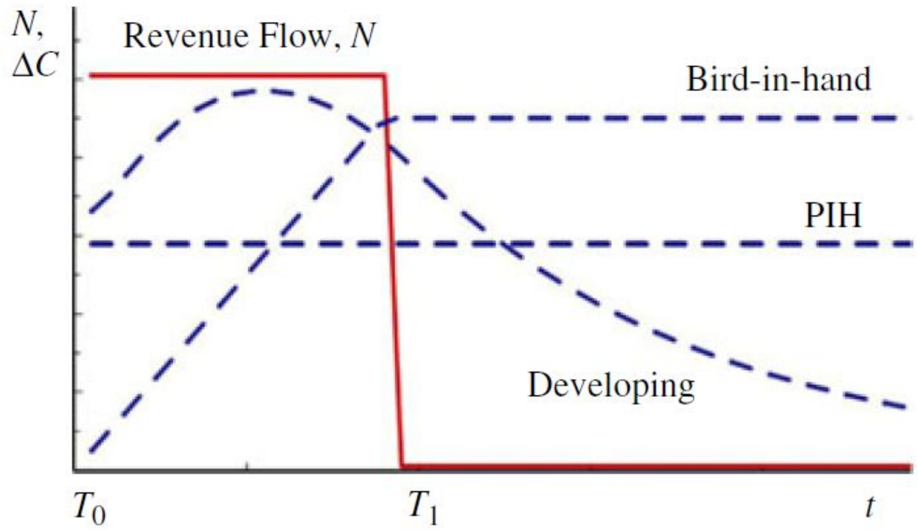
In this section, we present the theoretical background and the empirical studies related to natural resources and government spending.

2.2.1 The theoretical background

The conventional theories of natural resources management, based on the "Permanent Income Hypothesis" (PIH), recommends that resource rent should be saved in Sovereign Wealth Funds (SWF) to avoid instability inherent to extractive revenue volatility (Bems and de Carvalho Filho, 2011; Barnett and Ossowski, 2002). The policy implication is that after the discovery of a non-renewable resource, the increase in consumption should be equal to the expected annuity of the resource, the rest of the resource windfall being saved to ensure a continuous increase of consumption. A more conservative view of the PIH, the "bird-in-the-hand" approach, recommends that all the resource rents should be saved in sovereign wealth funds, and the consumption increase should be restricted to the interest generated by the rent (Van der Ploeg and Venables, 2011).

While the conservative approaches may limit countries' exposal to macroeconomic instability and ensure inter-generational equity, they have been criticized for overlooking current poverty and capital need in developing countries. A new strand of the literature contextualizes this recommendation. For developing countries facing financial constraints and capital scarcity, investing in domestic economy specifically in physical and human capital offers better pay-offs than saving in SWF (Van der Ploeg and Venables, 2011). Figure 2.1 shows the resource revenue flows N (in solid line) and the consumption path (in dashed line) for the three policy rules. The resource is extracted for period T_0 to T_1 and the resource is exhausted after T_1. In contrast to developed countries, where both the Permanent income hypothesis and Bird-in-hand hypothesis would be optimal, for developing countries Van der Ploeg and Venables (2011) show that because of capital scarcity and current poverty the optimal policy rule is to increase revenue spending for present generations so that they scale-up their infrastructure gap. This should be materialized in terms of public investment since the essential of the resource rent goes to the government as tax revenue.

However, it is worth noticing that this normative policy rule is what a welfare-maximizing benevolent and far-sighting government would follow as Van der Ploeg and Venables (2011) point out. The public choice theory has shown that governments maximize their own utility functions which often diverge from those of their



Source: Van der Ploeg and Venables (2011)

Figure 2.1: Incremental Consumption and Revenue Flow

people. In any case, some stylized facts show that "massive domestic investments have not given growth pay-off" in resource-abundant countries (Torvik, 2009). Gelb (1988) shows, in the cases of six oil-exporting countries (Algeria, Ecuador, Indonesia, Nigeria, Trinidad and Tobago, and Venezuela), that the effects of public investment undertaken between 1975 and 1978 on growth did survive after the windfall. The reason is that public investment expenditures fail to effectively increase in public capital networks—the engine of growth. The increase in public investment expenditures might be politically motivated but economically inefficient (Robinson and Torvik, 2005).

Robinson and Torvik (2005) propose a "white elephants" model of public investment based on probabilistic voting and show that economically inefficient investment projects are politically appealing. The inefficient projects have a large political benefit compared to efficient projects. Public investment is a source of rent-seeking activities specifically when institutions are weak. Rent-seeking governments tend to invest in more visible projects or projects that benefit their interest groups which increase their chance to be re-elected. Torvik (2009) argue that politically efficient spending hardly coincides with the economically efficient ones. A way to limit this pure rent-seeking behavior is to tie the link between the private sector and the public sector in public infrastructure provision.

Public-private partnerships are deemed to provide more efficiency in public policies (Ke, 2014; Miraftab, 2004). Besides bringing the expertise required to manage large scale public projects, the public-private partnership may influence project selection as private actors are profit-motivated. Moreover, in the case of resource-rich countries, the infrastructure might be crucial to the exploitation of the resource. Such conditions make public-private partnership investment less sensitive to political interest and henceforth more efficient. Peters (1998) argues that public-private partnership provides both instruments and institutions for public policies.

In the light of this literature, we hypothesize that extractive resources have different impact on public capital depending on whether the private sector is involved or not in the investment project.

2.2.2 The empirical literature

The resource curse literature identifies three main mechanisms through which the curse occurs (Gylfason, 2002): Dutch-disease through degradation of the competitiveness of domestic economy; a crowding-out effect on capital accumulation (human and physical); and deterioration in the quality of institutions. These different mechanisms are intrinsically linked to the ways natural resource revenue are managed. Thus, public spending is key to understanding the resource curse. According to Bhattacharyya and Hodler (2014), the link between natural resource rents and public spending gives a direct view of the resource curse than the relationship between resource rent and growth or income. However, the literature on the relationship between natural resources and public spending provides mixed evidence.

Several works analyzed the relationship between natural resource rents and public spending using both its functional and economic classification. From the functional classification side, the literature is interested in the effect of resource rent on education and healthcare spending (Cockx and Francken, 2014, 2016). Cockx and Francken (2014) provide evidence, based on a sample of 140 countries over the period 1995-2009 that natural resource-rich countries tend to spend less on education. Similarly, Cockx and Francken (2016) showed that natural resource dependence exerts an adverse effect on healthcare expenditure. Their study is based on 118 countries over the period 1990-2008. Likewise, some studies showed that natural resource abundance is negatively correlated with human capital accumulation (Behbudi et al., 2010; Gylfason et al., 1999; Gylfason, 2002).

From the economic classification of public spending perspective, the literature investigates the effect of resource rent on public investment expenditure (or public capital) and current consumption expenditure (Berg et al., 2013; Bhattacharyya and Collier, 2013; Karimu et al., 2017; Philippot, 2008). Berg et al. (2013) develop a Dynamic Stochastic General Equilibrium (DSGE) model to assess the effect of the resource rent on public investment. Applying their model to Central African Economic and Monetary Community (CEMAC) region and Angola, they found that the sustainable investment approach can address the resource curse menace. Bhattacharyya and Collier (2013) analyze the effect of resource rent on the public capital over the period 1970-2005. Their results show that resource rents reduce significantly and substantially the stock of public capital. The quality of institutions contributes to mitigating this adverse effect on the public capital stock. Their study relies on a global sample of 45 countries (22 OECD countries and 26 advanced and developing economies among which three Sub-Saharan African countries). However, Karimu et al. (2017) analyze the impact of natural resource rent on public investment on a sample of thirty-nine (39) Sub-Saharan African countries. They found a positive effect of natural resource rents on public investment in Sub-Saharan Africa. The authors add that "the aggregate effect of natural resource rents is larger in countries with weak political institutions".

Our analysis fits into this aspect of the literature and is mostly related to Bhattacharyya and Collier (2013) and Karimu et al. (2017). We rely on the IMF's new public capital dataset which has two advantages. First, the data assume a partial transmission of public investment into public capital in the perpetual inventory equation. Assuming a full transmission of public investment into public capital is not a good way to measure public capital. In fact, an increase in public investment expenditure might be resulting from rent-seeking behavior (whether it is political or economic rent). In resource-rich countries, when institutions are poor and hence the control on executives weak, governments can deliberately choose to increase the public investment but in inefficient projects with "negative social surplus" (Robinson and Torvik, 2005). Also, developing countries are deemed to have limited managerial capacity in terms of project appraisal, selection, implementation, and evaluation. A surge in public investment expenditures resulting from resource windfalls might not be fully translated into public capital. Dabla-Norris et al. (2012) provide evidence that Public Investment Management Index (PIMI) is lower in oil-rich countries. In all cases, the scaling-up effect of public investment based on investment expenditures in developing countries can be misleading. The increase of public investment does not lead to an effective increase in public capital stock and the volume of money invested can end up being wasted. Second, the data distinguish full public provision's public capital and public-private partnership capital. Using this dataset allows analyzing the role of public-private partnership in the relationship between extractive resources and public capital. Indeed, extractive resources entail investment in public infrastructures such as railways, roads, and social infrastructures which implicate the private sector in the form of Public-Private Partnership (PPP) investment. Public-private partnership limits rent-seeking behavior and politically motivated investment as compared to full public provision investment. Indeed, private sector participation improves the decision-making process by performing as accountability mechanisms (Takano, 2017). Moreover, PPP schemes are deemed to bring more efficiency in terms of financing and management for public infrastructure delivery (Ke, 2014; Miraftab, 2004). Moreover, we investigate the role of different types of institutional quality. Bhattacharyya and Collier (2013) consider democracy (polity 2 index) and the constraints on executive developed by Hall and Jones (1999) which capture mainly the political aspects of institutions. Precisely, we examine contractual institutions (Azomahou et al., 2018; Nunn, 2007) such as the rule of law and regulatory quality, political institutions such as voice and accountability and political stability & absence of violence, governance quality like corruption and government effectiveness; and their interactions with each type of extractive resources. By large, the literature on natural resources and public investment does not consider enough the type of resources, the role of the private sector and public investment efficiency although the recent literature on public investment and growth highlights the importance of the efficiency of the investment. This is important, specifically, in developing countries with weak institutions (Keefer and Knack, 2007; Torvik, 2009). For instance, Pritchett (2000) documented 31 projects financed by the World Bank at the cumulative cost of 915 million $US that achieved the median rate of return of zero in one Sub-Saharan African country between 1972 and 1991.[9]

2.3 Data and Descriptive Analyses

This section defines the variables used, describes the data and their sources. We discuss the measures of public capital, extractive resources, institutional and the other control variables. The sample covers 95 developing countries for which the data for our main variables are available over the period 1996-2015.

2.3.1 Measuring Public Capital

A large part of the empirical literature on public capital uses public investment expenditures because of the lack of data on public capital, specifically for developing countries despite several warnings (Dabla-Norris et al., 2012; Gupta et al., 2014;

[9]The anecdotal cases include the World Bank financed Morogoro Shoe factory in Tanzania which cost $40 million and peak production was 4% of planned capacity (Pritchett, 2000); the Industrial Development Corporation of Zambia; Nigeria Tinapa project which cost $450 million; Yamoussoukro basilica (the world biggest religious edifice) and Senegal monument of “African renaissance” ($27 million).

Kamps, 2006; Keefer and Knack, 2007; Pritchett, 2000). Besides the fact that not all public investment is fully translated into public capital, it is more the stock of public capital network than the additions to it that provide productive services (IMF, 2017); hence the interest of considering public capital stock per capita.

Kamps (2006) provides a first attempt to build public capital stock data based on "the perpetual inventory equation" (equation 2.1 below) for 22 OECD countries over the period 1960-2001.

$$K_{it} = K_{it-1} - \delta_{it} \times K_{it-1} + I_{it} \tag{2.1}$$

Where K_{it} is the country public capital stock at time t, I_{it} the current public investment and δ_{it} the depreciation rate.

Based on Kamps (2006)'s methodology, Arslanalp et al. (2010) estimate public capital stock on a sample of 48 countries including OECD and developing countries. Bhattacharyya and Hodler (2014) used this dataset. However, the dataset covers only 26 developing countries among which three Sub-Saharan African countries and the method implies a full transformation of public investment to public capital.

In the present study, we use the new dataset of public capital developed by the IMF (IMF, 2017). This dataset covers 170 (developed and developing) countries. Apart from covering a large sample of developing countries, the dataset has the advantages for distinguishing "full public provision" investment from public-private partnership (PPP) investment and its "perpetual inventory equation" (equation 2.2 below)is more flexible than that of Kamps (2006) and Arslanalp et al. (2010) as public investment is not considered to be fully translated into public capital [$(1 - \delta_{it}/2) < 1$].

$$K_{it} = K_{it-1} - \delta_{it} \times K_{it-1} + (1 - \delta_{it}/2) \times I_{it} \tag{2.2}$$

Our measure of public capital relies on these data which do not assume a full transmission of public investment expenditure into public capital. Doing so, we are able to identify the effect of extractive resources on an effective change in public capital. The procedure remains the same for Public-Private Partnership capital data.

Figure 2.2 shows the evolution of the average full public provision public capital per capita and public-private partnership public capital per capita over the period 1996-20015. Both variables are evolving in two stages. Public-private partnership capital experienced a sharp increase before 2002 and a slow-down after this year. In return full public provision public capital per capita encountered a relatively slow growth before 2007 and an acceleration from 2007. Public-private partnership capital is low compared to full public provision public capital it grows at a higher rate. These trends might be explained by the 2007 financial crisis. The weakening of the momentum of investment in partnership with the private sector could be driven by the crisis of 2007-2008.

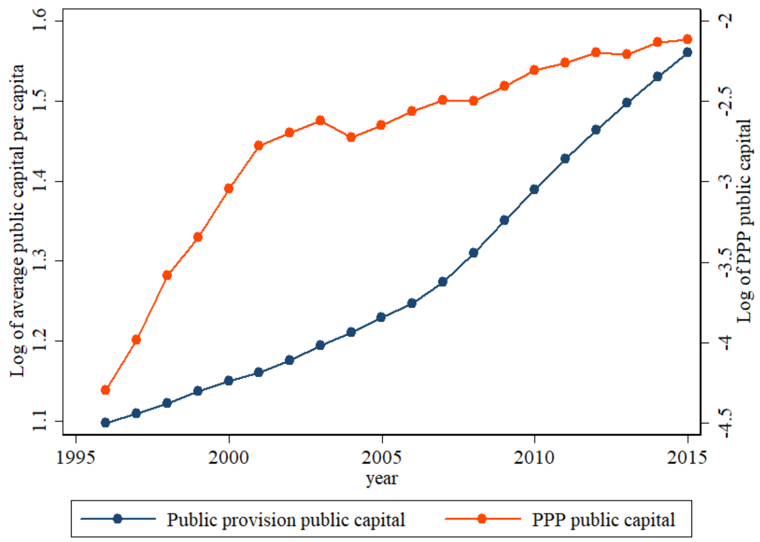


Figure 2.2: Evoltion of public capital per capita

2.3.2 Measuring extractive resource windfall

A plethora of measures have been used in the literature to assess natural resources windfall. Some of these measures turn out to capture resource dependence rather than measures of resource windfall. Resource dependence refers to the degree to which a country relies on resource revenues whereas resource abundance refers to a country's estimated finite endowment of subsoil wealth (Badeeb et al., 2017; Brunnschweiler, 2008). These measures include primary exports as share of total export (Sachs and Warner, 1995), primary exports per worker (Lederman and Maloney, 2003), resource exports as share of merchandise exports (Davis, 1995), ratio of resource rents to GDP (Stijns, 2006) and subsoil resource wealth (Ding and Field, 2005; Brunnschweiler, 2008).[10] The resource export over total exports (or GDP) is the most widespread in the literature. As we can expect, a high share of natural resource in national income (or exports) for a given country can be less informative in terms of its resource wealthiness specifically in developing countries when the size

[10]For further discussion on the measures of resource wealth see Badeeb et al. (2017), Brunnschweiler (2008) and Stijns (2006).

of the economy is smaller and export less diversified. It can be the byproduct of previous economic policy choices and therefore endogenous.

In this paper, we measure extractive resource by the resource rents normalized by the population instead of the GDP (or the exports) to limit the influence of the economic conditions. Additionally, as in Bhattacharyya and Collier (2013), we use commodity price indices as instruments of resource rents to deal with the endogeneity. The resource rents data are from the World Development Indicators. Extractive resources prices data are determined on the international market and are therefore less likely to be correlated to countries' domestic economic conditions. Moreover, change in extractive resources revenue depends on the variation of resource prices. The resource price is hence a relevant instrument for extractive resource endowment. The data on resource prices are from the IMF commodity price index dataset.

Figure 2.3 displays the evolution of the average oil, natural gas, coal and mineral resources rent per capita. Three global trends are observed over the period 1996-2015: a stagnation before 2000; a sharp increase between 2000 and 2007 and slowdown and even decrease after 2007. Mineral resource rent experiences spectacular growth between 2002 and 2008 and has become the first source of rents since 2008. The increase in coal rent is relatively small.

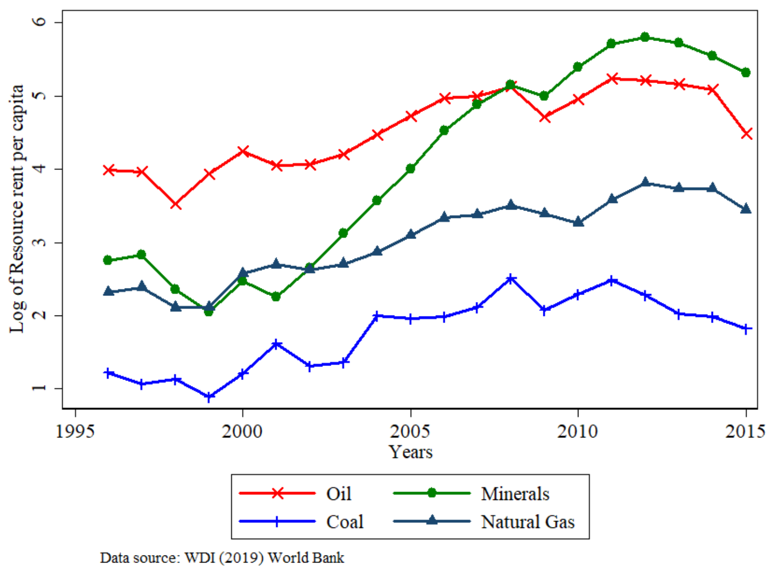


Figure 2.3: Evoltion of extractive resource rents per capita

2.3.3 Measuring Institutions

To investigate how institutions shape the relationship between extractive resources and public capital we consider a broader set of institutional quality. We are interested specifically on how the interaction between contractual institutions and specific extractive resource affect public capital accumulation. We measure contractual institutions using *rule of law* and *regulatory quality*. The additional set of institutional variables include control of corruption, government effectiveness (for economic institutions), political stability and voice and accountability (for political institutions). The data are gathered from the World Governance Indicators (Kaufmann et al., 2011).

2.3.4 Other control variables

The previous literature on the determinants of public investment (Berg et al., 2013; Bhattacharyya and Collier, 2013; De Haan et al., 1996; Karimu et al., 2017; Kotera and Okada, 2017; Shelton, 2007; Sturm, 2001) guide the choice of control variables included in the model. This literature considers, the GDP *per capita*, private investment, foreign aid, openness to trade and absorptive capacity as the main determinants of public investment (public capital).

The GDP *per capita* controls for level of development (Karimu et al., 2017; Sturm, 2001). The expected sign is positive. The higher the level of development of a country, the more it can afford to finance public capital effectively.

Foreign aid is resources for financing domestic economy. Donors often target aid to improvement of the economic environment and investment in health and education (Karimu et al., 2017). Also, aid can alleviate idiosyncratic shocks that affect the domestic economy (Sturm, 2001). We measure foreign aid by net ODA received *per capita*. Thus, we expect a positive relationship between foreign aid and public capital.

Openness to trade, not only, eases capital goods importation but also increases the demand for public investment specifically on infrastructure (Sturm, 2001). Indeed, to be competitive in the international market the domestic economy needs to invest in its infrastructure. Countries that are opened to trade are likely to increase their investment in public capital. The sum of export and import of goods and services as percent of GDP measure the openness to trade.

We also control for private capital. Theoretically, private investment can complement or substitute public capital. The net effect of private investment depends on the size of each effect. We expect a net positive effect of private investment on public capital because the private sector is still underdeveloped in developing countries and is likely to complement rather than crowd out to public capital (Shonchoy et al., 2010).

Public debt can contribute to financing public capital. However, high public debt increases debt burden and limit country capacity to finance public capital. We use public and publicly guaranteed external debt stock that we normalize by the size of the population.

Absorptive capacity matters for public investment spending management (Berg et al., 2013). We use tertiary school enrollment as a proxy of administrative capacity. Table 2.A1 in Appendix presents detail information about the data sources as well as the definition of the variables.

2.4 Estimation strategy

This section presents the empirical model, the estimation methods adopted to identify the relationship between extractive resources and public capital. As we are interested in the role of institutions in this relationship, we estimate the following equation 2.3:

$$K_{it} = \alpha_i + \phi_t + \gamma_1 ER_{it} + \gamma_2 Inst_{it} + X'_{it}\Lambda + \epsilon_{it} \tag{2.3}$$

where our dependent variable K_{it} denotes public capital stock *per capita* for country i at year t. ER_{it} and $Inst_{it}$ denote respectively our variables of interest extractive resources and institutional quality. X'_{it} is a set of our control variables and Λ the vector of associated parameters. α_i and ϕ_t are respectively country fixed and time fixed effects. $\gamma_{i,i=1,2,3}$ are our parameters of interest to be estimated.

Identifying the effect of extractive resources on public capital is challenging for a couple of reasons. First, considerable variability of extractive resource rents both across countries and over time might affect the results. To cope with this issue, we normalized public capital and extractive resource variables with the size of the population and the natural log. The estimated coefficients are elasticities. Second, endogeneity might be a serious concern in this relationship. A large share of extractive resources rents might reflect countries economic conditions rather than resource wealth. We resort to instrumental variables methods to deal with this problem. In particular, we use the prices of extractive resources and its first lag as instruments for resource rents. The variability in resource price determines that of resource rents for a given country. But we do not expect resource price to be influenced by country domestic conditions; at least countries' public capital. The rationale behind introducing the lag is that countries (or companies) anticipate resource price and can manage to sell when the prices increase with limited storage capacity (physical or financial). We rely on two Stage Least Square (2SLS) method to estimate equation 2.3. Nevertheless, as robustness, we use Limited information maximum likelihood method as well.

For equation 2.3 to be properly identified, the instruments should satisfy two conditions. First, extractive resources prices must be correlated with resource rents. Second, the variations in extractive resources prices affect public capital only through resource rents. In other words, the extractive resources prices must be uncorrelated with the error terms.

We test whether our instruments satisfy the first condition using Kleibergen and Paap (2006)'s LM statistic. It tests the correlation between the excluded instrument and the endogenous regressors. The null hypothesis is that "the minimal canonical correlation between the endogenous variables and the instruments is statistically different from zero" (Bazzi and Clemens, 2013). For the model to be identified the null hypothesis might be rejected. Also, as weak instruments are biased towards OLS estimates, we report the F-statistic from the first stage to examine the strength of our instruments. The rule of thumb is that the F-statistic value should greater or equal to 10 (Stock and Yogo, 2005; Staiger and Stock, 1997).

Further, we report Hansen J statistics (Hansen and Singleton, 1982) to test whether our instruments satisfy the exogeneity restriction. The joint null hypothesis is that the instruments are uncorrelated with the error terms and that the excluded instruments are properly excluded from the second stage regression. A rejection of the null hypothesis means that the instruments might be invalid, but its non-rejection does not necessarily mean that the exclusion restriction is satisfied.

2.5 Baseline Results

In this section we present the results of the aggregated extractive resources on full public provision and PPP public capital (5.1); then we desaggregate into each type of extractive resources (5.2) and a focus Africa region (5.3).

2.5.1 Extractive resources and public capital: Does Public-Private Partnership mitigate "the curse on public capital"?

Tables 2.1A and 2.1B bellow presents the results of the regressions for equation 2.3 using two-stage least squares (2SLS) method with resource prices and its lag as instruments for resource rents. The dependent variables are full public provision public capital per capita and PPP public capital respectively. The governance variables are voice and accountability, political stability and government effectiveness, regulatory quality, rule of law, and control of corruption.

Most of the control variables are significant and have the expected signs. Economic development increases public capital per capita. On average, 1% increase in GDP per capita significantly increases public capital per capita by about 5.5%. This result is in line with that of Bhattacharyya and Hodler (2014) for which high income eases public capital accumulation. Private capital creates a leverage effect on public capital. The effect is significant at 1% level in all the specifications. 1% increase in private capital per capita increases public capital by 4%. In fact, a dynamic private sector increases government incentive to invest in public capital for domestic economy competitiveness. Karimu et al. (2017) found the same result although the effect was not significant. Openness to trade increases public capital. This result is similar to Karimu et al. (2017). Surprisingly, the effect of aid is negative and insignificant. This might be related to the fact that aid is mostly targeted to social expenditures. Public debt is harmful to public capital accumulation in most of the regressions. Our control of administrative capacity, tertiary school enrollment, has a positive and significant effect on public capital accumulation. Countries that benefit from a high rate of university school enrollment are more likely to be able to hire competent civil servants and therefore have good capacity to handle projects selection, appraisal, monitoring and execution. Good administrative capacity helps to address absorptive capacity for efficient investment expenditures.

The effect of extractive resources on public capital is negative and significant at 1% level. The coefficients associated with the extractive resources are comprised between -0.035 (column 5 table 2.1A) and -0.063 (column 6 table 2.1A). On average, an increase of 1% in extractive resources leads to 6% decrease in public capital per capita. Good governance contributes to mitigating the adverse effect of extractive resources on public capital. This results confirm those of Bhattacharyya and Hodler (2014) while they are at odds with Karimu et al. (2017).

In accordance with our assumption, the effect of extractive resources on PPP public capital is positive while its effects on full public provision public capital is negative. This result sheds some light on the capacity of the private sector to monitor public investment so that the government will reduce spending on wasteful projects. An increase in extractive resources by 1% leads to an increase in PPP capital by 0.23% on average. The scope of the effect differs from the type of resource. Natural gas has the highest effect on PPP capital per capita followed by oil, natural gas and mining respectively.

The coefficients of the governance variables show some heterogeneity across the type of institutions and the type of public capital. For full public provision, the coefficients of voice and accountability and control of corruption are not significant. By contrast, the coefficients of political stability, government effectiveness, regulatory quality and rule of law are significant at 1% threshold (Table 2.1A). For PPP public capital however, voice and accountability, rule of law and control of corruption are the significant determinant of public capital (Table 2.1B).

Table 2.1A: Extractive Resources and Public Capital

Variables	Dependent variable: Log of Public capital per capita (IV 2SLS)					
	(1)	(2)	(3)	(4)	(5)	(6)
Log of GDP pc	0.605***	0.552***	0.546***	0.543***	0.371***	0.599***
	(0.108)	(0.110)	(0.115)	(0.107)	(0.109)	(0.111)
Log of Private Capital pc	0.344***	0.348***	0.357***	0.358***	0.402***	0.341***
	(0.0587)	(0.0582)	(0.0578)	(0.0570)	(0.0576)	(0.0570)
Openness to trade (Log)	0.124***	0.127***	0.122***	0.107***	0.0914**	0.128***
	(0.0391)	(0.0385)	(0.0385)	(0.0375)	(0.0360)	(0.0391)
Log Aid per capita	-0.00698	-0.00620	-0.00656	-0.00726	-0.0189	-0.00449
	(0.0148)	(0.0144)	(0.0147)	(0.0141)	(0.0136)	(0.0150)
Log of public Debt per capita	-0.0525***	-0.0449**	-0.0548***	-0.0616***	-0.0339*	-0.0519***
	(0.0195)	(0.0195)	(0.0191)	(0.0195)	(0.0180)	(0.0198)
School enrollment (tertiary)	0.135***	0.134***	0.140***	0.144***	0.127***	0.138***
	(0.0303)	(0.0296)	(0.0301)	(0.0296)	(0.0286)	(0.0304)
Log of Extractive Resources pc	**-0.0630*** **	**-0.0559*** **	**-0.0579*** **	**-0.0587*** **	**-0.0352** **	**-0.0639*** **
	(0.0148)	**(0.0147)**	**(0.0149)**	**(0.0143)**	**(0.0139)**	**(0.0146)**
Voice and Accountability	**0.0459**					
	(0.0300)					
Political Stability		**0.0445*** **				
		(0.0172)				
Government Effectiveness			**0.108*** **			
			(0.0367)			
Regulatory Quality				**0.143*** **		
				(0.0363)		
Rule of Law					**0.348*** **	
					(0.0386)	
Control of Corruption						**0.0317**
						(0.0372)
Observations	1120	1120	1120	1120	1120	1120
Number of countries	95	95	95	95	95	95
KP LM Statistic (P-value)	0.000	0.000	0.000	0.000	0.0449	0.000
KP F Statistic	58.79	58.95	56.06	61.12	59.61	58.51
Hansen J-Statistic (P-value)	0.947	0.765	0.853	0.978	0.946	0.917

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 2.1B: Extractive Resources and PPP Public capital

Variables	Dependent variable: Log of PPP Public capital per capita (IV 2SLS)					
	(1)	(2)	(3)	(4)	(5)	(6)
Log of GDP pc	1.178***	1.184***	1.221***	1.211***	1.013***	0.951***
	(0.341)	(0.371)	(0.380)	(0.349)	(0.376)	(0.348)
Log of Private Capital pc	0.245	0.215	0.211	0.212	0.288	0.316
	(0.193)	(0.191)	(0.193)	(0.190)	(0.204)	(0.193)
Openess to trade (Log)	-0.0428	-0.0120	-0.0189	-0.0276	-0.0381	-0.0828
	(0.114)	(0.114)	(0.113)	(0.114)	(0.111)	(0.111)
Log Aid per capita	0.0722	0.0949**	0.0980**	0.0949**	0.0862**	0.0891**
	(0.0447)	(0.0424)	(0.0409)	(0.0416)	(0.0433)	(0.0430)
Log of public Debt per capita	-0.0344	-0.0344	-0.0467	-0.0535	-0.0423	-0.0407
	(0.0699)	(0.0726)	(0.0671)	(0.0679)	(0.0704)	(0.0703)
Shool enrollement (tertiary)	0.205*	0.218*	0.234*	0.237**	0.209*	0.259**
	(0.122)	(0.121)	(0.120)	(0.121)	(0.122)	(0.118)
Log of Extractive Resources pc	**0.216*** **	**0.211*** **	**0.200*** **	**0.202*** **	**0.229*** **	**0.225*** **
	(0.0581)	**(0.0609)**	**(0.0580)**	**(0.0551)**	**(0.0601)**	**(0.0568)**
Voice and Accountability	**0.327** **					
	(0.141)					
Political Stability		**0.0655**				
		(0.0789)				
Government Effectiveness			**0.0646**			
			(0.185)			
Regulatory Quality				**0.0962**		
				(0.171)		
Rule of Law					**0.369** **	
					(0.172)	
Control of Corruption						**0.541*** **
						(0.131)
Observations	870	870	870	870	870	870
Number of countries	83	83	83	83	83	83
KP LM Statistic (P-value)	0.000	0.000	0.000	0.000	0.000	0.000
KP F Statistic	52.10	49.87	53.95	56.58	54.67	51.15
Hansen J-Statistic (P-value)	0.133	0.0961	0.110	0.110	0.0934	0.131

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

2.5.2 Extractive Resources and Public Capital: Does the type of resource matter?

In table 2.2 we investigate the specificity of each type of resources. Most of the control variables remain significant. We consider the rule of law as our institutional variable because it is a significant determinant for both full public provision and PPP public capital. However, the results are similar with the other governance indicators. The results show that oi, gas and coal exert an adverse effect on full public provision public capital per capita while the effect on PPP public capital is positive for all type of extractive resources. But the size of the effect differs. Natural gas has the highest negative and significant effect on public capital whereas mining resources (metal and mineral) have a lower negative effect. These heterogeneities shed light on the importance of considering the type of resources. Regardless of the resources considered, extractive resources are positively associated with PPP public capital accumulation. However, for full public provision public capital.

To sum up, extractive resources exert an adverse effect on public capital in developing countries regardless of the type of resource even though the size of the negative effect vary following the resource; the higher being natural gas while the effect of mining is not significant. By contrast, the effect on PPP public capital is positive and significant regardless of the type of the resources. However, an important aspect of extractive resources we should keep in mind is that the exploitation of some of them required public infrastructures such as road, electricity supply and railway more than others. Their exploitation might entail the supply of these infrastructures. These often take place as a public-private partnership (PPP) investment.

2.5.3 A regional focus: the case of Africa

In this section, we focus our analysis on Africa for at least two reasons. Firstly, because among developing regions, the case of Africa is more problematic. African extractive resources wealthiness contrast with its endemic poverty and its development level as compared to the other regions of the world. The continent accounts for about 30% of the world mineral reserves and; 8% and 7% for oil and natural gas proven reserves respectively (AfDB). Also, the extractive sector has a significant contribution to public finance in Africa.[11]. However, simulating the effect of commodity boom on a typical African commodify exporter, Collier and Goderis (2007)

[11] An average minerals account for 70% of African total exports and about 28% of GDP. African Development Bank (AfDB) estimates that Africa's extractive resources will contribute over USD 30 billion per annum in government revenue for the next 20 years: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/anrc/AfDB_ANRC_BROCHURE_en.pdf

Table 2.2: Extractive Resources and Public Capital: Does the type of resource matter?

	Dependent variable: Log of Public capital per capita				Dependent variable: Log of PPP Public capital per capita			
	(1)	(2)	(3)	(4)	(1)	(3)	(5)	(7)
Log of GDP pc	0.399***	0.416***	0.400***	0.402***	0.811*	1.197***	0.470	1.438***
	(0.0618)	(0.0573)	(0.0644)	(0.0581)	(0.450)	(0.391)	(0.500)	(0.383)
Log of Private Capital pc	0.101**	0.0657*	0.0815**	0.0697*	0.523**	0.0548	0.269	0.0622
	(0.0401)	(0.0363)	(0.0401)	(0.0360)	(0.257)	(0.185)	(0.242)	(0.199)
Openess to trade (Log)	-0.0242*	-0.0224	-0.0280**	-0.0262**	-0.0937	0.0830	-0.00284	0.0474
	(0.0139)	(0.0140)	(0.0143)	(0.0129)	(0.118)	(0.129)	(0.127)	(0.120)
Log Aid per capita	-0.0170	-0.0281	-0.0606***	-0.00967	0.0879*	0.0907**	0.0948*	0.122***
	(0.0169)	(0.0185)	(0.0226)	(0.0172)	(0.0481)	(0.0412)	(0.0507)	(0.0416)
Log of public Debt per capita	0.385***	0.306***	0.470***	0.321***	-0.0964	-0.0159	0.153*	-0.0948
	(0.121)	(0.107)	(0.129)	(0.0953)	(0.0713)	(0.0719)	(0.0910)	(0.0694)
Log of tertiary school enrollement	0.0860***	0.113***	0.134***	0.0992***	0.469**	0.0831	0.459**	0.0535
	(0.0304)	(0.0283)	(0.0312)	(0.0275)	(0.210)	(0.158)	(0.198)	(0.167)
Rule of Law	0.293***	0.377***	0.323***	0.363***	0.444***	0.350***	0.267**	0.514***
	(0.0533)	(0.0366)	(0.0489)	(0.0377)	(0.104)	(0.117)	(0.114)	(0.106)
lnoilpc	**-0.0556****				**0.379*****			
	(0.0261)				**(0.103)**			
lnminpc		**-0.0166**				**0.139*****		
		(0.0101)				**(0.0464)**		
lngaspc			**-0.113*****				**0.435*****	
			(0.0351)				**(0.113)**	
lncoalpc				**-0.0414****				**0.150***
				(0.0187)				**(0.0801)**
Observations	1126	1127	1124	1124	876	876	873	873
Number of countries	95	95	95	95	83	83	83	83
KP LM Statistic (P-value)	0.033	0.041	0.000	0.039	5.85e-07	0.0113	1.76e-05	0.0690
KP F Statistic	23.77	91.10	26.48	47.45	35.81	48.05	28.96	30.68
Hansen J-Statistic (P-value)	0.179	0.0866	0.767	0.712	0.000638	0.643	0.460	0.132

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

find that "if global history repeats itself, after two decades output will be around 25 percent lower than it would have been without the booms." Moreover, Carmignani and Chowdhury (2010) study "the nexus between natural resources and growth in Sub-Saharan Africa (SSA) and find that **SSA is indeed special: resources dependence retards growth in SSA, but not elsewhere**". For Collier (2010) natural resources constitute an opportunity and "the economic future of Africa will be determined by whether this opportunity is seized or missed".

Secondly, according to the World Bank[12], closing Sub-Saharan Africa infrastructure gap (both quantity and quality) could increase GDP *per capita* growth by 2.6% per year. Understanding how extractive resources can contribute to building good quality infrastructure for sustained economic growth is an important economic policy issue for Africa.

In table 2.3 we regress equation 2.3 on 40 African countries. The results are similar to those found with the all sample. Extractive resources exert an adverse effect on public capital. On average, the negative effect is even stronger in the case of African countries than in the global sample of developing countries. The control variables remain significant and have the expected signs. Openness to trade, private capital and GDP per capita have a positive effect on public capital in Africa. Unlike in the full sample regressions where the effect of aid is negative and non-

[12] https://www.africa.com/closing-africas-infrastructure-gap/

significant, the effect of aid on public capital per capita in Africa is positive and strongly significant. However, the role of institutions is mixed. Political stability and rule of law have a positive effect on public capital while the effect of voice and accountability, regulatory quality and government effectiveness is non-significant. The effect of corruption is negative and significant which is counter-intuitive.

In table 2.4 we regress equation 2.3 on 30 African countries where we have data on public-private partnership capital data. Here again, the results are similar to those in table 2.1B. Extractive resources exert a positive effect on public capital. On average, the positive effect of extractive resources on public-private partnership capital in Africa is higher than developing countries average.

Some of the control variables are no longer significant. Opposite to public capital, aid and private capital have a non-significant effect on public private partnership capital. This result is expected since aid is mostly given to governments rather than the private sector. Openness to trade has a negative and significant effect on public-private partnership capital per capita. The effect of public debt is negative but not significant in all the regressions. Here again, the effect of institutions depends on the type of institution. Voice and accountability and Political stability affect positively the public-private partnership capital per capita while the effect of rule of law, regulatory quality, government effectiveness and corruption is non-significant.

Summing up, we found that in the sample of African countries, extractive resources exert an adverse effect on public capital and positive effect on public-private partnership public capital. The negative effect on public capital is stronger in Africa than the sample of developing countries while the positive effect on public-private partnership is stronger in Africa than in the developing countries on average.

2.6 Robustness Checks

To check the robustness of our results we performed several tests. First, we use the fuller version of Limited information maximum likelihood estimator instead of the 2SLS method which is deemed to perform better even with weak instruments (Murray, 2006). The results are reported in table 2.A3 and table 2.A4 in appendix. Second, our results still hold when we use five-years average data instead of yearly data because of cyclical concern, when we divide our sample into low income countries and middle income countries, and when we drop oil major producers to control for potential outliers.

Table 2.3: African sample regressions: Public capital per capita

	Dependent variable: Log of Public capital per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Log of Private Capital pc	0.380***	0.435***	0.396***	0.410***	0.470***	0.382***
	(0.112)	(0.110)	(0.108)	(0.108)	(0.112)	(0.101)
Openess to trade (Log)	0.418***	0.323***	0.396***	0.352***	0.257**	0.458***
	(0.146)	(0.120)	(0.134)	(0.124)	(0.115)	(0.132)
Log Aid per capita	0.0831**	0.0675*	0.0811**	0.0716**	0.0577*	0.0944***
	(0.0365)	(0.0345)	(0.0370)	(0.0339)	(0.0322)	(0.0356)
Log of public Debt per capita	-0.0581	-0.0341	-0.0550	-0.0484	-0.0112	-0.0922**
	(0.0356)	(0.0316)	(0.0338)	(0.0322)	(0.0305)	(0.0373)
Log of GDP pc	1.157***	0.950***	1.131***	1.038***	0.725***	1.372***
	(0.232)	(0.199)	(0.225)	(0.207)	(0.196)	(0.228)
School enrollement (tertiary)	0.0344	0.0371	0.0336	0.0318	0.0420	0.0355
	(0.0475)	(0.0444)	(0.0476)	(0.0452)	(0.0425)	(0.0488)
Log of Extractive Resources pc	**-0.102*** **	**-0.0773*** **	**-0.101*** **	**-0.0866*** **	**-0.0592** **	**-0.128*** **
	(0.0347)	**(0.0292)**	**(0.0349)**	**(0.0307)**	**(0.0286)**	**(0.0338)**
Voice and Accountability	-0.0846					
	(0.0795)					
Political Stability and Absence of violence		0.0645**				
		(0.0302)				
Government Effectiveness			-0.0384			
			(0.0658)			
Regulatory Quality				0.0578		
				(0.0720)		
Rule of Law					0.298***	
					(0.0785)	
Control of Corruption						-0.305***
						(0.0759)
Observations	419	419	419	419	419	419
Number of countries	40	40	40	40	40	40
KP LM Statistic (P-value)	0.008	0.024	0.012	0.012	0.148	0.000
KP F Statistic	9.239	12.09	8.225	10.49	10.69	10.90
Hansen J-Statistic (P-value)	0.218	0.210	0.263	0.256	0.563	0.301

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.4: African sample regressions: Public-private partnership capital

	Dependent variable: Log of Public-Private Partnership Capital					
	(1)	(2)	(3)	(4)	(5)	(6)
Log of Private Capital pc	0.197	0.274	0.168	0.158	0.211	0.165
	(0.464)	(0.456)	(0.391)	(0.415)	(0.438)	(0.450)
Openess to trade (Log)	-1.245**	-1.006**	-0.970*	-0.926**	-1.018**	-1.120**
	(0.524)	(0.460)	(0.496)	(0.444)	(0.466)	(0.509)
Log Aid per capita	-0.0442	-0.0382	-0.0161	0.00692	-0.0124	-0.0416
	(0.106)	(0.106)	(0.116)	(0.0946)	(0.0974)	(0.109)
Log of public Debt per capita	-0.192	-0.219*	-0.265**	-0.234**	-0.244*	-0.219
	(0.131)	(0.127)	(0.111)	(0.116)	(0.132)	(0.135)
Log of GDP pc	2.193**	2.433**	2.813***	3.053***	2.565**	2.418**
	(1.031)	(1.015)	(0.972)	(0.917)	(1.080)	(1.021)
lnschoolenroll	-0.548	-0.516	-0.504	-0.492	-0.512	-0.537
	(0.358)	(0.352)	(0.356)	(0.319)	(0.341)	(0.370)
Log of Extractive Resources pc	**0.566*** **	**0.532*** **	**0.484** **	**0.448*** **	**0.507*** **	**0.561*** **
	(0.173)	**(0.160)**	**(0.208)**	**(0.154)**	**(0.174)**	**(0.178)**
Voice and Accountability	0.835**					
	(0.425)					
Political Stability		0.351*				
		(0.184)				
Government Effectiveness			0.0230			
			(0.648)			
Regulatory Quality				-0.382		
				(0.424)		
Rule of Law					0.264	
					(0.538)	
Control of Corruption						0.706
						(0.459)
Observations	271	271	271	271	271	271
Number of countries	30	30	30	30	30	30
KP LM Statistic (P-value)	0.000	0.000	0.005	0.000	0.001	0.000
KP F Statistic	12.75	12.94	7.398	10.94	11.80	10.91
Hansen J-Statistic (P-value)	0.701	0.648	0.689	0.659	0.740	0.682

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.7 Conclusion

Public investment in developing resource-rich countries is often associated with rent-seeking behavior. As a result, a massive increase in public investment expenditures yields limited economic outcomes while any growth model would predict the opposite (Torvik, 2009). This puzzle legitimizes the doubt around the ability of these investments to generate effective public capital accumulation in developing resource-rich countries. Little attention has been paid to this aspect of public investment in the literature on the relationship between natural resources and public investment despite several warnings in the literature (Barhoumi et al., 2018; Dabla-Norris et al., 2012; Gupta et al., 2014; Pritchett, 2000). While Karimu et al. (2017) consider public investment expenditures as their measure on public capital Bhattacharyya and Collier (2013) admit a full transmission of public investment into public capital in their perpetual inventory equation (equation 2.1). Consequently, these previous investigations yield contrasted conclusions. While Bhattacharyya and Collier (2013) found a negative effect of natural resources on public capital, Karimu et al. (2017) found that natural resources increase public investment in Sub-Saharan Africa and the effect is even higher when political institutions are weak. Moreover, while the implication of the private sector in public capital delivering become increasing, the private sector often is ignored.

In this paper, we examine the effect of extractive resources on public capital on a sample of 95 developing countries over the period 1996 to 2015. Using IMF's new dataset on public capital, we are able to distinguish full public provision public capital from Public-Private Partnership capital. Also its perpetual inventory equation (equation 2.2) is more flexible than that considered by Bhattacharyya and Collier (2013). Employing instrumental variables estimation techniques, our results show two keys findings. On the one hand, extractive resource exerts a negative effect on full public provision capital in developing countries which is in line with Bhattacharyya and Collier (2013). The size of the effect varies following the type of resources. The negative effect of mineral resources is not significant compared to energy resources (gas, coal and oil). This is consistent with the infrastructure required for resource exploitation. Indeed, mining exploitation might require paved roads and railways, while oil can be exploited without these infrastructures. On average, 1% increase in extractive resources per capita leads to 0.06% decrease in public capital per capita. On the other hand, extractive resources are associated with an increase in public-private partnership capital. The effect is robust regardless of the type of resource.

These findings shed light on the fact that rent-seeking behavior (political or economic) might motivate public investment increase in resource-rich countries. "Tying the hands" between the private sector and the public sector in investment projects can scale-up public capital. The paper calls for a closer look at the scaling-up effect of natural resources on public investment in developing countries claimed in the literature specifically when institutions are weak.

Two policy recommendations emerged from these findings. Fist, beyond the classical recommendation on improving governance or counting on benevolent far-sighted government to address the resource curse on public capital in developing resource-rich countries, this paper shows that a partnership between the public and the private sector in the implementation of public investment projects can contribute to mitigating the curse. Developing resource-rich countries should implicate more the private sector in investing on public capital specifically in infrastructure. This has the advantage of addressing the 'curse on public capital' (Bhattacharyya and Collier, 2013) due to both the proverbial inefficiency of developing countries in implementing (large scale) public investment (Gupta et al., 2014; Dabla-Norris et al., 2012) and pure politically motivated investment (Robinson and Torvik, 2005). Second, the designing of public-private partnership is key to social welfare maximizing partnership. Developing countries should invest in civil servant capacity building on designing public-private partnership projects. In any case, public-private partnership is not the panacea. Its designing should matter. Henceforth, future research could implement case studies on some experiences of public-private partnership investment projects in resource-rich countries.

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List of countries

All sample

Albania; Algeria; Angola; Armenia; Azerbaijan; Bangladesh; Belarus; Belize; Benin; Bhutan; Bosnia and Herzegovina; Botswana; Brazil; Burkina Faso; Burundi; Cabo Verde; Cambodia; Cameroon; Central African Republic; Chad; China; Colombia; Comoros; Democratic Republic of Congo; Congo, Republic of; Costa Rica; Cote d'Ivoire; Dominican Republic; Ecuador; Egypt; El Salvador; Ethiopia; Fiji; Gabon; Gambia, The; Georgia; Ghana; Guatemala; Guinea; Guinea Bissau; Honduras; India; Indonesia; Iran; Jordan; Kazakhstan; Kenya; Kyrgyz Republic; Lao P.D.R.; Lebanon; Lesotho; Liberia; FYR Macedonia; Madagascar; Malawi; Maldives; Mali; Mauritania; Mauritius; Mexico; Moldova; Mongolia; Montenegro, Rep. Of; Morocco; Mozambique; Myanmar; Nepal; Nicaragua; Niger;Nigeria; Pakistan; Paraguay; Peru; Philippines; Rwanda; Senegal; Serbia; Sierra Leone; South Africa; Sri Lanka; Sudan; Tajikistan; Tanzania; Thailand; Togo; Tunisia; Turkey; Uganda; Ukraine; Uzbekistan; Venezuela; Vietnam; Yemen; Zambia; Zimbabwe.

African countries

Algeria; Angola; Benin; Botswana; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Democratic Republic of Congo; Congo, Republic of; Cote d'Ivoire; Egypt; Ethiopia; Gabon; Gambia; Ghana; Guinea; Guinea Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mauritius; Morocco; Mozambique; Niger; Nigeria; Rwanda; Senegal; Sierra Leone; South Africa; Sudan; Tanzania; Togo; Tunisia; Uganda; Zambia; Zimbabwe.

Table 2.A1: Data sources and descriptions

Variables	Definition	Sources
Public capital per capita	Stock of public capital divided by the total population	IMF Investment and Capital Stock Dataset, 2017
Private capital	Stock of private capital divided by the total population	IMF Investment and Capital Stock Dataset, 2017
Extractive resource rents	oil rents, natural gas rents, coal rents (hard and soft) and mineral rents per capita	WDI (2018)
Public-Private Partnership capital	Stock of PPP capital divided by the total population	IMF Investment and Capital Stock Dataset, 2017
Extractive resource prices	Calculated price index of oil, natural gas, coal, mineral	IMF commodity prices database
GDP per capita	Annual percentage growth rate of GDP per capita based on constant 2005 US dollars	WDI (2018)
Population	Population is the midyear estimate of the total population based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.	WDI (2018)
Openness to trade	Openness to trade is the sum of exports and imports of goods and services (in % of GDP)	WDI (2018)
Public debt	Public and publicly guaranteed external debt stock divided by the total population	WDI (2018)
Aid	Aid is the Net official development assistance (ODA) per capita. It consists of disbursements of loans made on concessional terms and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries.	WDI (2018)
Control of Corruption	“Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests”.	WGI (2018)
Rule of Law	“Reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence”.	WGI (2018)
Political Stability and Absence of Violence	“Measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism”.	WGI (2018)
Voice and Accountability	“Reflects perceptions of the extent to which a country’s citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media”.	WGI (2018)
Government Effectiveness	“Reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy”.	WGI (2018)
Regulatory Quality	“Reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development”.	WGI (2018)

Table 2.A2: Descriptive Statistics

VARIABLES	**N**	**mean**	**sd**	**min**	**max**
GDP_pc	2526	5468	8735	122.9	72671
Trade	2449	80.53	40.16	0.0269	531.7
Pubk_pc	2560	8.112	13.54	0.0253	139.8
Privk_pc	2560	11.75	16.68	0.235	183.7
PPPk_pc	2300	0.199	0.398	0	4.730
Oilpc	2534	52235	241431	0	3.068e+06
Minpc	2546	3975	17526	0	263394
Gaspc	2526	4779	32238	0	736050
Coalpc	2525	635.0	3391	0	95386
Extractpc	2515	62000	263031	0	3.319e+06
Debtpc	2120	1078	1463	0	12386
All Metals Index	2580	81.99	46.03	32.72	170.0
Crude Oil petroleum Price index	2580	119.7	65.29	31.28	222.5
Natural Gas Price Index	2580	148.2	60.49	57.45	271.0
Coal Price Index	2580	88.93	47.30	37.31	192.2
Tertiary School Enrollment	1599	24.27	20.27	0.194	95.43
Voice and Accountability	2578	-0.396	0.770	-2.233	1.343
Political Stability and Absence of Violence	2558	-0.365	0.876	-3.181	1.283
Government Effectiveness	2559	-0.383	0.668	-2.089	1.572
Regulatory Quality	2560	-0.335	0.695	-2.344	1.543
Rule of Law	2574	-0.448	0.690	-2.130	1.555
Control of Corruption	2574	-0.427	0.688	-1.773	1.725

Table 2.A3: Limited information maximum likelihood estimator 1

	Dependent variable: Log of Public capital per capita											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
lnextractpc	**-0.063*****	**-0.071*****	**-0.056*****	**-0.069*****	**-0.058*****	**-0.096*****	**-0.059*****	**-0.081*****	**-0.035****	**-0.054*****	**-0.064*****	**-0.083*****
	(0.015)	**(0.016)**	**(0.015)**	**(0.016)**	**(0.015)**	**(0.021)**	**(0.014)**	**(0.016)**	**(0.014)**	**(0.016)**	**(0.015)**	**(0.017)**
lnprivk_pc	0.344***	0.378***	0.348***	0.352***	0.357***	0.380***	0.358***	0.382***	0.402***	0.421***	0.341***	0.356***
	(0.059)	(0.061)	(0.058)	(0.057)	(0.058)	(0.058)	(0.057)	(0.059)	(0.058)	(0.060)	(0.057)	(0.057)
lntrade	0.124***	0.078*	0.127***	0.089**	0.122***	0.089**	0.107***	0.083**	0.091**	0.050	0.128***	0.118***
	(0.039)	(0.040)	(0.038)	(0.040)	(0.039)	(0.037)	(0.038)	(0.037)	(0.036)	(0.041)	(0.039)	(0.039)
lnaidpc	-0.007	-0.016	-0.006	-0.033***	-0.007	-0.023*	-0.007	-0.014	-0.019	-0.024*	-0.004	-0.007
	(0.015)	(0.014)	(0.014)	(0.013)	(0.015)	(0.013)	(0.014)	(0.013)	(0.014)	(0.013)	(0.015)	(0.014)
lndebtpc	-0.052***	-0.021	-0.045**	0.011	-0.055***	-0.025	-0.062***	-0.026	-0.034*	0.002	-0.052***	-0.037*
	(0.019)	(0.018)	(0.019)	(0.020)	(0.019)	(0.020)	(0.020)	(0.021)	(0.018)	(0.018)	(0.020)	(0.019)
lngdp_pc	0.605***	0.441***	0.552***	0.408***	0.546***	0.526***	0.543***	0.515***	0.371***	0.275**	0.599***	0.536***
	(0.108)	(0.111)	(0.110)	(0.117)	(0.115)	(0.117)	(0.107)	(0.113)	(0.109)	(0.115)	(0.111)	(0.114)
lnschoolenroll	0.135***	0.116***	0.134***	0.132***	0.140***	0.123***	0.144***	0.109***	0.127***	0.116***	0.138***	0.130***
	(0.030)	(0.032)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.034)	(0.029)	(0.031)	(0.030)	(0.031)
Voice and Accountability	0.046	0.408***										
	(0.030)	(0.096)										
lnextractxVA		-0.051***										
		(0.012)										
Political Stability			0.044***	0.411***								
			(0.017)	(0.082)								
lnextractxPS				-0.056***								
				(0.012)								
Government Effectiveness					0.108***	0.651***						
					(0.037)	(0.151)						
lnextractxGE						-0.080***						
						(0.022)						
Regulatory Quality							0.143***	0.564***				
							(0.036)	(0.130)				
lnextractxRQ								-0.066***				
								(0.018)				
Rule of Law									0.348***	0.686***		
									(0.039)	(0.123)		
lnextractxRL										-0.055***		
										(0.017)		
Control of Corruption											0.032	0.311**
											(0.037)	(0.123)
lnextractxCC												-0.041**
												(0.018)
Observations	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120	1,120
Number of Countries	95	95	95	95	95	95	95	95	95	95	95	95
KP LM Statistic (P-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.000	0.000	0.000
KP F Statistic	58.79	31.52	58.95	42.20	56.06	35.52	61.12	39.90	59.61	40.06	58.51	40.38
Hansen J-Statistic (P-value)	0.947	0.0625	0.765	0.562	0.853	0.928	0.978	0.845	0.946	0.663	0.917	0.805

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.A4: Limited information maximum likelihood estimator 2

	Dependent variable: Log of Public-Private Partnership Capital				
	(1)	(2)	(3)	(4)	(5)
Log of Private Capital pc	0.291	0.601**	0.0548	0.0623	0.269
	(0.205)	(0.276)	(0.185)	(0.200)	(0.243)
Openess to trade (Log)	-0.0400	-0.127	0.0830	0.0447	-0.00331
	(0.111)	(0.122)	(0.129)	(0.120)	(0.127)
Log Aid per capita	0.0857**	0.0828	0.0907**	0.122***	0.0947*
	(0.0434)	(0.0508)	(0.0413)	(0.0418)	(0.0508)
Log of public Debt per capita	-0.0415	-0.0954	-0.0159	-0.0944	0.154*
	(0.0705)	(0.0727)	(0.0719)	(0.0695)	(0.0912)
Log of GDP pc	1.001***	0.631	1.197***	1.418***	0.464
	(0.379)	(0.495)	(0.391)	(0.388)	(0.502)
RuleofLaw	0.373**	0.540**	0.0832	0.0540	0.461**
	(0.172)	(0.226)	(0.158)	(0.168)	(0.198)
lnschoolenroll	0.205*	0.432***	0.350***	0.514***	0.266**
	(0.123)	(0.106)	(0.117)	(0.106)	(0.114)
lnextractpc	**0.232*****				
	(0.0613)				
lnoilpc		**0.442*****			
		(0.123)			
lnminpc			**0.139*****		
			(0.0465)		
lncoalpc				**0.156***	
				(0.0830)	
lngaspc					**0.437*****
					(0.113)
Observations	870	876	876	873	873
Number of countries	83	83	83	83	83
KP LM Statistic (P-value)	0.000	0.000	0.011	0.069	0.000
KP F Statistic	54.67	35.81	48.05	30.68	28.96
Hansen J-Statistic (P-value)	0.0940	0.0009	0.643	0.133	0.460

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Part II

Natural Resources, Environmental Policies and Deforestation

Chapter 3

Mining and Strategic Environmental Commitment in Africa

[1]

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3.1 Introduction

The mining sector provides a unique opportunity for African countries to mobilize revenue domestically for financing development as stated in the Africa Mining Vision (African Union, 2009). Indeed, Africa possesses around 30% of the world mineral resources (Edwards et al., 2014) with an enormous growth potential (Signé and Johnson, 2021; Taylor et al., 2009). For instance, from 1999 to 2016, African Extractive Industries Transparency Initiative (EITI) countries have accumulated more than US$700 billion as direct tax revenue from the extractive companies (EITI, 2018). It also contributes to foreign currency reserves and, to some extent, to reabsorb unemployment through direct and indirect employment. According to Collier (2010), "the economic future of Africa will be determined by whether this opportunity is seized or missed".

The energy transition, which is imperative in the context of climate change, also offers a great opportunity for mineral-holding countries, whose demand is increasing due to the growing demand of the clean energy sector. Africa has enormous resources that are essential to the energy transition. For example, Congo DRC produces two-thirds of the world's cobalt, South Africa 70% of the world's platinum and 45% of the world's chrome (IEA, 2019). Rwanda and Congo, DRC together produce about 70% of the world's supply of tantalum (30% and 40% respectively) which is critical for electronics (IEA, 2019). African-level estimates show that Africa produces about 80% of the total global supply of platinum, 50% of manganese, two-thirds of cobalt, and a significant amount of chromium (Signé and Johnson, 2021) not to mention that a large amount of reserves also remain undiscovered. The exploitation of these resources, while an opportunity for the countries that hold them, carries enormous environmental costs if the resources are not properly regulated.

Given the opportunity offered by the extractive sector in terms of domestic revenue mobilization, foreign currency reserves and employment states might strategically interact with each other, to attract foreign investment in the mining sector at the expense of their commitment to mitigate climate change. Addressing the challenge of climate change requires collective efforts (IPCC, 2014). However, the no binding nature of climate agreements limits countries' actual commitment and opens the door to strategic behavior. In the absence of coordination, this strategic behavior may lead to a kind of "Prisoner's Dilemma" and deters any climate mitigation policy. This temptation is stronger in the African context where countries lack competitiveness and capital is scarce (Onwuekwe, 2006). By contrast to advanced economies, developing regions and African countries in particular face a double challenge. They have to conciliate their development imperatives with the environmental concerns. The extractive sector and particularly the mining industry is at the heart of these challenges. While Oman (1999) emphasizes that state competition for foreign firms' location tends to be intense in a specific industry and intra-regional, there is no evidence of such strategic interaction in Africa. Environmental policy is subject to a game of the kind and more so, since the environmental costs are relegated to future generations. How to conciliate mining sector attractiveness while committing to climate mitigation policies? How African countries can escape this double edge-sword dilemma?

Mobilizing mining revenue for development is already challenging. A skeptical view widely dominates the literature on the potential contribution of the mining sector to economic development. Abundant natural resources yield poor economic outcomes (Sachs and Warner, 1995, 1999, 2001), exert adverse effects on governance and institutional quality (Ross, 2001), deter political stability (Bhavnani and Lupu, 2016) and fuel conflicts (Collier et al., 2004; Ross, 2004; Berman et al., 2017). Recent literature shows that the curse is not a destiny and well design policies matter (Brunnschweiler, 2008; Brunnschweiler and Bulte, 2008; James, 2015). However, significant environmental costs would be unbearable for future generations in the context of climate change. Understanding the role of mining activities in states strategic interaction in their environmental policy is an important step to designing better environmental coordination mechanisms and common enforcement to escape an environmental race to the bottom.

This paper analyzes the strategic interaction between African countries in their commitment to mitigate climate change while considering the role of mining. The paper contributes to the literature in three main aspects. First, we study strategic interaction between African countries in their environmental policies and the dominant outcome from such interaction. To the best of our knowledge, this paper is the first to empirically assess the strategic interaction in environmental policies in Africa. Previous studies only focus on competition among the US states and within the European Union (Fredriksson and Millimet, 2002; Konisky, 2007), partly because of the lack of data on environmental policy in developing countries[2]. We contribute to this literature not only by using a sample of developing countries in Africa but also by including in our strategic interaction model both time and space dynamics of environmental policy. Considering time a space dynamic allows us to disentangle the direct and indirect effects in both the long-run and the short-run. We also control for country exposure to climate shocks.

Second, we examine the role of mining in such strategic interaction. Previous

[2]See Konisky and Woods (2012) for extensive discussion on environmental policy measures.

literature on strategic interaction focuses on the outcome of the strategic interaction without particular interest on the drivers of the strategic interaction. The strategic nature of the mining sector on African economies motivates such interest.

Third, the previous literature on environmental race, both theoretical and empirical, typically assumes that countries do not care about their reputation. Taking into account a situation where countries consider their reputation in the context of increasing climate awareness, we distinguish *de jure* and *de facto* environmental policies. *de jure* policy refers to country adherence to international environmental treaties. *de facto* environmental policy represents the actual environment control. In their *de jure* environmental policy country would consider their reputation in their strategic interaction while in their de facto policy countries would pay more attention to their competitiveness regarding the reaction of their competitors. Another advantage of this distinction is that in poor institutional quality context and asymmetric power between states and foreign investors, a wide gap can exist between environmental policies on paper and in practice. This is important in environmental policy since the climate cost is global and relegated to future generations. Indeed, the effectiveness of the legal enforcement of environmental standards depends on the institutional environmental environment and the administrative capacity to implement these standards.

We use a panel data of 35 African countries over the period 2001-2017. Relying on spatial econometrics specifications, we establish three key results. First, we find that countries adopt a strategic behavior in response to the environmental policy of their neighbors. A 1% increase (decreases) in neighbors' environmental enforcement increases (decreases) in one's own adherence by 0.3% and 0.8% respectively for *de jure* and *de facto* environmental policy. Second, we find a race to the top for *de jure* environmental policy while countries exhibit a race to the bottom in their *de facto* environmental policy. Consequently, countries' strategic behaviors lead to an increasing in *de jure* environmental enforcement, while their *de facto* environmental enforcement is weakening. Third, we find evidence of heterogeneity in the effect of mining regarding the type of environmental policy and the time profile of the effect.

The rest of the paper is organized as follows. We discuss the related literature in section 3.2. Section 3.3 describes the data. In section 3.4, we discuss the methodology and the results. Section 3.5 undertakes robustness checks of the results. Section 3.6 derives policy implications and future research prospects.

3.2 Strategic interaction in environmental policy: A race to the bottom or a race to the top ?

Increasing globalization raises concerns about competition among states to attract mobile capital (Davies and Vadlamannati, 2013; Kim and Wilson, 1997; Oates, 1999, 2002). Such competition labeled as a *'race'* has been studied, essentially, in taxation, labor regulation and environmental policy literature. Regardless of the domains, the debate is articulated around whether states strategically interact in their policy setting and if so, what is the outcome of such interaction : "race to the top" (efficiency-enhancing) or a "race to the bottom" (inefficient). This literature yields a mixed conclusion both theoretically and empirically.

A large consensus exists on states' strategic interaction in their environmental policies. The idea of the potential strategic interactions[3] in environmental policy stems from both international trade and environmental regulation literature (Engel, 1997; Levinson, 2003; Olney, 2013; Potoski, 2001; Wood, 1991). Environmental policies are major sources of comparative advantage in international trade and in foreign direct investment locations (the Pollution Haven Hypothesis). Some evidence suggests that weak environmental enforcement attracts Foreign Direct Investment (Dean et al., 2009; Xing and Kolstad, 2002).[4] Consequently, states strategically respond to their competitors' behavior to attract or retain FDI, or to benefit from comparative advantage in international trade against trade partners. However, the debate is whether the strategic interaction leads to a "race to the top" or a "race to the bottom".

A race to the top occurs when countries' strategic interaction in their environmental policy enhances social welfare. The defenders of the "race to the top" labeled "revisionist" in the words of Engel (1997) contend that the effects of state environmental competition are "welfare-enhancing, rather than welfare-reducing". The revisionist argument is theoretically grounded in neoclassical economics according to which the pursuit of each state's best interest leads to optimal allocation between environmental preferences and economic attractiveness (Revesz, 1992). Moreover, stringent environmental standards may lead to innovation (Porter and Van der Linde, 1995). A key assumption is that there are no interstate externalities. This assumption seems to be strong in the context of global warming where environmental degradation everywhere contribute to the degradation of the global climate.

[3] See Brueckner (2003) for a review on strategic interaction models.

[4] It is worth mentioning that this is subject to a debate in the literature. See Eskeland and Harrison (2003) for a nuanced discussion.

A race to the bottom occurs when countries strategically respond to each other by lowering their environmental standards (Konisky, 2007). In response to lax environmental policies of their competitors, countries react by lowering their environmental standards. The noncooperative game theory, in particular the Prisoner Dilemma, provides a theoretical background for the race to the bottom. Although all countries benefit from optimally stringent environmental standards if they cooperate, the dominant behavior is a destructive competition towards lax environmental standards.

Since the intuition of the race to the bottom is straightforward, it occupies a large body of the literature (Fredriksson and Millimet, 2002; Konisky, 2007). Konisky (2007) emphasizes that: “Regulatory competition among state governments suggests that their regulatory behavior is interdependent. While this assumption is fundamental to the race to the bottom theory, it has received scant attention in empirical studies. Instead, most of the literature focuses on whether firm economic investment decisions are sensitive to inter-jurisdictional differences in the stringency of environmental regulation”. Using annual state-level pollution regulation data from 1985 to 2000, Konisky (2007) found that environmental regulatory behavior is influenced by the interactions with the competing states for economic investment. Such interaction is more likely to take place between resource-rich countries with limited investment capacity. In China, Hong et al. (2019) argue that local governments tend to prioritize economic growth to environmental quality. Fredriksson and Millimet (2002) find that in the US, states improve their environmental standards in response to an improvement in their neighbors with relatively already stringent regulations. However, an increase in environmental standards by states with relatively lax policy has no effect on their neighbors. Barrett (1994) argues that, in a context of imperfectly competitive international markets, governments have the incentive to set low environmental standards for businesses operating in those markets.

A major limitation of this literature, both theoretically and empirically, is that countries do not care about their reputation. Taking into account a situation where country considers that their reputation matters in the context of increasing climate awareness, we distinguish a *de jure* environmental policy and a *de facto* environmental policy. In their *de jure* environmental policy country would consider their reputation in their strategic interaction while in their de facto policy countries would pay more attention to their competitiveness regarding the reaction of their competitors.

3.3 Data and main indicators

The dataset covers 35 African countries over the period 2001-2017. The list of countries is provided in Table 3.6.1. We gather the data from different sources. In the following subsection, we describe the data and presents some descriptive analyses. Data sources and variables' definition are given in Table 4.A2.

3.3.1 Environmental policy

By contrast to developed countries where environmental policy data exist for quite a long period (OECD environmental policy dataset for instance), measuring environmental policy in Africa is challenging. To the best of our knowledge, there is no dataset on environmental policy in Africa over a significant period. The environmental performance index dataset is released biennially in even-numbered over the period 2006-2018 (Wendling et al., 2018) and cannot be assembled into a panel data because of methodological change. Also, the World Bank CPIA environmental sustainability rating started in 2005. The challenge is how to proxy environmental policy in Africa in a context of lack of data. To deal with these issues, we refer to two different measures of environmental policy in Africa: domestic environmental commitment which is a *de facto* measure of country environmental policy and international environmental commitment which is a *de jure* measure.

We follow the same methodology as Combes et al. (2016) to compute a *de facto* environmental policy measure. The authors build an indicator called "domestic efforts for climate mitigation (DECM)" which is the residuals of the regression of per capita CO_2 emissions over a set of control variables (GDP per capita, openness to trade, population, foreign direct investment and foreign aid). They argue that the error term provides a *de facto* measure of domestic effort to climate mitigation because the regression controls exogenous factors that predict the "structural emissions". Therefore, the residuals catch the autonomous climate policy (Combes et al., 2016).

We estimate a dynamic panel model estimated with a System-GMM (Blundell and Bond, 2000) as in Combes et al. (2016). We then normalize the residuals from -10 (lax environmental policy) to +10 (stringent environmental policy). See Table 4.A3 in Appendix for further details.

Figure 3.1 displays the kernel density estimate of the *de facto* environmental policy measure. We observe three modalities in the distribution showing heterogeneities of the *de facto* measure of environmental policy in the sample.

The *de jure* environmental policy is a count of country adhesion to international

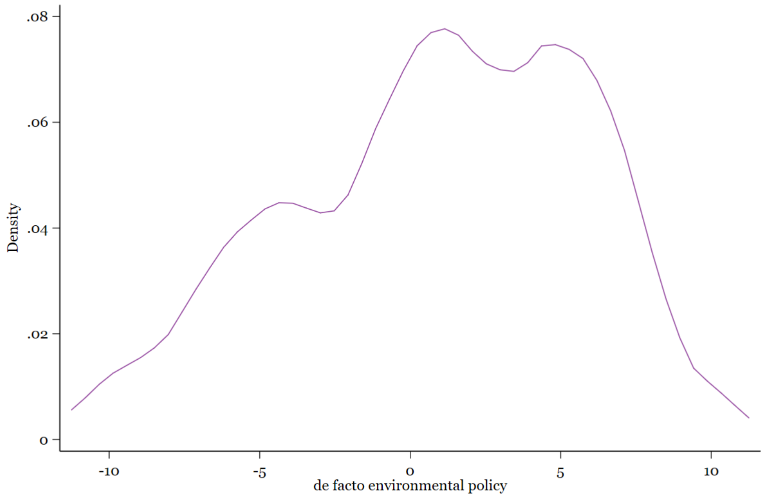

Figure 3.1: Kernel density estimate of *de facto* environmental policy

treaties. Although international treaties may not be binding, they are deemed to be more contingent than the domestic laws. Also, country commitment to international enforcement is a good signal of their environmental policy.

Figure 3.2 displays the box plots of the *de jure* environmental policy in three years periods, except the last box which is two years. We observe an increase in the quartiles over time. The median is around 75.

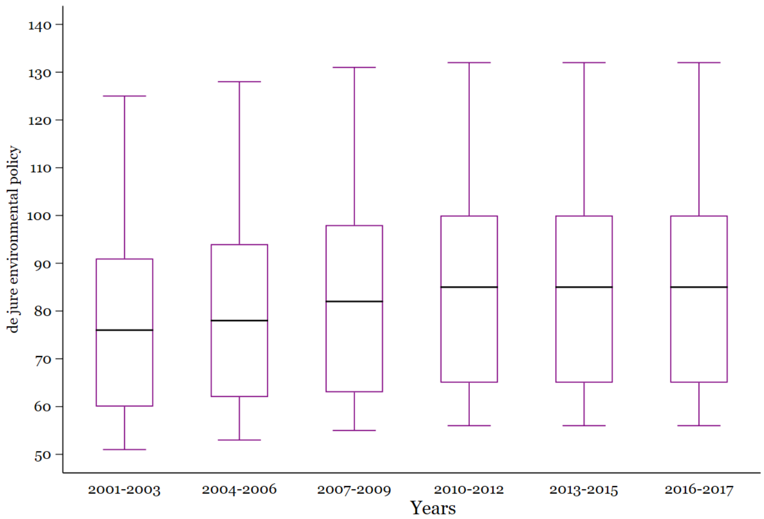

Figure 3.2: Box plots of the *de jure* environmental policy

Figure 3.3 shows a contrasted evolution of the year average of the two environmental policies. Countries' adhesion to international environmental treaties (*de jure*) increases over the period 2001 to 2017 while the domestic environmental enforcement (*de facto*) decreases. African countries are committing in international environmental treaties but these commitments seem to be ineffective in terms of actual policies. The nonbinding nature of treaties may explain these trajectories.

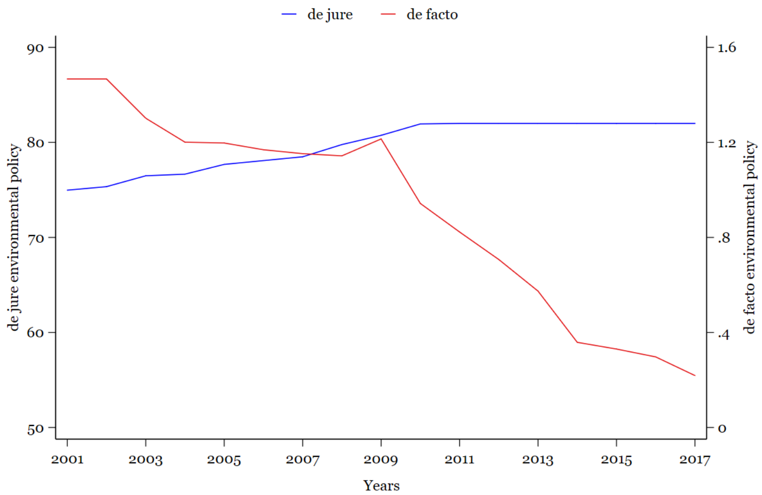

Figure 3.3: Average environmental policy

3.3.2 Mineral resources rent

Because we are interested in mining activities we do not consider the other extractive resources such as oil and natural gas. We use mineral resource rents as % of GDP as our measure mining activities. Some alternative measures could be the subsoil wealth computed by the World Bank, and mining concession. However, these datasets are limited in terms of time and country coverage. The subsoil dataset is not available yearly while the dataset on mining concession data cover only a few countries. Subsequently, we resort to resource rents. The data are from the World Bank World Development Indicators.

3.3.3 Other control variables

Temperature and precipitation shocks: to control for the effect of climate shocks we use the absolute value of the deviation of the temperature, respectively precipitation, to its long-run average. Temperature (precipitation) shocks are natural events that can affect country environmental commitment. Countries that are most exposed to these shocks are expected to have stronger environmental commitment than the less exposed ones. Data on temperature and precipitation are from the University of East Anglia Climatic Research Unit.

GDP growth: We include GDP growth as a control to account for the economic dynamism. We suspect a correlation between country economic performance and its environmental policy.

Democracy index: The democracy index is collected from the Polity IV dataset. It measures the quality of democracy. The index is between -10 (autocratic regime) to +10 (full democracy). It varies from -9 to 9 in our sample. The mean is 1.96, meaning that on average, democracy is weak in Africa. In his strategic interaction model Konisky (2007) controls the political orientation of the state governors. The data are from the Polity IV project database (Marshall and Jaggers, 2002).

Population density: The population density is the number of inhabitants per km^2. Higher population density is associated with higher urbanization and thus more environmental concerns. Population density data are from WDI.

Foreign Direct Investment (FDI):[5] is the annual FDI net inflows to the country. We expect a negative association between FDI and environmental commitment: lax environmental policies favor FDI inflows while stringent environmental policies could deter them. See Table 4.1 and 4.A2 in the Appendix for respectively the descriptive statistics and more details in the variables and data sources.

Forest rents: “Forest rents are roundwood harvest times the product of average prices and a region-specific rental rate” (WDI, 2019). The intuition is that countries deriving a substantial part of their wealth from forest may have different consideration toward the environment.

Control of corruption: “Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as ‘capture’ of the state by elites and private interests” (WGI,2019). Countries with strong institutional enforcement can set strong environmental policy.

3.4 Empirical strategy

The race to the bottom theory implies that, confronted with economic competition, countries are inclined to relax their environmental standards to attract mobile capital. Coupled with strategic behavior such as the ‘Prisoner’s Dilemma’ governments may try to gain competitive advantage over other countries. If all countries behave similarly, the equilibrium strategy will be the continued relaxing of environmental commitment. The race to the bottom argues that the equilibrium outcome is

[5] We would have preferred using the FDI of the mining sector, but unfortunately these data are not available. However, aggregated FDI should not bias the results.

Table 3.1: Descriptive statistics on the pooled data

Variables	mean	st. dev.	min	max
GDP growth	4.68	5.67	-36.04	63.38
Mineral resource rents	2.28	4.56	0.00	46.62
Temperature shocks	2.07	1.77	0.00	15.90
de facto environmental policy	0.91	4.76	-10	10
de jure environmental policy	79.66	29.66	0.00	132
CO_2 emissions per capita	0.98	1.78	0.02	9.84
Democracy index	1.96	5.05	-9	9
Population density	72.64	86	2.22	485.65
GDP per capita (in thousands of USD)	2.26	3.7	0.21	20.51
Total population (millions)	22.4	29.6	0.63	191
Aid per capita	53.24	43.19	-8.27	393.50
Openness to trade	73.01	33.69	20.72	311.35
Foreign Direct Investment (inflows)	4.98	9.52	-4.85	103.34
Control of corruption	-0.67	0.56	-1.83	1.22
Forest rents	6.07	6.06	0	40.43

Notes: Number of countries (N) =35; Waves (T)=17; NT=595

suboptimal, since countries would be better off collectively setting a high level of commitments rather than relaxing them (Konisky, 2007). To assess the presence of competition among countries in environmental regulatory behavior, we consider a spatial-temporal dynamic regression where a country's behavior as a function of other countries' behaviors. The model takes the form:

$$\begin{aligned} E_{it} &= \tau E_{it-1} + \delta \sum_{j=1}^{N} \omega_{ij} E_{jt} + \mathbf{x}_{1it}'\boldsymbol{\beta} + \boldsymbol{\theta} \sum_{j=1}^{N} \omega_{ij} \mathbf{x}_{2jt}' \qquad (3.1) \\ & + a_i + \gamma_t + u_{it}, \qquad i = 1, \cdots, N;\ t = 1, \cdots, T;\ j \neq i \end{aligned}$$

where E_{it} is a measure of environmental commitment (*de jure* vs. *de facto* environmental policy), u_{it} is a normally distributed error term, ω_{ij} are the weight assigned to country j both for the autoregressive component E_{it-1} and for the spatially lagged control variable $\mathbf{x}_2$, a_i is the individual fixed effect, and γ_t denotes the time effect.

An element ω_{ij} of ω, the weighting matrix, takes the following form:

$$\omega_{ij} = \begin{cases} \frac{1/d_{ij}}{\sum_j 1/d_{ij}} & \text{if} \quad j \neq i \\ 0 & \text{otherwise} \end{cases}$$

with d_{ij} being the Euclidean distance between the capitals of countries i and j. Alternatively, we compute other matrices for robustness purpose. Considering a matrix M, its components m_{ijt} are computed using a variable X as:

$$m_{ijt} = \begin{cases} \frac{(|X_{it}-X_{jt}|)^{-1}}{\sum_j (|X_{it}-X_{jt}|)^{-1}} & \text{if} \quad j \neq i \\ 0 & \text{otherwise} \end{cases}$$

where X is the weighting variable. The elements of M are based on the absolute difference in population between countries i and j. The interest of taking the inverse of the absolute difference is that the weighting matrix attributes a higher weight to countries that have a smaller absolute difference in variable X.

The variable of primary interest in this model is the strategic interaction or spatial lag term $\sum_{j=1}^{N} \omega_{ij} E_{jt}$. This term represents a weighted average of environmental commitment in neighboring states. Detecting the presence of a strategic interaction requires testing for the significance of δ. A statistically significant and positive coefficient suggests that one state's environmental commitment effort is a function of other states' environmental commitment efforts. A statistically significant and negative spatial coefficient would imply that there is strategic substitution effect among countries. The null hypothesis is that there is no effect, which implies a lack of environmental competition, thereby undermining both the race to the bottom and the race to the top arguments.

While estimating Equation (3.1) establishes whether there is strategic interaction among countries, the race to the bottom (vs. to the top) suggests a specific asymmetric dynamics among countries. More specifically, we should observe a state responding to its competitors only in situations where its own environmental commitment might put it at a disadvantage for attracting economic investment relative to these competitors. Following Fredriksson and Millimet (2002), such asymmetric effects model is given by:

$$\begin{aligned} E_{it} &= \tau E_{it-1} + \delta_0 D_{it} \sum_{j=1}^{N} \omega_{ij} E_{jt} + \delta_1 (1 - D_{it}) \sum_{j=1}^{N} \omega_{ij} E_{jt} \\ &\quad + \mathbf{x}'_{1it} \boldsymbol{\beta} + \boldsymbol{\theta} \sum_{j=1}^{N} \omega_{ij} \mathbf{x}'_{2jt} + a_i + \gamma_t + u_{it}, \qquad i = 1, \cdots, N, \ t = 1, \cdots, T \ j \neq i \end{aligned} \tag{3.2}$$

where:

$$D_{it} = \begin{cases} 1 & \text{if} \quad E_{it} > \sum_{j=1}^{N} \omega_{ij} E_{jt}, \quad j \neq i \\ 0 & \text{otherwise} \end{cases}$$

Strategic interaction consistent with the race to the bottom assumes country responsiveness to competitor countries in years in which one's own environmental commitment effort is greater than one's competitors, but not in years in which it is lower. This means that we expect a positive and significant coefficient δ_0, but not δ_1 or when the two parameters are positive and significant, $\delta_0 > \delta_1$. As a result, Equation (3.2) assumes that strategic interaction occurs only when the average stringency of competitors' environmental commitment is lower than the state's own level.

The likelihood function of Equation 3.1, our spatial dynamic fixed effects model adapted from Yu et al. (2008) is:

$$L_{n,T}(\theta, \alpha_n) = -\frac{nT}{2}\ln 2\pi - \frac{nT}{2}\ln\sigma^2 + T\ln|S_n(\lambda)| - \frac{1}{2\sigma^2}\sum_{t=1}^{T} V'_{nt}(\zeta)V_{nt}(\zeta) \quad (3.3)$$

where $V_{nt}(\zeta) = S_n(\lambda)E_{nt} - \tau E_{n,t-1} - \delta W_n E_{n,t-1} - X_{nt}\beta - \alpha_n$. $\theta = (\delta', \lambda, \sigma^2)'$ and $\zeta = (\delta', \lambda, \alpha'_n)'$

We refer the reader to Yu et al. (2008) for more details on the properties of the function and the underlying assumptions.

3.4.1 Direct and indirect effects

The space-time dynamic structure of the model in Equations (3.1) and (3.2) allows us to compute direct and indirect effects of the explanatory variables on the dependent variable in the long and short-run. As the model reflects the spatial dependence between countries, a change in an explanatory variable in a given country will affect the country itself (direct effects) and potentially its neighbors (indirect effects) (LeSage and Pace, 2009). Table 3.2 below provides the computation formula of these effects in a dynamic spatial Durbin model (DSDM) as in Equations (3.1) and (3.2).

Table 3.2: Direct and indirect effects

	Direct effect	Indirect effect
Short-run	$[(I-\delta W)^{-1} \times (\beta + W\theta)]^{\bar{d}}$	$[(I-\delta W)^{-1} \times (\beta + W\theta)]^{\overline{rsum}}$
Long-run	$[((1-\tau)I-\delta W)^{-1} \times (\beta + W\theta)]^{\bar{d}}$	$[((1-\tau)I-\delta W)^{-1} \times (\beta + W\theta)]^{\overline{rsum}}$

Source: Apdated from Elhorst (2014). Note: $\bar{d}$ denotes the operator that calculates the mean diagonal elements of a matrix, $\overline{rsum}$ the operator that calculates the mean row and sum of the non-diagonal elements.

One of the advantages of the DSDM is that it allows estimating the long and short-run effects of our variable of interest on environmental policy response. The short-run effects are the partial derivative of the dependent variable with respect to an explanatory variable at a particular time period; the dynamic aspect of the model (coefficient τ in Equation 3.1) being ignored. The long-run effects are the partial derivatives of the dependent variable with respect to an explanatory variable at a particular time period while setting $E_{it-1} = E_{it} = E^*$ and $WE_{it} = WE^*$. Long-run effects are similar to a steady-state where environmental policies remain constant over time in all countries.

3.4.2 Estimation strategy and specification tests

The estimation strategy of the dynamic model fits into two categories: instrumental variables or generalized method of moments (IV/GMM) and bias-corrected maximum likelihood (ML) or quasi-maximum likelihood (QML) estimator (Elhorst, 2014; Belotti et al., 2017). The QML estimator and the IV/GMM have the advantage of not relying on the normality of the error term. However, the QML estimator outperforms the IV/GMM because the Jacobian term in the log-likelihood function of ML estimators restricts the spatial coefficient δ to the interval $[1/r_{min}, 1]$ where r_{min} denotes the "most negative purely real characteristic root" of the row-normalized spatial matrix. (Elhorst, 2014). Hence we use the QML estimator in this study. The QML estimator for dynamic spatial models is developed by (Yu et al., 2008; Lee and Yu, 2010; Elhorst, 2014). It is a consistent estimator in the presence of spatially lagged-dependent variables and robust to distributional misspecification (Lee, 2004).[6] Indeed, the temporally and spatially lagged-dependent variables in Equation (3.1) and (3.2) raise endogeneity concerns sourced essentially from simultaneity between E_{it} and $\sum_{j=1}^{N} \omega_{ij} E_{jt}$ and omitted variables potentially correlated with E_{it-1}.

Following LeSage and Pace (2009), we test the suitability of the dynamic spatial Durbin model (DSDM) to estimate Equations (3.1) and (3.2) against the dynamic spatially autoregressive model (DSAR) and the spatial error model (SEM). The DSDM specification is reduced to a DSAR model if the coefficients of the spatially lagged explanatory variable are not statistically different from zero which amounts to testing the joint nullity of the spatially lagged explanatory variables ($\boldsymbol{\theta} = 0$ in Equation 3.1). For *de jure* environmental policy, $\chi^2(3) = 79.98$ is significant at 1% level (Prob>χ^2=0.000). For *de facto* environmental policy, $\chi^2(3) = 70.00$ is also significant at 1% level (Prob>χ^2=0.000). Hence we reject the null hypothesis of $\boldsymbol{\theta} = 0$; thus the DSAR specification is rejected.

The DEM is also a special case of the DSDM if $\delta\boldsymbol{\beta}+\boldsymbol{\theta} = 0$ (Equation 3.1). For *de jure* environmental policy, $\chi^2(3) = 98.29$ is significant at 1% level (Prob>χ^2=0.000).

[6] See the likelihood function Equation 3.3 in Appendix.

For *de facto* environmental policy, $\chi^2(3) = 75.76$ is also significant at 1% level (Prob>χ^2=0.000). Here again, we reject the null hypothesis of $\delta\boldsymbol{\beta} + \boldsymbol{\theta} = 0$. Hence both the DSAR and the SEM specifications are rejected and DSDM is suitable for our analysis. The DSDM is a fixed effects model.

3.4.3 Results

Strategic interaction and dynamics of environmental policy

Table 3.3 presents the results of the strategic interaction model (Equation 3.1) for both *de jure* and *de facto* environmental policy.

The coefficients of the spatial lagged-variable are positive ($\delta > 0$) and statistically significant at 1% level. This supports a presence of spatial interaction among African countries: stringent (lax) environmental policy in a given country leads to environmental policy enforcement (relaxation) in its neighbors. This result is consistent with other findings in the United States (Fredriksson and Millimet, 2002; Konisky, 2007) and in the European Union (Holzinger and Sommerer, 2011). Using environmental abatement costs, Fredriksson and Millimet (2002) find that the US States are engaged in strategic environmental policymaking interactions. Similarly, in a sample of 48 US States, Konisky (2007) confirms the strategic interaction between States in their environmental policy. We go beyond the time-static model adopted by these authors to consider time dynamics as well in our strategic interaction model. Our results show that the time dynamics also matters in environmental policy. The coefficient of E_{it-1} is positive and strongly significant in both *de jure* and *de facto*.

3.4.4 Direct, indirect and total effects

Thanks to the spatial and temporal dynamics structure of the model, we can break down into direct and indirect effects, the impact of the explanatory variables on the environmental policy responses. Indeed, in a given country, variation in any explanatory variables affects the country itself (direct effects) and eventually its neighbors (indirect effects or spillover effects) (LeSage and Pace, 2009; Elhorst, 2014).

We presume that mineral resource rents, GDP growth and FDI have spillover effects on environmental policy. This is confirmed by our specification tests which show that the spatial lags of these variables are statistically significant. Mineral resource rents affect both environmental policy directly and indirectly. The direct effect on *de jure* environmental policy is negative and significant in the short-run while insignificant in the long-run. Also, the indirect effect is negative in the short-run while it is positive in the long-run. In the short-run, an increase in country mineral resource rents decreases not only its willingness to participate in international environmental agreements but also prevents its neighbors to participate. An explanation is that mining resources might be shared across bordering countries (for instance gold in Burkina Faso, Ghana and Mali). In such a case, an increase of the rents in a given country makes its neighbors willing to attract investment and therefore more reluctant to enforce their environmental policy. In the long-run however, the direct effect of mining activities on *de jure* environment policy is statistically nonsignificant. All long-run effects operate through neighbor's environmental policies. In total, mining deteriorates countries willing to participate in international environmental treaties and results in weak *de facto* commitment in the long-run.

GDP growth has spillovers effect on both *de facto* and *de jure* environmental policies. The direct effect of GDP growth on *de jure* environmental enforcement is positive and significant in the short-run but not in the long-run. The indirect effect is positive and significant in the short-run while negative in the long-run. The trade-off between economic growth and environmental protection is not clearly established when it comes to international environmental treaties adhesion. However, this trade-off is clear with *de facto* environmental policy. Countries may be mimicking each other *de jure* environmental policy while still involved in lax environmental commitment. The total effect of GDP growth on *de jure* environmental policy is positive and significant in the short-run and negative in the long-run. For *de facto* policy, it is negative in the short-run and positive in the long-run. Economic growth enforces effective policy in the long-run while it leads to weak enforcement in the short-run.

The spillover effects of FDI on *de jure* environmental policy is not significant. However, on *de facto* environmental policy, the short-run direct and indirect effects are negative and significant. The total effect is negative and statistically significant in the short-run and positive in the long-run. To attract FDI, countries lower their environmental standards. Nevertheless, FDI increase environmental policy (*de facto*) enforcement.

3.4.5 Short-run and long-run effects

The effect of mining rents on *de jure* environmental policy is negative in the short-run and positive in the long-run. Countries with significant mining rents are reluctant to engage in international environmental commitments in the short-run. However, in the long-run mining rents increase *de jure* environmental policy stringency. This is coherent with the nexus between natural resource exploitation and the environment. In the long-run, as citizens' standard of living increases, they value more the quality of the environment and they demand more environmental protection which leads to an increase in international commitment. We observe the opposite when it comes to *de facto* environmental policy. Mining activities increase *de facto* environmental enforcement in the short-run while it leads to lax environmental policy in the long-run.

Table 3.3: Strategic interactions: Direct and indirect vs. short run and long-run effects

	Dpendent variable *de jure* environmental policy								**Dependent variable: *de facto* environmental policy**							
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.*de jure* environmental policy	0.888***								0.942***							
	(0.0236)								(0.0353)							
Mineral resource rents	-0.0291***	-0.245***	-0.0345***	-0.357***	-0.391***	-0.391	1.949	1.558***	0.00586	0.101***	0.0278**	0.761**	0.789**	-0.0747***	-0.0606**	-0.135***
	(0.00869)	(0.0305)	(0.00882)	(0.0541)	(0.0577)	(3.606)	(3.626)	(0.428)	(0.00498)	(0.0129)	(0.0108)	(0.311)	(0.321)	(0.0272)	(0.0270)	(0.0180)
Temperature shocks	0.0379**		0.0397**	0.0171*	0.0568**	0.414	-0.633	-0.219**	0.00602		0.00814	0.0437	0.0518	0.0256	-0.0342	-0.00859
	(0.0183)		(0.0180)	(0.00906)	(0.0265)	(1.721)	(1.732)	(0.105)	(0.00777)		(0.00887)	(0.0532)	(0.0614)	(0.0286)	(0.0375)	(0.00939)
Precipitation shocks	0.000634		0.000632	0.000277	0.000909	0.00567	-0.00907	-0.00340	0.000438**		0.000519**	0.00271*	0.00322*	0.00158*	-0.00214**	-0.000555**
	(0.000430)		(0.000437)	(0.000207)	(0.000637)	(0.0127)	(0.0134)	(0.00246)	(0.000182)		(0.000218)	(0.00162)	(0.00181)	(0.000840)	(0.00103)	(0.000225)
GDP Growth	0.0144**	0.0660***	0.0160**	0.100***	0.116***	0.188	-0.643	-0.455***	-0.0117***	-0.0684***	-0.0281***	-0.563**	-0.591**	0.0214	0.0791***	0.101***
	(0.00674)	(0.0225)	(0.00662)	(0.0353)	(0.0372)	(1.370)	(1.383)	(0.153)	(0.00432)	(0.0114)	(0.00903)	(0.242)	(0.250)	(0.0242)	(0.0275)	(0.0148)
FDI	0.00145	-0.0134	0.00127	-0.0189	-0.0176	0.0159	0.0520	0.0680	-0.00698***	-0.0292***	-0.0143***	-0.253**	-0.267**	0.00305	0.0428***	0.0458***
	(0.00205)	(0.0138)	(0.00205)	(0.0186)	(0.0190)	(0.0925)	(0.122)	(0.0765)	(0.00223)	(0.00751)	(0.00440)	(0.116)	(0.120)	(0.0143)	(0.0146)	(0.00978)
Democracy index	-0.0631***		-0.0632***	-0.0274**	-0.0906***	-0.643	0.989	0.346***	0.0390***		0.0462***	0.246*	0.292**	0.142***	-0.191***	-0.0491***
	(0.0181)		(0.0189)	(0.0119)	(0.0300)	(2.237)	(2.242)	(0.103)	(0.00621)		(0.00941)	(0.134)	(0.142)	(0.0517)	(0.0563)	(0.00689)
Control of corruption	0.522**		0.519***	0.218**	0.737**	5.199	-8.164	-2.966**	-0.195**		-0.231***	-1.151**	-1.382**	-0.679**	0.930**	0.251**
	(0.203)		(0.201)	(0.0949)	(0.287)	(18.52)	(18.66)	(1.491)	(0.0781)		(0.0842)	(0.487)	(0.550)	(0.322)	(0.383)	(0.100)
Poulation density	-0.0150***		-0.0149***	-0.00635***	-0.0212***	-0.146	0.229	0.0831***	0.0101***		0.0120***	0.0626**	0.0746**	0.0363***	-0.0491***	-0.0128***
	(0.00264)		(0.00270)	(0.00206)	(0.00454)	(0.468)	(0.467)	(0.0210)	(0.000957)		(0.00148)	(0.0278)	(0.0290)	(0.0119)	(0.0120)	(0.00119)
Openness to trade	0.00104		0.00109	0.000456	0.00155	0.00864	-0.0149	-0.00624	-0.00380***		-0.00441***	-0.0226**	-0.0270**	-0.0131***	0.0178***	0.00476***
	(0.00163)		(0.00168)	(0.000726)	(0.00239)	(0.0318)	(0.0373)	(0.0101)	(0.000813)		(0.000931)	(0.00996)	(0.0105)	(0.00499)	(0.00526)	(0.00110)
Forest rent	0.00988		0.00988	0.00408	0.0140	0.0762	-0.133	-0.0572	0.0192***		0.0226***	0.116**	0.138**	0.0678**	-0.0921**	-0.0243***
	(0.0143)		(0.0137)	(0.00583)	(0.0194)	(0.371)	(0.408)	(0.0841)	(0.00713)		(0.00769)	(0.0540)	(0.0601)	(0.0316)	(0.0373)	(0.00848)
δ	0.300***								0.852***							
	(0.0415)								(0.0383)							
σ_e^2	0.470***								0.0960***							
	(0.0539)								(0.0120)							
# Observations	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Log likelihood	-563.4	-563.4	-563.4	-563.4	-563.4	-563.4	-563.4	-563.4	-126.5	-126.5	-126.5					

Notes: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ SR: short-run LR: long-run.

Temperature shocks have a positive and significant effect on *de jure* environmental policy, while their effect on *de facto* environmental policy is statistically non-significant. Climate shocks increase countries willingness to engage in international environmental treaties but do not necessarily translate into effective climate mitigation policy. The non-binding nature of international agreements might explain this result. In the short-run, an increase in temperature shocks increases countries' adherence to international environmental agreements.

We also control for political institutions (democracy index), population density, economic growth and FDI. The effect of democracy depends on the measure of environmental policy and the time length. In the short-run, democracy degrades countries adherence in international environmental treaties while its effect, in the long-run, is positive and significant at 1% level. With *de facto* environmental policy, we observe the opposite. Democracy is associated with more enforcement of environmental policy in the short-run while in the long-run democratic countries tend to dedicate less effort to environmental policy enforcement. This contrasted result might be explained by an asymmetry between citizens' demand for environmental protection and government response. In the long-run, governments respond to citizens demand for environmental enforcement by participating in international treaties which is visible than effectively putting effort to mitigate the environmental impact of economic activities. Similarly, Neumayer (2002) find that democracy induces international environmental commitment but not necessarily environmental outcomes. Governments focus mostly on economic growth rather than on the environment.

Population density has a significant effect on *de jure* environmental policy. An increase in population density increases country *de jure* environmental enforcement in the long-run while its effect is negative in the short-run.

Economic growth has also a contrasted effect on *de jure* and *de facto* environmental policy. In the short-run, its effect on *de jure* environmental policy is positive while negative on *de facto* policy. In the long-run, economic growth increases countries *de facto* environmental enforcement policy while it decreases their *de jure* counterpart.

FDI affect only *de facto* environmental policy. In the sort-run, FDI decrease *de facto* environmental policy stringency while in the long-run, they increase environmental enforcement. To attract FDI countries may lower their environmental standards in the short-run. The effect of openness to trade is similar to the one of FDI. An increase in openness to trade decreases *de facto* environmental policy in the short-run and raises environmental standards.

To sum up, we find evidence of strategic interactions between African countries in their environmental policy. However, at this stage of the analysis the direction of the spatial pattern (race to the top or race to the bottom) is still undetermined. For evidence of any environmental race to the bottom or race to the top (asymmetric dynamics among states), we need to estimate Equation 3.2 (Fredriksson and Millimet, 2002; Konisky, 2007).

3.4.6 Test of race to the bottom vs. race to the top

Table 3.4 summarizes the results of the test of the race to the bottom (to the top) for both *de jure* and *de facto* environmental policy. We use the same control variables as in the previous strategic interaction regressions. Evidence of the race to the bottom suggests that δ_0 is positive and significant while δ_1 is not significant (Fredriksson and Millimet, 2002; Konisky, 2007). Indeed, countries react to change in the environmental policy of their neighbors only when their own environmental policy is more stringent than their competitors. Conversely, a race to the top would suggest that δ_1 is positive and significant while δ_0 is not significant. In this case, countries react to neighbors' environmental policy by strengthening their policy only when their standards are lower. An intermediary situation is where both coefficients δ_0 and δ_1 are significant. In this case, we may need to compare to size of the coefficients to determinants the dominants equilibrium. Figures 3.A1 and 3.A2 in Appendix display the distributions of *de jure* and *de facto* environmental policies according to $D_{it} = 0$ and $D_{it} = 1$.

Table 3.4: Test of the race to the bottom vs. race to the top

	δ_0	δ_1
de jure environmental policy	**0.169*****	0.394***
	(0.0403)	(0.0818)
de facto environmental policy	0.857***	**0.244*****
	(0.0412)	**(0.0786)**

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

For *de jure* environmental policy, δ_0 and δ_1 are all significant at 1% level. However, the size of δ_1 is stronger and more than two times bigger than the size of δ_0. This implies that the strategic interaction is stronger in countries where the *de jure* environmental standards of neighbors are higher. This result supports a clustered race to the top.

For *de facto* environmental policy, δ_0 δ_1 are also significant. However, in that case δ_1 is much lower than δ_0 implying that the strategic interaction is stronger in countries where the *de facto* environmental policy of the neighbors are higher. African countries are engaged in a race to the bottom in their *de facto* environmental policy.

This result explains the contrasted evolution of *de jure* and *de facto* environmental policy presented in Figure 3.3. While African countries continue to engage in international environmental treaties, their domestic effort to mitigate climate change is decreasing.

3.5 Robustness checks

In this section, we conduct a series of robustness checks for the results of our two models: the strategic interaction and the test of the race to the bottom vs. to the top.

3.5.1 Strategic interaction

Table 3.5 summarizes the our robustness analysis. The full estimation tables are in Appendix. We test the consistency of the strategic interaction and the race results by using alternative weighting matrices. For all our three alternative matrices δ remain positive and significant for both *de jure* and *de facto* environmental policies. Moreover the size of δ is similar across weighting matrices. Ford *de jure* environmental policy, δ are 0.057; 0.0648 and 0.0485 respectively for population, GDP per capita and mineral rents matrices. For *de facto* environmental policy, δ are 0.122; 0.127 and 0.155 respectively for population, GDP per capita and mineral rents matrices. The finding that States interact strategically in response to their neighbors' environmental policy is robust.

Table 3.5: Strategic interaction and races

	de jure environmental policy			*de facto* environmental policy		
Weighting matrices	δ	δ_0	δ_1	δ	δ_0	δ_1
Population	0.0573**	0.0526	0.141***	0.122***	0.143***	0.117*
	(0.0233)	(0.0462)	(0.0336)	(0.0330)	(0.0290)	(0.0621)
GDP per capita	0.0648**	0.0102	0.110***	0.127***	0.106**	0.0739*
	(0.0303)	(0.0552)	(0.0373)	(0.0314)	(0.0521)	(0.0437)
Mineral rent	0.0485*	0.0540	0.127***	0.155***	0.118***	0.00244
	(0.0254)	(0.0405)	(0.0361)	(0.0432)	(0.0385)	(0.0471)

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

3.5.2 Race to the bottom vs. race to the top

The results of a race to the top for *de jure* environmental policy and a race to the bottom for *de facto* environmental policy is robust to change in weighting matrix (Table 3.5. See full estimation tables in Appendix from Table 3.A5 to Table 3.A22.). For *de jure* environmental policy, δ_0 is not significant for all the matrices while δ_1 is positive and significant. This result supports the race to the top in *de jure* environmental policy. For *de facto* policy δ_0 is significant at 1% level and larger than δ_1: African countries exhibit a race to the bottom in their *de facto* environmental policies.

3.6 Conclusion

In the context of climate change, Africa is caught between a double imperative: mobilizing domestic revenue for financing development and protecting the environment. While the mining sector constitutes an opportunity for domestic revenue mobilization (Collier, 2010), it poses at the same time enormous environmental issues (Edwards et al., 2014).

In this paper, we investigate how mining affects deforestation and environmental policies. We use two environmental policy measures for this purpose. A *de jure* environmental policy, which is the adherence of countries to international environmental treaties and a *de facto* measure which is the country's commitment to climate change mitigation proposed by Combes et al. (2016). Relying on a sample of 35 African countries over the period 2001-2017, We find that countries adopt a strategic behavior in response to the environmental policy of their neighbors (competitors). These strategic reactions lead either to a race to the bottom where all countries will tend to lower their environmental standards or a race to the top where countries imitate each other in setting stronger environmental standards. We test this hypothesis in third place. For *de jure* environmental policy, our results support a race to the top. Countries respond mostly to the adherence of their competitors to international environmental treaties by joining as well. However, for *de facto* environmental policy, the strategic behavior leads to a race to the bottom.

Three main policy recommendations emerge from these results. First, international environmental treaties must be more binding. As African countries increasingly engage in environmental treaties, their actual commitment to mitigate climate change are slackening. Imaginative solutions that involve setting up clearly defined environmental rating systems (as the notations in finance) can motivate countries to strengthen their environmental standards due to the reputation stakes involved.

Such notations have the advantage, not only for putting countries in a virtuous circle of environmental competition but also; they can be used to allocate funding in the Green Climate Fund (GCF) framework for instance.

Second, the coordination of environmental policies is imperative to avoid a race to the bottom. Regional economic communities are appropriate frameworks for such coordination. This coordination can be done by following the example of WAEMU and ECOWAS. However, it must be done through concrete actions and with monitoring and evaluation mechanisms to avoid free-riding. Such coordination can also help avoiding "Prisoner's Dilemma" while designing policies to attract foreign investment. Zhang et al. (2018) support that in China, central coordination enforces local environmental policy.

Third, at the country level, mining is an environmental cost often left to the affected local populations. Countries need to be much more careful about environmental aspects and put in place mechanisms that limit the effects of mining activity on deforestation.

We draw two future research prospects from our findings. First, there is no environmental policy data in developing countries for long period. Moreover, existing institutional quality data weakly document the environmental aspects of governance in developing countries specifically in Africa. Country international environmental treaty participation and domestic effort to climate mitigation are limited environmental policy measures. Future research focusing on developing world governance indicators (WGI) type dataset on environmental governance for developing countries is an important step for sound climate mitigation policies. Second, this study focuses on a sample of countries level analysis of deforestation. However, local case studies can give detailed insights on the extent to which mining activities affect deforestation and how to mitigate it.

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Appendix

3.6.1 List of countries

Benin, Botswana, Burundi, Cameroon, Centrale Africa Republique, Chad, Congo Republique, Congo DRC, Côte d'Ivoire, Equatorial Guinea, Eswatini, Gabon, Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Tunisia, Uganda, Zambia and Zimbabwe.

Table 3.A1: Data sources and variables description

Variables	Definition	Type[a]	Sources
Temperature shocks	Absolute value of the yearly average temperature deviation to its long-run trend	Cont.	University of East Anglia Climatic Research Unit
Mining rents	Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	Cont.	WDI (2019)
de facto environmental policy	An index of environmental policy build upon domestic effort for climate mitigation	Int.	Authors' computation based on Combes et al. (2016)
de jure environmental policy	A count of country adhesion to international environmental treaties	Cont.	Environmental Treaties and Resource Indicators dataset
GDP growth	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2010 U.S. dollars. GDP is the sum of gross value	Cont.	WDI (2019)
Population	Population is the midyear estimate of the total population based on the *de facto* definition of population, which counts all residents regardless of legal status or citizenship.	Cont	WDI (2019)
Openness to trade	Openness to trade is the sum of exports and imports of goods and services (in % of GDP)	Cont.	WDI (2019)
Aid	Aid is the Net official development assistance (ODA) per capita. It consists of disbursements of loans made on concessional terms and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries.	Cont.	WDI (2019)
Foreign Direct Investment	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP.	Cont.	WDI (2019)
Democracy index	Measures of institutional quality mainly democracy. Polity is ranged from -10 (autocratic) to +10 (full democracy)	Int.	Polity IV Project (2019)
GDP per capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes.	Cont.	WDI (2019)
Population density	Population density is midyear population divided by land area in square kilometers. The population is based on the *de facto* definition of population, which counts all residents.	Cont.	WDI (2019)
CO_2 emissions per capita	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Cont.	WDI (2019)
Control of corruption	"Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests."	Cont.	WGI(2019)
Forest rents	"Forest rents are roundwood harvest times the product of average prices and a region-specific rental rate."	Cont.	WDI(2019)

[a] Cont.: continuous; Int.: integer.; Dum.: dummy

Estimation tables

Table 3.A2: System-GMM estimation of *de facto* environmental policy

Dependent variable: Log of CO_2 emissions per capita			
	(1)	(2)	(3)
L.CO2 emissions per capita (log)	0.874***	0.869***	0.880***
	(0.0792)	(0.0807)	(0.0895)
GDP per capita (log)	0.180*	0.215**	0.214*
	(0.0956)	(0.107)	(0.113)
Total population (log)	0.0510**	0.0700**	0.0739**
	(0.0243)	(0.0318)	(0.0342)
Openness to trade (log)	0.139*	0.197***	0.207**
	(0.0724)	(0.0762)	(0.0813)
Foreign Direct Investment (log)		-0.00190	-0.000535
		(0.00957)	(0.00993)
Aid per capita (log)			-0.000790
			(0.0214)
Constant	-2.804***	-3.643***	-3.714***
	(1.010)	(1.343)	(1.334)
Time fixed effects	Yes	Yes	Yes
# Observations	560	537	535
Number of countries	35	35	35
AR(1) p-value	0.000	0.000	0.000
AR(2) p-value	0.510	0.555	0.532
Hansen test p-value	0.142	0.220	0.283
Number of instruments	26	29	32

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$ Residuals from the complete specification (column 3) is used to compute the index of *de facto* policy.

Table 3.A3: Race test regression: *de facto*

	Dependent variable *de facto* environmental policy (for δ_0)							
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.*de facto* environmental policy	0.993***							
	(0.0475)							
Mineral resource rents	0.00909	0.108***	0.0553	0.887	0.942	-0.117***	-0.0207	-0.138***
	(0.00648)	(0.00833)	(0.0542)	(0.987)	(1.041)	(0.0130)	(0.0135)	(0.0134)
Temperature shocks	0.00870		0.0128	0.0579	0.0707	0.00895	-0.0207	-0.0117
	(0.0106)		(0.0139)	(0.0967)	(0.108)	(0.00946)	(0.0215)	(0.0122)
Precipitation shocks	0.000743*		0.00101*	0.00504	0.00604	0.000705*	-0.00158*	-0.000878*
	(0.000387)		(0.000612)	(0.00617)	(0.00668)	(0.000397)	(0.000844)	(0.000460)
GDP Growth	-0.0187***	-0.0916***	-0.0625	-0.834	-0.897	0.0881***	0.0414***	0.130***
	(0.00701)	(0.0109)	(0.0538)	(0.998)	(1.051)	(0.0112)	(0.0139)	(0.0129)
FDI	-0.00349	-0.0160***	-0.0114	-0.151	-0.162	0.0149***	0.00768	0.0226***
	(0.00240)	(0.00505)	(0.0114)	(0.211)	(0.222)	(0.00568)	(0.00488)	(0.00577)
Democracy index	0.0297***		0.0400**	0.196	0.236	0.0277***	-0.0630***	-0.0352***
	(0.00950)		(0.0168)	(0.213)	(0.227)	(0.0100)	(0.0205)	(0.0114)
Control of corruption	-0.222**		-0.297**	-1.417	-1.713	-0.205**	0.470***	0.265**
	(0.0951)		(0.136)	(1.597)	(1.706)	(0.0800)	(0.182)	(0.108)
Population density	0.0132***		0.0178***	0.0874	0.105	0.0123***	-0.0279***	-0.0156***
	(0.000980)		(0.00540)	(0.0974)	(0.103)	(0.00217)	(0.00245)	(0.00118)
Openness to trade	-0.00218***		-0.00284**	-0.0135	-0.0164	-0.00195***	0.00449***	0.00253***
	(0.000668)		(0.00110)	(0.0146)	(0.0155)	(0.000600)	(0.00136)	(0.000845)
Forest rent	0.0280***		0.0379**	0.188	0.226	0.0263***	-0.0594***	-0.0331***
	(0.00830)		(0.0154)	(0.208)	(0.222)	(0.00884)	(0.0170)	(0.00897)
δ_0	**0.857*** **							
	(0.0412)							
σ_e^2	0.0995***							
	(0.0152)							
# Observations	320	320	320	320	320	320	320	320
Number countries	20	20	20	20	20	20	20	20
Log likelihood	-79.66	-79.66	-79.66	-79.66	-79.66	-79.66	-79.66	-79.66

	Dependent variable: *de facto* environmental policy (δ_1)							
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.*de facto* environmental policy	0.825***							
	(0.0323)							
Mineral resource rents	-0.00895	0.0187	-0.00873	0.0236	0.0149	0.0410	0.559	0.600
	(0.0217)	(0.0476)	(0.0208)	(0.0602)	(0.0561)	(1.250)	(11.01)	(11.74)
Temperature shocks	-0.00559		-0.00477	-0.00173	-0.00649	0.00538	0.0175	0.0229
	(0.00982)		(0.00965)	(0.00362)	(0.0131)	(0.459)	(1.785)	(1.850)
Precipitation shocks	0.000183		-0.000123	-0.000215	-0.000337	-0.0232	-0.799	-0.822
	(0.000169)		(0.0313)	(0.0113)	(0.0420)	(1.112)	(14.58)	(15.59)
GDP Growth	0.000413	-0.000919	0.000642	0.000724	0.00137	0.0138	-0.0251	-0.0113
	(0.00579)	(0.00978)	(0.0103)	(0.0160)	(0.0235)	(0.303)	(1.611)	(1.695)
FDI	-0.0292***	-0.0117	-0.0293	-0.0262	-0.0555	-0.157	0.681	0.524
	(0.00492)	(0.0188)	(0.0206)	(0.0295)	(0.0436)	(1.237)	(10.58)	(11.29)
Democracy index	0.00453		0.00436	0.00173	0.00609	0.0331	-0.0864	-0.0533
	(0.00698)		(0.0117)	(0.00434)	(0.0158)	(0.372)	(2.275)	(2.405)
Control of corruption	-0.128		-0.130	-0.0367	-0.167	-0.283	6.771	6.488
	(0.135)		(0.139)	(0.0468)	(0.181)	(7.449)	(97.55)	(104.4)
Population density	0.00117		0.00203	0.000982	0.00301	0.0211	-0.189	-0.168
	(0.00461)		(0.0154)	(0.00567)	(0.0208)	(0.623)	(2.905)	(3.042)
Openness to trade	-0.00384*		-0.00408	-0.00135	-0.00544	-0.0297	0.248	0.218
	(0.00204)		(0.0115)	(0.00416)	(0.0154)	(0.495)	(2.745)	(2.896)
Forest rent	0.0174		0.0166	0.00607	0.0227	0.0792	-0.585	-0.506
	(0.0229)		(0.0244)	(0.00912)	(0.0329)	(0.889)	(10.30)	(11.02)
δ_1	**0.244*** **							
	(0.0786)							
σ_e^2	0.0822***							
	(0.0149)							
# Observations	240	240	240	240	240	240	240	240
Number countries	15	15	15	15	15	15	15	15
Log likelihood	-34.31	-34.31	-34.31	-34.31	-34.31	-34.31	-34.31	-34.31

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 3.A4: Race test regression: *de jure*

	Dependent variable *de jure* environmental policy (for δ_0)							
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.*de jure* environmental policy	0.873***							
	(0.0349)							
Mineral resource rents	-0.00591	-0.0457	-0.00705	-0.0538	-0.0608*	-0.0734	-0.0716	-0.145
	(0.0110)	(0.0282)	(0.0107)	(0.0334)	(0.0362)	(1.227)	(20.83)	(22.05)
Temperature shocks	0.0866***		0.0893***	0.0181**	0.107***	0.657	-1.708	-1.051
	(0.0227)		(0.0219)	(0.00739)	(0.0278)	(1.561)	(26.41)	(27.96)
Precipitation shocks	0.00152*		0.00153*	0.000327	0.00186*	0.0123	-0.0166	-0.00434
	(0.000795)		(0.000801)	(0.000218)	(0.00100)	(0.0221)	(0.361)	(0.382)
GDP Growth	-0.00483	-0.0158	-0.00521	-0.0193	-0.0246	-0.0401	0.00550	-0.0346
	(0.0120)	(0.0208)	(0.0113)	(0.0246)	(0.0262)	(0.546)	(9.151)	(9.689)
FDI	-0.00269	0.00624	-0.00245	0.00659	0.00414	-0.0167	0.0811	0.0644
	(0.00304)	(0.0157)	(0.00311)	(0.0178)	(0.0186)	(0.270)	(4.543)	(4.812)
Democracy index	-0.0646***		-0.0652***	-0.0140*	-0.0792***	-0.477	1.483	1.006
	(0.0227)		(0.0228)	(0.00787)	(0.0302)	(0.918)	(15.22)	(16.10)
Control of corruption	1.325***		1.306***	0.259**	1.566***	9.960	-18.81	-8.846
	(0.394)		(0.401)	(0.107)	(0.481)	(26.83)	(451.4)	(477.9)
Population density	-0.0355***		-0.0356***	-0.00713**	-0.0427***	-0.283	0.333	0.0509
	(0.0107)		(0.0110)	(0.00314)	(0.0134)	(0.637)	(10.65)	(11.28)
Openness to trade	0.00108		0.00109	0.000208	0.00130	0.00834	-0.0118	-0.00350
	(0.00201)		(0.00211)	(0.000437)	(0.00253)	(0.0439)	(0.705)	(0.746)
Forest rent	0.0388		0.0369	0.00776	0.0446	0.270	-0.818	-0.548
	(0.0278)		(0.0279)	(0.00656)	(0.0341)	(0.613)	(9.742)	(10.30)
δ_0	**0.169*** **							
	(0.0403)							
σ_e^2	0.568***							
	(0.0778)							
# Observations	288	288	288	288	288	288	288	288
Number countries	18	18	18	18	18	18	18	18
Log likelihood	-314.0	-314.0	-314.0	-314.0	-314.0	-314.0	-314.0	-314.0

	Dependent variable: *de jure* environmenta				
	Main	Wx	SR direct	SR indirect	SR total
L.*de jure* environmental policy	0.888***				
	(0.0344)				
Mineral resource rents	-0.0250**	-0.275***	-0.0415***	-0.464***	-0.505***
	(0.0126)	(0.0296)	(0.0115)	(0.102)	(0.103)
Temperature shocks	0.0405		0.0441	0.0300	0.0740
	(0.0292)		(0.0292)	(0.0246)	(0.0522)
Precipitation shocks	0.000351		0.000358	0.000271	0.000630
	(0.000493)		(0.000495)	(0.000373)	(0.000853)
GDP Growth	0.0131***	0.0134	0.0141***	0.0329*	0.0470**
	(0.00458)	(0.0116)	(0.00479)	(0.0195)	(0.0217)
FDI	-0.00946	0.0739**	-0.00541	0.113**	0.108**
	(0.00581)	(0.0292)	(0.00533)	(0.0486)	(0.0490)
Democracy index	-0.0471**		-0.0475**	-0.0325	-0.0799*
	(0.0200)		(0.0206)	(0.0217)	(0.0409)
Control of corruption	0.604***		0.613***	0.397**	1.010***
	(0.168)		(0.174)	(0.199)	(0.344)
Population density	-0.00747***		-0.00753***	-0.00496**	-0.0125***
	(0.00183)		(0.00195)	(0.00248)	(0.00414)
Openness to trade	0.00434		0.00452	0.00288	0.00740
	(0.00323)		(0.00317)	(0.00232)	(0.00528)
Forest rent	0.0127		0.0133	0.00859	0.0219
	(0.0130)		(0.0126)	(0.00904)	(0.0211)
δ_1	**0.394*** **				
	(0.0818)				
σ_e^2	0.315***				
	(0.0649)				
# Observations	272	272	272	272	272
Number countries	17	17	17	17	17
Log likelihood	-219.9	-219.9	-219.9	-219.9	-219.9

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3.A5: Robustness: Strategic interaction with population weighting, de jure policy

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De jure environmental policy	0.914***							
	(0.0118)							
Mineral resource rents	-0.0137*	-0.0329***	-0.0143**	-0.0353***	-0.0497***	-0.283	-1.835	-2.117
	(0.00742)	(0.0115)	(0.00718)	(0.0108)	(0.0127)	(0.385)	(11.72)	(12.07)
Temperature shocks	0.0846***		0.0865***	0.00540*	0.0919***	1.212	3.046	4.258
	(0.0213)		(0.0207)	(0.00301)	(0.0229)	(0.798)	(22.99)	(23.68)
Precipitation shocks	0.000763*		0.000761*	4.94e-05	0.000811*	0.0107	0.0247	0.0354
	(0.000457)		(0.000452)	(3.96e-05)	(0.000486)	(0.0101)	(0.251)	(0.259)
GDP Growth	0.00220	0.00255	0.00241	0.00282	0.00523	0.0383	0.173	0.211
	(0.00526)	(0.0113)	(0.00515)	(0.0116)	(0.0122)	(0.104)	(2.538)	(2.615)
FDI	-2.99e-05	0.0164	0.000320	0.0176	0.0179	0.0464	0.710	0.756
	(0.00288)	(0.0121)	(0.00290)	(0.0126)	(0.0139)	(0.138)	(4.084)	(4.208)
Democracy index	-0.0347*		-0.0347*	-0.00225	-0.0369*	-0.483	-1.027	-1.509
	(0.0177)		(0.0179)	(0.00165)	(0.0192)	(0.389)	(9.716)	(10.00)
Control of corruption	0.0718		0.0647	0.00368	0.0684	0.899	2.840	3.739
	(0.213)		(0.204)	(0.0130)	(0.215)	(3.676)	(69.38)	(72.06)
Population density	-0.00744***		-0.00728***	-0.000466*	-0.00774***	-0.103	-0.263	-0.366
	(0.00192)		(0.00189)	(0.000274)	(0.00212)	(0.0718)	(1.977)	(2.037)
Openness to trade	0.00119		0.00124	7.26e-05	0.00131	0.0173	0.0453	0.0626
	(0.00165)		(0.00167)	(0.000111)	(0.00176)	(0.0262)	(0.386)	(0.402)
rho	0.0573**							
	(0.0233)							
sigma2_e	0.485***							
	(0.0573)							
Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-575.2	-575.2	-575.2	-575.2	-575.2	-575.2	-575.2	-575.2

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Population is used as weighting matrix.

Table 3.A6: Robustness: Strategic interaction with population weighting, de facto policy

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.914***							
	(0.0347)							
Mineral resource rents	-0.00663*	0.0152**	-0.00635*	0.0160**	0.00969	-0.0787	-0.0345	-0.113
	(0.00371)	(0.00710)	(0.00360)	(0.00779)	(0.00887)	(0.673)	(12.52)	(12.88)
Temperature shocks	-0.00689		-0.00617	-0.000757	-0.00693	-0.0334	-0.0121	-0.0456
	(0.00743)		(0.00720)	(0.00102)	(0.00815)	(0.985)	(6.538)	(6.657)
Precipitation shocks	0.000266		0.000270	3.80e-05	0.000308	0.000834	-0.0136	-0.0128
	(0.000179)		(0.000178)	(2.94e-05)	(0.000204)	(0.0238)	(0.320)	(0.328)
GDP Growth	-0.00836**	-0.00466	-0.00857**	-0.00666	-0.0152*	-0.0116	0.190	0.179
	(0.00383)	(0.00670)	(0.00358)	(0.00742)	(0.00912)	(1.241)	(13.42)	(13.77)
FDI	-0.00553**	-0.00304	-0.00553**	-0.00426	-0.00979	-0.0205	-0.0327	-0.0531
	(0.00227)	(0.00616)	(0.00220)	(0.00672)	(0.00683)	(0.747)	(7.558)	(7.748)
Democracy index	0.0133**		0.0134**	0.00198	0.0154**	0.0223	-0.101	-0.0789
	(0.00575)		(0.00590)	(0.00120)	(0.00697)	(1.102)	(8.271)	(8.451)
Control of corruption	0.00337		-0.000327	0.000684	0.000357	-0.715	5.312	4.597
	(0.0785)		(0.0771)	(0.0108)	(0.0875)	(7.703)	(60.22)	(61.48)
Population density	-0.00117*		-0.00110*	-0.000149	-0.00125*	-0.00282	0.0269	0.0241
	(0.000655)		(0.000665)	(9.74e-05)	(0.000748)	(0.115)	(0.932)	(0.953)
Openness to trade	-0.00345***		-0.00342***	-0.000485**	-0.00391***	-0.0141	0.0640	0.0499
	(0.000821)		(0.000803)	(0.000203)	(0.000950)	(0.322)	(2.874)	(2.941)
rho	0.122***							
	(0.0330)							
sigma2_e	0.100***							
	(0.0120)							
Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-134.7	-134.7	-134.7	-134.7	-134.7	-134.7	-134.7	-134.7

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Population is used as weighting matrix.

Table 3.A7: Robustness: Strategic interaction with GDP per capita weighting

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.de jure environmental policy	0.913***							
	(0.0146)							
Mineral resource rents	-0.0170**	-0.0469**	-0.0177**	-0.0489**	-0.0665***	-0.209	2.440	2.231
	(0.00709)	(0.0231)	(0.00691)	(0.0241)	(0.0252)	(5.921)	(191.0)	(196.6)
Temperature shocks	0.0804***		0.0818***	0.00581	0.0877***	0.939	-2.434	-1.495
	(0.0197)		(0.0193)	(0.00371)	(0.0221)	(6.322)	(188.9)	(194.4)
Precipitation shocks	0.000741*		0.000739*	5.14e-05	0.000790*	0.00670	-0.0725	-0.0658
	(0.000437)		(0.000429)	(4.28e-05)	(0.000462)	(0.0703)	(2.284)	(2.351)
GDP growth	0.00369	-0.0102	0.00391	-0.00840	-0.00450	0.133	3.027	3.160
	(0.00592)	(0.0172)	(0.00589)	(0.0192)	(0.0224)	(2.909)	(97.57)	(100.4)
FDI	0.00113	0.00380	0.00128	0.00355	0.00483	0.0692	1.706	1.775
	(0.00227)	(0.0113)	(0.00223)	(0.0112)	(0.0110)	(1.024)	(33.98)	(34.98)
Democracy index	-0.0371**		-0.0374**	-0.00274	-0.0401*	-0.284	6.693	6.409
	(0.0187)		(0.0190)	(0.00228)	(0.0207)	(5.807)	(192.4)	(198.0)
Control of corruption	0.153		0.150	0.0106	0.160	1.992	-2.982	-0.990
	(0.219)		(0.213)	(0.0167)	(0.227)	(35.01)	(1,145)	(1,179)
Population density	-0.00626***		-0.00614***	-0.000463	-0.00660***	-0.0607	0.616	0.556
	(0.00218)		(0.00218)	(0.000352)	(0.00248)	(0.722)	(23.55)	(24.24)
Openness to trade	0.000944		0.00103	6.30e-05	0.00109	0.0168	0.0937	0.110
	(0.00168)		(0.00168)	(0.000128)	(0.00179)	(0.185)	(5.952)	(6.129)
Forest rents	0.00655		0.00677	0.000351	0.00712	0.0854	1.079	1.165
	(0.0129)		(0.0123)	(0.000913)	(0.0131)	(0.787)	(22.80)	(23.47)
ρ	0.0648**							
	(0.0303)							
σ_e^2	0.486***							
	(0.0572)							
Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-576.0	-576.0	-576.0	-576.0	-576.0	-576.0	-576.0	-576.0

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A8: Robustness: Strategic interaction with GDP per capita weighting

	Dependent variable de jure environmental policy							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.de facto environmental policy	0.890***							
	(0.0355)							
Mineral resource rents	-0.00124	0.000182	-0.00141	0.000413	-0.000992	-0.0479	-0.763	-0.811
	(0.00535)	(0.0118)	(0.00523)	(0.0144)	(0.0168)	(1.270)	(13.07)	(13.38)
Temperature shocks	-0.00582		-0.00505	-0.000642	-0.00569	-0.164	0.0462	-0.118
	(0.00764)		(0.00738)	(0.00109)	(0.00840)	(1.889)	(15.03)	(15.35)
Precipitation shocks	0.000295		0.000295	4.53e-05	0.000340	0.00793	0.00298	0.0109
	(0.000188)		(0.000189)	(3.49e-05)	(0.000221)	(0.0579)	(0.275)	(0.276)
GDP Growth	-0.00793*	-0.00372	-0.00805**	-0.00499	-0.0130	-0.254	0.165	-0.0892
	(0.00432)	(0.00960)	(0.00410)	(0.0113)	(0.0130)	(2.673)	(16.91)	(17.19)
FDI	-0.00551**	-0.00459	-0.00558***	-0.00594	-0.0115*	-0.162	0.0376	-0.124
	(0.00220)	(0.00551)	(0.00215)	(0.00618)	(0.00685)	(1.787)	(17.84)	(18.28)
Democracy index	0.0155**		0.0156**	0.00239*	0.0180**	0.373	-0.0347	0.338
	(0.00610)		(0.00608)	(0.00136)	(0.00732)	(2.815)	(14.29)	(14.41)
Control of corruption	-0.0338		-0.0356	-0.00520	-0.0408	-0.571	3.374	2.803
	(0.0849)		(0.0835)	(0.0122)	(0.0952)	(7.275)	(72.37)	(74.20)
Population density	0.000399		0.000471	7.38e-05	0.000544	0.00662	-0.0556	-0.0490
	(0.00103)		(0.000994)	(0.000148)	(0.00114)	(0.0994)	(0.711)	(0.726)
Openness to trade	-0.00357***		-0.00355***	-0.000509***	-0.00406***	-0.0742	0.0939	0.0197
	(0.000693)		(0.000694)	(0.000161)	(0.000777)	(0.571)	(4.649)	(4.751)
Forest rent	0.0102		0.0102	0.00150	0.0117	0.195	-0.828	-0.633
	(0.00808)		(0.00752)	(0.00122)	(0.00865)	(1.224)	(11.80)	(12.09)
ρ	0.127***							
	(0.0314)							
σ_e^2	0.0990***							
	(0.0121)							
# Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-130.6	-130.6	-130.6	-130.6	-130.6	-130.6	-130.6	-130.6

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A9: Robustness: Strategic interaction with mineral rents weighting

	Dependent variable de jure environmental policy							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.de jure environmental policy	0.912***							
	(0.0158)							
Mineral resource rents	-0.0110*	-0.0202	-0.0113*	-0.0223	-0.0337*	-0.161	-0.391	-0.552
	(0.00604)	(0.0158)	(0.00586)	(0.0169)	(0.0187)	(0.227)	(7.339)	(7.547)
Temperature shocks	0.0848***		0.0863***	0.00466	0.0910***	1.059*	0.819	1.878
	(0.0195)		(0.0189)	(0.00310)	(0.0211)	(0.558)	(16.52)	(17.00)
Precipitation shocks	0.000822*		0.000827*	4.31e-05	0.000870*	0.0102	0.0117	0.0219
	(0.000460)		(0.000451)	(3.56e-05)	(0.000476)	(0.00681)	(0.123)	(0.127)
GDP Growth	0.00626	-0.00574	0.00649	-0.00439	0.00210	0.0750	-0.0162	0.0588
	(0.00702)	(0.0119)	(0.00679)	(0.0124)	(0.0140)	(0.109)	(2.239)	(2.313)
FDI	0.000352	-0.00148	0.000452	-0.00221	-0.00176	0.000919	-0.0115	-0.0106
	(0.00245)	(0.0107)	(0.00243)	(0.0112)	(0.0122)	(0.0797)	(2.347)	(2.419)
Democracy index	-0.0366**		-0.0369*	-0.00207	-0.0390*	-0.454	-0.281	-0.735
	(0.0186)		(0.0189)	(0.00173)	(0.0202)	(0.377)	(10.05)	(10.34)
Control of corruption	0.0956		0.0943	0.00369	0.0980	1.087	-0.484	0.603
	(0.205)		(0.200)	(0.0109)	(0.209)	(2.601)	(29.70)	(30.92)
Population density	-0.00689***		-0.00673***	-0.000369	-0.00710***	-0.0824	-0.0541	-0.136
	(0.00230)		(0.00227)	(0.000266)	(0.00246)	(0.0514)	(1.510)	(1.552)
Openness to trade	0.00106		0.00118	4.96e-05	0.00123	0.0134	-0.0162	-0.00284
	(0.00163)		(0.00162)	(9.65e-05)	(0.00169)	(0.0219)	(0.400)	(0.411)
Forest rent	0.0117		0.0121	0.000572	0.0126	0.145	0.0375	0.182
	(0.0146)		(0.0137)	(0.000846)	(0.0143)	(0.188)	(3.318)	(3.410)
ρ	0.0485*							
	(0.0254)							
σ_e^2	0.487***							
	(0.0572)							
# Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-576.3	-576.3	-576.3	-576.3	-576.3	-576.3	-576.3	-576.3

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral resource rents are used as weighting matrix.

Table 3.A10: Robustness: Strategic interaction with mineral rents weighting

	Dependent variable de facto environmental policy							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.De facto environmental policy	0.923***							
	(0.0322)							
Mineral resource rents	-0.00629	0.0220**	-0.00596	0.0246**	0.0187	-0.0893	-0.0982	-0.188
	(0.00453)	(0.00940)	(0.00437)	(0.0114)	(0.0126)	(0.641)	(1.243)	(1.086)
Temperature shocks	-0.00620		-0.00542	-0.000912	-0.00633	-0.0703	0.148	0.0775
	(0.00767)		(0.00741)	(0.00142)	(0.00873)	(0.597)	(0.796)	(0.543)
Precipitation shocks	0.000262		0.000265	4.94e-05	0.000314	0.000820	-0.00734	-0.00652
	(0.000175)		(0.000174)	(3.88e-05)	(0.000209)	(0.0485)	(0.0863)	(0.0732)
GDP Growth	-0.00895**	-0.00207	-0.00911**	-0.00393	-0.0130*	-0.0630	0.242	0.179
	(0.00412)	(0.00500)	(0.00380)	(0.00606)	(0.00717)	(1.122)	(1.495)	(1.007)
FDI	-0.00661***	-3.49e-05	-0.00657***	-0.00124	-0.00781	0.00780	0.0827	0.0905
	(0.00212)	(0.00538)	(0.00210)	(0.00648)	(0.00741)	(1.817)	(1.912)	(0.621)
Democracy index	0.0160***		0.0161***	0.00316*	0.0193**	0.0499	-0.394	-0.345
	(0.00589)		(0.00601)	(0.00191)	(0.00777)	(3.010)	(4.074)	(2.818)
Control of corruption	0.00161		-0.00130	-0.000103	-0.00140	0.531	-1.088	-0.557
	(0.0832)		(0.0817)	(0.0152)	(0.0963)	(8.656)	(15.24)	(12.76)
Population density	0.000246		0.000318	6.89e-05	0.000387	0.00841	-0.0116	-0.00319
	(0.000812)		(0.000819)	(0.000161)	(0.000973)	(0.115)	(0.126)	(0.0524)
Openness to trade	-0.00376***		-0.00374***	-0.000675***	-0.00441***	-0.0105	0.0840	0.0735
	(0.000807)		(0.000804)	(0.000247)	(0.000942)	(0.693)	(0.881)	(0.559)
Forest rent	0.0102		0.0104	0.00194	0.0123	0.0605	-0.265	-0.204
	(0.00695)		(0.00637)	(0.00143)	(0.00765)	(1.299)	(1.994)	(1.547)
ρ	0.155***							
	(0.0432)							
σ_e^2	0.100***							
	(0.0123)							
# Observations	560	560	560	560	560	560	560	560
Number countries	35	35	35	35	35	35	35	35
Log likelihood	-134.9	-134.9	-134.9	-134.9	-134.9	-134.9	-134.9	-134.9

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral resource rents are used as weighting matrix.

Table 3.A11: Robustness: Race with population matrix, δ_0

	Dependent variable de jure environmental policy							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.De jure environmental policy	0.928***							
	(0.0223)							
Mineral resource rents	-0.0144**	-0.0522***	-0.0153**	-0.0535***	-0.0688***	-0.389	-0.701	-1.091
	(0.00610)	(0.0192)	(0.00616)	(0.0197)	(0.0219)	(1.888)	(23.09)	(24.40)
Temperature shocks	0.0668**		0.0698**	0.00448	0.0743**	1.254	-0.152	1.102
	(0.0323)		(0.0313)	(0.00482)	(0.0345)	(3.385)	(24.65)	(25.86)
Precipitation shocks	5.99e-05		5.61e-05	4.51e-06	6.06e-05	0.00107	0.00547	0.00654
	(0.000361)		(0.000361)	(2.82e-05)	(0.000381)	(0.0113)	(0.0898)	(0.0945)
GDP Growth	0.00395	0.00332	0.00432	0.00435	0.00867	0.0928	-0.121	-0.0280
	(0.00437)	(0.00723)	(0.00430)	(0.00762)	(0.00864)	(0.456)	(3.985)	(4.192)
FDI	-0.00728	0.0217	-0.00680	0.0209	0.0141	-0.0729	-0.136	-0.209
	(0.00853)	(0.0201)	(0.00843)	(0.0216)	(0.0244)	(0.772)	(9.473)	(10.00)
Democracy index	-0.0344*		-0.0357*	-0.00248	-0.0382*	-0.644	-0.0606	-0.705
	(0.0193)		(0.0199)	(0.00282)	(0.0219)	(1.505)	(12.09)	(12.70)
Control of corruption	0.219		0.224*	0.0111	0.235*	3.734	2.411	6.145
	(0.135)		(0.129)	(0.0146)	(0.135)	(7.335)	(88.57)	(93.72)
Population density	-0.00351*		-0.00354**	-0.000232	-0.00377*	-0.0599	-0.00781	-0.0678
	(0.00180)		(0.00176)	(0.000252)	(0.00193)	(0.119)	(1.163)	(1.227)
Openness to trade	0.00281		0.00307	0.000143	0.00321	0.0534	0.0681	0.121
	(0.00330)		(0.00318)	(0.000286)	(0.00334)	(0.136)	(1.137)	(1.199)
Forest rent	0.0176		0.0176	0.00115	0.0188	0.343	-0.156	0.186
	(0.0135)		(0.0127)	(0.00150)	(0.0137)	(1.131)	(7.436)	(7.766)
rho	0.0526							
	(0.0462)							
sigma2_e	0.303***							
	(0.0553)							
Observations	288	288	288	288	288	288	288	288
Number countries	18	18	18	18	18	18	18	18
Log likelihood	-227.9	-227.9	-227.9	-227.9	-227.9	-227.9	-227.9	-227.9

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Population is used as weighting matrix.

Table 3.A12: Robustness: Race with population matrix, δ_1

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De jure environmental policy	0.944***							
	(0.0420)							
Mineral resource rents	-0.0225	-0.152*	-0.0275	-0.177*	-0.205*	1.187	1.319	2.506
	(0.0204)	(0.0798)	(0.0209)	(0.0948)	(0.106)	(14.47)	(15.83)	(7.111)
Temperature shocks	0.0858***		0.0886***	0.0145**	0.103***	0.290	-1.472	-1.182
	(0.0247)		(0.0239)	(0.00630)	(0.0293)	(11.70)	(11.87)	(2.138)
Precipitation shocks	0.00192*		0.00193*	0.000329	0.00226*	0.0115	-0.0356	-0.0241
	(0.00110)		(0.00109)	(0.000231)	(0.00131)	(0.303)	(0.305)	(0.0321)
GDP Growth	-0.0154	0.0545**	-0.0140	0.0606***	0.0466*	-0.663	0.144	-0.519
	(0.0207)	(0.0217)	(0.0201)	(0.0229)	(0.0267)	(4.463)	(4.659)	(1.548)
FDI	-0.00548	0.00791	-0.00511	0.00783	0.00272	-0.0954	0.0557	-0.0397
	(0.00368)	(0.00800)	(0.00384)	(0.00937)	(0.0120)	(0.718)	(0.760)	(0.252)
Democracy index	-0.0706***		-0.0715***	-0.0120*	-0.0835***	-0.0335	0.931	0.897
	(0.0238)		(0.0242)	(0.00622)	(0.0299)	(8.709)	(8.794)	(1.463)
Control of corruption	1.203**		1.173**	0.186*	1.358**	6.508	-23.65	-17.14
	(0.520)		(0.524)	(0.0968)	(0.606)	(228.3)	(231.2)	(33.79)
Population density	-0.0416***		-0.0415***	-0.00664***	-0.0481***	-0.137	0.722	0.585
	(0.00911)		(0.00921)	(0.00256)	(0.0111)	(5.732)	(5.902)	(1.477)
Openness to trade	0.00314		0.00330	0.000498	0.00380	0.0193	-0.0703	-0.0510
	(0.00227)		(0.00221)	(0.000358)	(0.00253)	(0.696)	(0.708)	(0.140)
Forest rent	0.0764***		0.0774***	0.0124**	0.0897***	-0.102	-0.934	-1.037
	(0.0293)		(0.0286)	(0.00592)	(0.0335)	(10.72)	(10.98)	(2.848)
rho	0.141***							
	(0.0336)							
sigma2_e	0.655***							
	(0.0800)							
Observations	272	272	272	272	272	272	272	272
Number countries	17	17	17	17	17	17	17	17
Log likelihood	-315.6	-315.6	-315.6	-315.6	-315.6	-315.6	-315.6	-315.6

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3.A13: Robustness: Race with GDP per capita matrix, δ_0

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.de jure environmental policy	0.938***							
	(0.0155)							
Mineral rents	-0.00993	-0.0483*	-0.0102	-0.0477*	-0.0579**	-0.205	-0.709	-0.914
	(0.0101)	(0.0247)	(0.00997)	(0.0259)	(0.0258)	(1.891)	(24.50)	(26.25)
Temperature shocks	0.0553*		0.0588*	-0.000166	0.0586*	1.309	-0.121	1.188
	(0.0323)		(0.0312)	(0.00347)	(0.0315)	(6.299)	(23.52)	(24.33)
Precipitation shocks	0.000305		0.000312	-4.24e-06	0.000307	0.00896	0.000671	0.00963
	(0.000249)		(0.000253)	(2.14e-05)	(0.000249)	(0.0733)	(0.173)	(0.168)
GDP growth	0.00202	-0.0227***	0.00216	-0.0226***	-0.0204***	0.129	-0.586	-0.457
	(0.00317)	(0.00699)	(0.00313)	(0.00681)	(0.00684)	(2.016)	(6.868)	(7.060)
FDI	-0.0167***	0.0435	-0.0166***	0.0429	0.0263	-0.394	0.112	-0.282
	(0.00466)	(0.0324)	(0.00492)	(0.0329)	(0.0341)	(1.207)	(7.887)	(8.352)
Democracy index	-0.00776		-0.00949	-0.000277	-0.00976	-0.324	0.0150	-0.309
	(0.0236)		(0.0235)	(0.00129)	(0.0235)	(3.237)	(6.052)	(5.525)
Control of Corruption	0.152		0.157	0.00123	0.158	5.277	0.720	5.997
	(0.175)		(0.172)	(0.0123)	(0.174)	(50.05)	(98.07)	(90.74)
Population density	-9.16e-05		-0.000162	-3.40e-05	-0.000196	-0.0181	-0.00281	-0.0209
	(0.00262)		(0.00260)	(0.000137)	(0.00259)	(0.309)	(0.462)	(0.374)
trade	0.00317		0.00317	-6.61e-05	0.00310	0.122	0.0373	0.159
	(0.00355)		(0.00363)	(0.000249)	(0.00358)	(1.274)	(2.252)	(1.996)
Forest rents	0.0198		0.0200	-9.76e-05	0.0199	0.378	0.171	0.549
	(0.0150)		(0.0145)	(0.00128)	(0.0145)	(0.961)	(11.17)	(11.97)
rho	0.0102							
	(0.0552)							
sigma2_e	0.242***							
	(0.0594)							
Observations	240	240	240	240	240	240	240	240
Number of countries	15	15	15	15	15	15	15	15
Log likelihood	-162.8	-162.8	-162.8	-162.8	-162.8	-162.8	-162.8	-162.8

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A14: Robustness: Race with GDP per capita matrix, δ_1

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De jure environmental policy	0.906***							
	(0.0235)							
Mineral resource rents	-0.00448	-0.0611***	-0.00652	-0.0668***	-0.0734***	-0.551	-0.377	-0.928
	(0.00660)	(0.0208)	(0.00659)	(0.0243)	(0.0261)	(5.918)	(21.64)	(21.86)
Temperature shocks	0.103***		0.106***	0.0130**	0.119***	1.932	0.775	2.707
	(0.0242)		(0.0236)	(0.00653)	(0.0286)	(12.99)	(41.63)	(41.63)
Precipitation shocks	0.00190**		0.00192**	0.000234	0.00215**	0.0309	0.00492	0.0359
	(0.000947)		(0.000942)	(0.000155)	(0.00107)	(0.217)	(0.784)	(0.795)
GDP Growth	0.00439	0.0125	0.00506	0.0166	0.0216	0.341	0.733	1.074
	(0.0137)	(0.0161)	(0.0134)	(0.0180)	(0.0264)	(3.049)	(16.29)	(16.86)
FDI	-0.00182	0.0118	-0.00141	0.0124	0.0110	0.0477	-0.0998	-0.0520
	(0.00298)	(0.00958)	(0.00281)	(0.0102)	(0.00934)	(0.813)	(4.006)	(4.126)
Democracy index	-0.0488**		-0.0491**	-0.00628	-0.0553**	-1.034	0.134	-0.900
	(0.0232)		(0.0238)	(0.00444)	(0.0276)	(5.592)	(19.41)	(19.51)
Control of corruption	1.090***		1.064***	0.132*	1.197***	19.60	-0.273	19.32
	(0.388)		(0.375)	(0.0788)	(0.438)	(125.5)	(364.9)	(359.7)
Population density	-0.0293***		-0.0290***	-0.00354*	-0.0325***	-0.508	-0.207	-0.715
	(0.00775)		(0.00758)	(0.00183)	(0.00893)	(3.592)	(10.87)	(10.82)
Openness to trade	0.000676		0.000673	8.57e-05	0.000758	0.00472	-0.0192	-0.0145
	(0.00188)		(0.00195)	(0.000255)	(0.00219)	(0.218)	(0.907)	(0.933)
Forest rents	0.0438**		0.0428**	0.00528	0.0481**	0.772	-0.105	0.667
	(0.0214)		(0.0212)	(0.00360)	(0.0242)	(5.743)	(16.98)	(16.82)
rho	0.110***							
	(0.0373)							
sigma2_e	0.637***							
	(0.0704)							
Observations	320	320	320	320	320	320	320	320
Number countries	20	20	20	20	20	20	20	20
Log likelihood	-367.7	-367.7	-367.7	-367.7	-367.7	-367.7	-367.7	-367.7

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A15: Robustness: Race with mining rents matrix, δ_0

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De jure environmental policy	0.960***							
	(0.0179)							
Mineral resource rents	-0.0285***	-0.0760***	-0.0298***	-0.0815***	-0.111***	-0.782	4.437	3.655
	(0.0106)	(0.0242)	(0.0106)	(0.0280)	(0.0320)	(10.32)	(43.12)	(44.18)
Temperature shocks	0.0773**		0.0798**	0.00499	0.0848**	2.178	-4.110	-1.932
	(0.0339)		(0.0334)	(0.00488)	(0.0364)	(15.15)	(31.67)	(29.30)
Precipitation shocks	0.000615		0.000616	4.09e-05	0.000657	0.0141	-0.0190	-0.00495
	(0.000487)		(0.000481)	(4.87e-05)	(0.000516)	(0.111)	(0.199)	(0.173)
GDP Growth	0.00536	-0.00354	0.00526	-0.00211	0.00315	0.177	-0.279	-0.102
	(0.00448)	(0.0115)	(0.00424)	(0.0125)	(0.0135)	(1.751)	(3.463)	(3.136)
FDI	-0.00712	0.0252	-0.00664	0.0269	0.0202	-0.246	-0.00638	-0.252
	(0.00984)	(0.0215)	(0.00953)	(0.0225)	(0.0266)	(2.675)	(5.100)	(4.661)
Democracy index	-0.0363*		-0.0365*	-0.00262	-0.0391*	-0.898	2.596	1.698
	(0.0215)		(0.0215)	(0.00278)	(0.0236)	(6.365)	(20.02)	(19.99)
Control of corruption	0.224		0.220	0.0143	0.234	5.851	-18.31	-12.46
	(0.189)		(0.175)	(0.0186)	(0.187)	(46.13)	(157.5)	(158.4)
Population density	-0.00552**		-0.00556**	-0.000395	-0.00596**	-0.150	0.373	0.223
	(0.00237)		(0.00239)	(0.000379)	(0.00270)	(0.965)	(2.920)	(2.904)
Openness to trade	0.00549		0.00567	0.000323	0.00599	0.117	-0.313	-0.197
	(0.00390)		(0.00383)	(0.000388)	(0.00405)	(0.661)	(2.970)	(3.055)
Forest rent	0.0115		0.0105	0.000531	0.0110	0.229	-0.684	-0.455
	(0.0160)		(0.0148)	(0.00113)	(0.0155)	(2.108)	(4.897)	(4.630)
rho	0.0540							
	(0.0405)							
sigma2_e	0.396***							
	(0.0633)							
Observations	304	304	304	304	304	304	304	304
Number countries	19	19	19	19	19	19	19	19
Log likelihood	-281.5	-281.5	-281.5	-281.5	-281.5	-281.5	-281.5	-281.5

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral rents are used as weighting matrix.

Table 3.A16: Robustness: Race with mining rents matrix, δ_1

	Dependent variable de jure environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De jure environmental policy	0.885***							
	(0.0211)							
Mineral resource rents	-0.00185	-0.0221	-0.00262	-0.0252	-0.0278	-0.0932	0.108	0.0150
	(0.00886)	(0.0201)	(0.00877)	(0.0234)	(0.0286)	(1.584)	(19.32)	(20.58)
Temperature shocks	0.0783***		0.0801***	0.0121*	0.0922***	0.545	1.119	1.664
	(0.0247)		(0.0246)	(0.00651)	(0.0305)	(8.064)	(62.32)	(66.08)
Precipitation shocks	0.00115		0.00117	0.000177	0.00134	0.00463	0.0218	0.0265
	(0.000852)		(0.000850)	(0.000149)	(0.000988)	(0.180)	(0.887)	(0.928)
GDP Growth	-0.00910	0.0176	-0.00854	0.0189	0.0103	-0.120	-1.140	-1.260
	(0.0149)	(0.0270)	(0.0147)	(0.0300)	(0.0360)	(1.763)	(24.91)	(26.57)
FDI	-0.00403	0.00862	-0.00374	0.00895	0.00521	-0.000293	0.358	0.357
	(0.00312)	(0.00815)	(0.00322)	(0.00888)	(0.0108)	(0.498)	(7.331)	(7.818)
Democracy index	-0.0328**		-0.0333**	-0.00526	-0.0385**	-0.209	0.237	0.0275
	(0.0151)		(0.0159)	(0.00360)	(0.0193)	(2.640)	(21.05)	(22.33)
Control of corruption	1.082**		1.059**	0.150*	1.210**	11.61	22.53	34.14
	(0.425)		(0.426)	(0.0787)	(0.488)	(65.84)	(961.7)	(1,026)
Population density	-0.0370***		-0.0368***	-0.00541**	-0.0423***	-0.288	-0.382	-0.670
	(0.00464)		(0.00465)	(0.00227)	(0.00674)	(2.781)	(25.46)	(27.06)
Openness to trade	9.95e-05		0.000133	-8.10e-06	0.000125	0.0141	0.0611	0.0752
	(0.00274)		(0.00270)	(0.000398)	(0.00308)	(0.178)	(1.930)	(2.054)
Forest rent	0.0412		0.0401	0.00569	0.0458	0.279	-0.292	-0.0121
	(0.0344)		(0.0344)	(0.00540)	(0.0393)	(2.666)	(21.45)	(22.75)
rho	0.127***							
	(0.0361)							
sigma2_e	0.577***							
	(0.0924)							
Observations	256	256	256	256	256	256	256	256
Number countries	16	16	16	16	16	16	16	16
Log likelihood	-281.0	-281.0	-281.0	-281.0	-281.0	-281.0	-281.0	-281.0

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral rents are used as weighting matrix.

Table 3.A17: Robustness: Race with population matrix, de facto policy δ_0

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.914***							
	(0.0489)							
Mineral resource rents	-0.00154	0.0125	-0.00119	0.0142	0.0130	-0.239	0.0111	-0.228
	(0.00488)	(0.00897)	(0.00480)	(0.00997)	(0.0120)	(2.784)	(2.873)	(0.799)
GDP Growth	-0.0124	-0.0127**	-0.0122	-0.0161***	-0.0283***	0.151	0.383	0.534
	(0.00791)	(0.00521)	(0.00772)	(0.00614)	(0.0106)	(5.121)	(5.286)	(1.360)
FDI	-0.000319	0.000807	-0.00105	0.00142	0.000372	-0.153	0.151	-0.00204
	(0.00760)	(0.00491)	(0.00734)	(0.00511)	(0.00834)	(2.976)	(3.095)	(0.938)
Democracy index	0.0174*		0.0172*	0.00275	0.0200*	-0.0634	-0.341	-0.405
	(0.0102)		(0.0101)	(0.00171)	(0.0117)	(4.032)	(4.286)	(1.488)
Control of corruption	0.0691		0.0754	0.0125	0.0878	-1.117	-0.980	-2.097
	(0.0769)		(0.0780)	(0.0138)	(0.0912)	(16.55)	(17.51)	(5.772)
Population density	-0.00154*		-0.00155*	-0.000252	-0.00180*	0.0182	0.0170	0.0352
	(0.000915)		(0.000939)	(0.000169)	(0.00109)	(0.468)	(0.492)	(0.162)
Openness to trade	-0.00661**		-0.00668**	-0.00112*	-0.00780**	0.0767	0.0597	0.136
	(0.00290)		(0.00288)	(0.000603)	(0.00343)	(2.060)	(2.102)	(0.447)
rho	0.143***							
	(0.0290)							
sigma2_e	0.102***							
	(0.0179)							
Observations	256	256	256	256	256	256	256	256
Number countries	16	16	16	16	16	16	16	16
Log likelihood	-63.50	-63.50	-63.50	-63.50	-63.50	-63.50	-63.50	-63.50

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Population is used as weighting matrix.

Table 3.A18: Robustness: Race with population matrix, de facto policy δ_0

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.837***							
	(0.0397)							
Mineral resource rents	-0.0127	-0.0141	-0.0135	-0.0173	-0.0308	-0.135	-0.112	-0.247
	(0.0121)	(0.0208)	(0.0116)	(0.0232)	(0.0263)	(0.719)	(6.647)	(6.974)
GDP Growth	-0.00326	-0.000654	-0.00285	-0.000499	-0.00335	-0.00839	0.00536	-0.00303
	(0.00456)	(0.00824)	(0.00436)	(0.00901)	(0.00962)	(0.265)	(0.948)	(0.958)
FDI	-0.00598***	-0.00793**	-0.00616***	-0.00934**	-0.0155***	-0.0548	-0.0641	-0.119
	(0.00180)	(0.00388)	(0.00185)	(0.00465)	(0.00543)	(0.176)	(2.098)	(2.209)
Democracy index	0.0121		0.0122	0.00203	0.0143	0.0993	-0.0331	0.0662
	(0.00767)		(0.00764)	(0.00202)	(0.00937)	(0.431)	(3.177)	(3.322)
Control of corruption	-0.0356		-0.0290	-0.00155	-0.0306	-0.266	-0.0787	-0.345
	(0.161)		(0.156)	(0.0247)	(0.177)	(2.922)	(25.53)	(26.71)
Population density	0.000871		0.00114	0.000313	0.00145	0.0100	0.0183	0.0283
	(0.00391)		(0.00413)	(0.000742)	(0.00478)	(0.0844)	(0.949)	(1.000)
Openness to trade	-0.00360***		-0.00364***	-0.000525	-0.00417***	-0.0285	-0.000839	-0.0294
	(0.000707)		(0.000676)	(0.000341)	(0.000912)	(0.0806)	(0.657)	(0.688)
rho	0.117*							
	(0.0621)							
sigma2_e	0.0939***							
	(0.0134)							
Observations	304	304	304	304	304	304	304	304
Number countries	19	19	19	19	19	19	19	19
Log likelihood	-63.05	-63.05	-63.05	-63.05	-63.05	-63.05	-63.05	-63.05

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Population is used as weighting matrix.

Table 3.A19: Robustness: Race with GDP per capita matrix, de facto policy δ_0

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.927***							
	(0.0520)							
Mineral resource rents	0.00261	0.00121	0.00237	0.00156	0.00392	0.0212	-0.0864	-0.0651
	(0.00603)	(0.00626)	(0.00586)	(0.00685)	(0.00962)	(0.433)	(1.070)	(1.030)
Temperature shocks	-0.00263		-0.00151	-0.000169	-0.00168	-0.0294	-0.0197	-0.0491
	(0.00990)		(0.00954)	(0.00134)	(0.0107)	(0.871)	(1.991)	(1.891)
Precipitation shocks	-4.47e-05		-4.12e-05	2.99e-06	-3.82e-05	0.00199	-0.00801	-0.00601
	(0.000457)		(0.000465)	(6.12e-05)	(0.000520)	(0.0391)	(0.115)	(0.115)
GDP Growth	-0.0135*	0.00805	-0.0135*	0.00765	-0.00586	-0.174	0.291	0.117
	(0.00760)	(0.00871)	(0.00697)	(0.00983)	(0.0124)	(0.989)	(2.103)	(1.980)
FDI	-0.00155	0.00685	-0.00126	0.00740	0.00614	-0.00948	-0.0740	-0.0835
	(0.00649)	(0.00447)	(0.00649)	(0.00505)	(0.00901)	(0.678)	(1.386)	(1.272)
Democracy index	0.0197*		0.0200**	0.00236	0.0223**	0.359	-0.405	-0.0461
	(0.0102)		(0.0101)	(0.00177)	(0.0113)	(1.963)	(4.998)	(4.873)
Control of corruption	0.0332		0.0293	0.00156	0.0308	1.051	-0.115	0.936
	(0.0879)		(0.0783)	(0.0102)	(0.0871)	(6.459)	(15.15)	(14.32)
Population density	-0.000278		-0.000218	6.92e-06	-0.000211	-0.00595	0.00190	-0.00405
	(0.00102)		(0.000975)	(0.000130)	(0.00108)	(0.0416)	(0.170)	(0.174)
Openness to trade	-0.00604**		-0.00603***	-0.000747	-0.00678**	-0.0931	0.127	0.0336
	(0.00241)		(0.00229)	(0.000527)	(0.00268)	(0.582)	(1.267)	(1.195)
Forest rent	0.00930		0.00933	0.00138	0.0107	0.106	-0.340	-0.235
	(0.00840)		(0.00826)	(0.00153)	(0.00958)	(1.029)	(1.908)	(1.691)
rho	0.106**							
	(0.0521)							
sigma2_e	0.0996***							
	(0.0178)							
Observations	272	272	272	272	272	272	272	272
Number countries	17	17	17	17	17	17	17	17
Log likelihood	-63.59	-63.59	-63.59	-63.59	-63.59	-63.59	-63.59	-63.59

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A20: Robustness: Race with GDP per capita matrix, de facto policy δ_1

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.847***							
	(0.0498)							
Mineral resource rents	-0.0149	-0.00210	-0.0152	-0.00296	-0.0181	-0.243	-0.00686	-0.250
	(0.0124)	(0.0228)	(0.0121)	(0.0248)	(0.0268)	(2.846)	(3.335)	(1.787)
Temperature shocks	-0.00852		-0.00762	-0.000701	-0.00832	-0.192	0.0592	-0.132
	(0.0107)		(0.0104)	(0.00112)	(0.0114)	(3.026)	(3.080)	(0.462)
Precipitation shocks	0.000372*		0.000373*	3.09e-05	0.000403*	0.00876	-0.00323	0.00553
	(0.000200)		(0.000192)	(2.69e-05)	(0.000210)	(0.134)	(0.136)	(0.0163)
GDP Growth	-0.00147	0.00850	-0.00119	0.0103	0.00914	0.103	0.0521	0.155
	(0.00671)	(0.00989)	(0.00656)	(0.0111)	(0.0138)	(2.166)	(2.359)	(0.936)
FDI	-0.00604***	-0.00140	-0.00594***	-0.00203	-0.00797*	-0.0700	-0.0290	-0.0991
	(0.00193)	(0.00359)	(0.00190)	(0.00363)	(0.00431)	(0.596)	(0.672)	(0.313)
Democracy index	0.0104		0.0103	0.000999	0.0113	0.281	-0.127	0.154
	(0.0102)		(0.0105)	(0.00131)	(0.0116)	(4.590)	(4.699)	(0.890)
Control of corruption	-0.0606		-0.0617	-0.00485	-0.0666	-1.785	0.877	-0.908
	(0.167)		(0.171)	(0.0169)	(0.186)	(29.21)	(30.52)	(8.993)
Population density	0.000935		0.00120	0.000192	0.00139	0.0215	0.00855	0.0301
	(0.00356)		(0.00346)	(0.000389)	(0.00379)	(0.233)	(0.345)	(0.271)
Openness to trade	-0.00355***		-0.00349***	-0.000281	-0.00377***	-0.0482	-0.000502	-0.0487
	(0.000737)		(0.000747)	(0.000180)	(0.000805)	(0.513)	(0.544)	(0.173)
Forest rent	0.0279		0.0286	0.00279	0.0314	0.736	-0.199	0.537
	(0.0267)		(0.0286)	(0.00357)	(0.0316)	(11.51)	(11.74)	(1.894)
rho	0.0739*							
	(0.0437)							
sigma2_e	0.0965***							
	(0.0154)							
Observations	288	288	288	288	288	288	288	288
Number countries	18	18	18	18	18	18	18	18
Log likelihood	-63.31	-63.31	-63.31	-63.31	-63.31	-63.31	-63.31	-63.31

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. GDP per capita is used as weighting matrix.

Table 3.A21: Robustness: Race with mining rents matrix, de facto policy δ_0

	Dependent variable de facto environmental policy							
	(1) Main	(2) Wx	(3) SR direct	(4) SR indirect	(5) SR total	(6) LR direct	(7) LR indirect	(8) LR total
L.De facto environmental policy	0.881***							
	(0.0461)							
Mineral resource rents	-0.000613	-0.00810	-0.00105	-0.00972	-0.0108	0.0936	0.232	0.326
	(0.00556)	(0.0110)	(0.00537)	(0.0120)	(0.0135)	(1.959)	(8.477)	(8.712)
Temperature shocks	-0.00710		-0.00594	-0.000926	-0.00687	-0.155	0.431	0.276
	(0.0106)		(0.0102)	(0.00156)	(0.0116)	(2.720)	(4.001)	(3.112)
Precipitation shocks	0.000262		0.000270	3.85e-05	0.000308	0.000419	-0.0130	-0.0126
	(0.000387)		(0.000394)	(5.81e-05)	(0.000448)	(0.0324)	(0.201)	(0.209)
GDP Growth	-0.0124*	0.00762	-0.0124**	0.00717	-0.00520	0.0343	-0.148	-0.114
	(0.00646)	(0.00725)	(0.00593)	(0.00834)	(0.0110)	(2.988)	(5.761)	(5.215)
FDI	-0.00338	-0.00537*	-0.00356	-0.00627**	-0.00983**	0.0783	0.142	0.221
	(0.00256)	(0.00275)	(0.00244)	(0.00301)	(0.00405)	(2.307)	(3.876)	(3.292)
Democracy index	0.0175		0.0177	0.00237	0.0201	-0.140	-0.198	-0.338
	(0.0113)		(0.0114)	(0.00191)	(0.0130)	(6.161)	(10.24)	(8.646)
Control of corruption	0.157		0.154*	0.0211	0.175*	-2.043	-0.813	-2.856
	(0.0968)		(0.0910)	(0.0162)	(0.105)	(71.72)	(85.19)	(48.85)
Population density	-0.000246		-0.000231	-1.46e-05	-0.000246	0.00796	-0.0355	-0.0275
	(0.00101)		(0.000969)	(0.000127)	(0.00109)	(0.268)	(0.412)	(0.332)
Openness to trade	-0.00314***		-0.00313***	-0.000385***	-0.00351***	-0.00279	0.0565	0.0537
	(0.000674)		(0.000671)	(0.000148)	(0.000714)	(0.489)	(1.165)	(1.117)
Forest rent	0.00671		0.00671	0.000972	0.00768	0.0611	-0.631	-0.570
	(0.00837)		(0.00813)	(0.00124)	(0.00928)	(0.939)	(6.312)	(6.590)
rho	0.118***							
	(0.0385)							
sigma2_e	0.105***							
	(0.0159)							
Observations	304	304	304	304	304	304	304	304
Number countries	19	19	19	19	19	19	19	19
Log likelihood	-79.07	-79.07	-79.07	-79.07	-79.07	-79.07	-79.07	-79.07

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral is used as weighting matrix.

Table 3.A22: Robustness: Race with mining rents matrix, de facto policy δ_1

	Dependent variable de facto environmental policy							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Main	Wx	SR direct	SR indirect	SR total	LR direct	LR indirect	LR total
L.De facto environmental policy	0.838***							
	(0.0340)							
Mineral resource rents	-0.0100	0.0471	-0.0102	0.0483	0.0381	-0.0590	0.354	0.295
	(0.0202)	(0.0355)	(0.0198)	(0.0353)	(0.0316)	(0.134)	(0.298)	(0.312)
Temperature shocks	-0.00895		-0.00807	-5.98e-05	-0.00813	-0.0515	-0.00942	-0.0609
	(0.00928)		(0.00911)	(0.000648)	(0.00924)	(0.0583)	(0.0530)	(0.0895)
Precipitation shocks	0.000196		-0.000587	4.70e-05	-0.000540	-0.00385	-0.00163	-0.00549
	(0.000192)		(0.0277)	(0.00145)	(0.0279)	(0.176)	(0.103)	(0.230)
GDP Growth	-0.00163	-0.00543	-0.00122	-0.00515	-0.00637	-0.00837	-0.0392	-0.0476
	(0.00510)	(0.00563)	(0.0105)	(0.00883)	(0.00988)	(0.0670)	(0.0707)	(0.0847)
FDI	-0.0252***	-0.00343	-0.0250***	-0.00330	-0.0283**	-0.160***	-0.0576	-0.218
	(0.00634)	(0.00836)	(0.00620)	(0.0103)	(0.0130)	(0.0435)	(0.166)	(0.192)
Democracy index	0.00278		0.00245	8.58e-05	0.00254	0.0155	0.00602	0.0215
	(0.00745)		(0.00783)	(0.000394)	(0.00790)	(0.0497)	(0.0273)	(0.0630)
Control of corruption	-0.106		-0.108	0.00108	-0.107	-0.683	-0.0112	-0.695
	(0.127)		(0.121)	(0.00798)	(0.120)	(0.766)	(0.505)	(0.959)
Population density	-0.00368		-0.00323	4.07e-05	-0.00319	-0.0204	0.000440	-0.0200
	(0.00568)		(0.00586)	(0.000304)	(0.00586)	(0.0370)	(0.0175)	(0.0431)
Openness to trade	-0.00302		-0.00305	-4.02e-05	-0.00309	-0.0194	-0.00439	-0.0237
	(0.00199)		(0.00230)	(0.000202)	(0.00236)	(0.0149)	(0.0186)	(0.0276)
Forest rent	0.00282		0.00358	0.000127	0.00370	0.0225	0.00806	0.0305
	(0.0180)		(0.0182)	(0.000948)	(0.0183)	(0.116)	(0.0614)	(0.144)
rho	0.00244							
	(0.0471)							
sigma2_e	0.0833***							
	(0.0145)							
Observations	256	256	256	256	256	256	256	256
Number countries	16	16	16	16	16	16	16	16
Log likelihood	-37.40	-37.40	-37.40	-37.40	-37.40	-37.40	-37.40	-37.40

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Mineral rents is the weighting matrix.

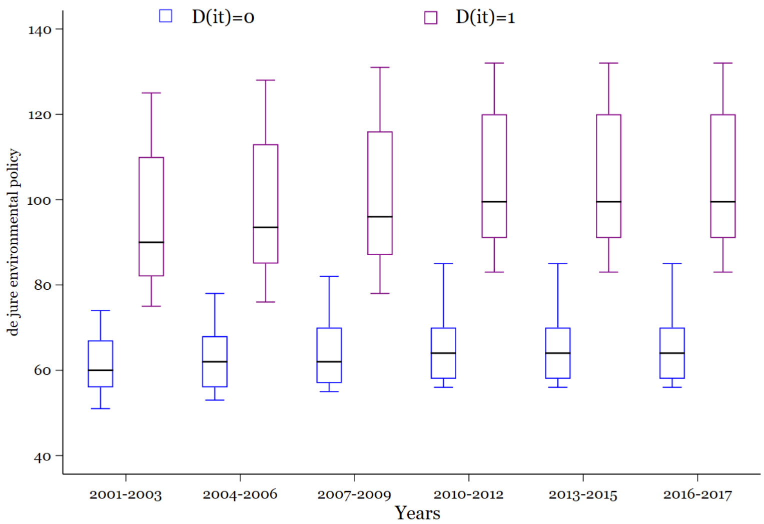

Figure 3.A1: Box plots of *de jure* environmental policy according to $D_{it} = 0$ and $D_{it} = 1$

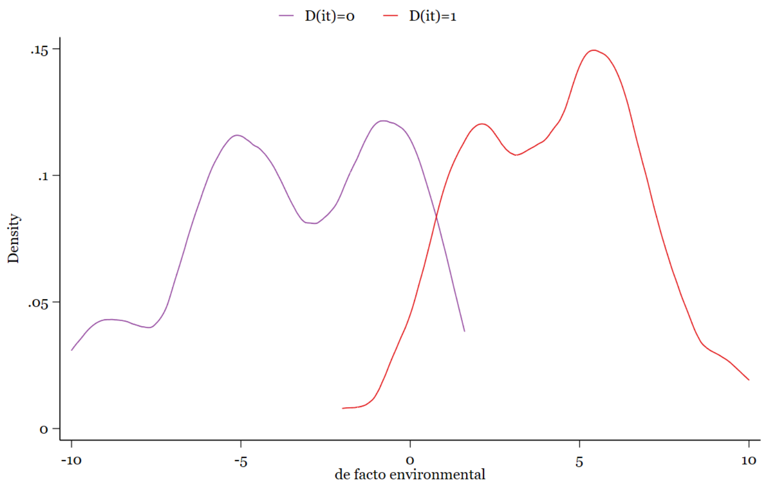

Figure 3.A2: Kernel density estimate of *de facto* environmental policy according to $D_{it} = 0$ and $D_{it} = 1$

Chapter 4

A Spatial Analysis of Mining and Deforestation: Evidence from Africa

[1]

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4.1 Introduction

Forest is the most important "natural brake" to climate change (Gibbs et al., 2007; Malhi et al., 2002). It stores 30% of current total carbon emissions from fossil fuels and industry (IPCC, 2001).[2] When a forest is destroyed or degraded, an important store of carbon dioxide is released into the atmosphere. According to Lawrence and Vandecar (2015) "completely deforesting the tropics could result in global warming equivalent to that caused by burning of fossil fuels since 1850". In Africa for instance, deforestation causes about 70% of total greenhouse gas emissions (Gibbs et al., 2007). Yet, forests are under threat of human activities in many countries worldwide.

A rich and fast-growing literature exists on the drivers of deforestation both at cross-country level (Combes et al., 2018; Culas, 2007; Damette and Delacote, 2012; Hosonuma et al., 2012; Kinda and Thiombiano, 2021; Leblois et al., 2017; Nguyen-Van and Azomahou, 2003, 2007; Scrieciu, 2007) and at local level (Amin et al., 2019; Bakehe, 2019; Ranjan, 2019).[3] Koop and Tole (1999), Culas (2007), Nguyen-Van and Azomahou (2003, 2007), Hübler (2017) and patrick Bakehe (2018) among others test empirically the Environmental Kuznet Curve (EKC) hypothesis for deforestation. The meta-analysis by Choumert et al. (2013) on 69 studies published between 1992 and 2012 shows that most of the studies corroborate the EKC hypothesis while they observe a turning point after 2001. Afawubo and Noglo (2019) and Bakehe (2019) investigate the role of remittances on mitigating deforestation in developing countries. Damette and Delacote (2012), Hosonuma et al. (2012), Leblois et al. (2017) and Scrieciu (2007) investigate a broad set of determinants of deforestation in developing countries while Combes et al. (2018) focus the role of access to man-made capital (public spending and credit). However, studies on the effect of mining on deforestation remain scant (Kinda and Thiombiano, 2021; Ranjan, 2019).

Mining activities are the fourth driver of deforestation globally, induce 7% of forest lost in developing countries (Hosonuma et al., 2012; Potapov et al., 2017) and raise enormous environmental concerns (Edwards et al., 2014; Durán et al., 2013). Jenkins and Yakovleva (2006) state that "the discovery, extraction and processing of mineral resources are widely regarded as one of the most environmentally and socially disruptive activities undertaken by business". Surprisingly, the current state of the literature overlooks the role of mining activities on deforestation; specifically in Africa. Existing studies on the impact of mining activities include air, water and soil pollution (Akiwumi and Butler, 2008; Hilson, 2002; Porgo and Gokyay, 2017); contributions on deforestation are limited.

[2] IPCC: Intergovernmental Panel on Climate Change

[3] See Leblois et al. (2017); Trigueiro et al. (2020) and Choumert et al. (2013) for a recent survey.

Our paper is related to Kinda and Thiombiano (2021) and Ranjan (2019). Kinda and Thiombiano (2021) consider the effect of extractives industries on deforestation in sample of 52 developing countries and find that mining and natural gas rents contribute to deforestation as opposed to oil rents. In a similar study, Ranjan (2019) investigates the effect of mining on deforestation in India. Using district level data (314 districts) from 2001 to 2014, the author find that districts producing mineral resources such as charcoal, iron and limestone suffer from 100 km^2 higher deforestation compared to districts that do not produce any of these minerals. Unlike Kinda and Thiombiano (2021) and Ranjan (2019), we focus on the effect of mining on deforestation in a sample of African countries and account for spatial spillovers, regional clusters and the role of envrionmental policies. Recent literature stress out the importance of taking into account spatial effects when investigating the drivers of deforestation (Amin et al., 2019). Also, unlike developed countries, African countries are caught between exploiting natural resources for development and protecting the environment. A significant environmental costs of mining activities would be unbearable for future generations in the context of climate change. Understanding how mining activities affect deforestation is a necessary step to conciliating extractives activities vs. environmnetal protection dilemma.

Using a panel data of 35 African countries over the period 2001-2017 and relying on spatial econometrics specifications, we establish three key results. First, we show that mining activity increases deforestation in Africa. An increase in mineral rent by a one-point percentage of GDP leads to forest loss of about 50 km^2. However, environmental policy contributes to reducing deforestation in EITI[4] member states. We also find evidence of heterogeneity among countries depending on regional economic community they belong to. Economic communities such as the ECOWAS[5] and the WAEMU[6] are associated with lower deforestation while others (ECCAS and SADC)[7] are associated with higher deforestation.

Our paper contributes to the literature in three main aspects. First, we examine the effect of mining on deforestation in Africa. While studies on the local impact of mining activities including air, water and soil pollution exist in Africa (Akiwumi and Butler, 2008; Hilson, 2002; Porgo and Gokyay, 2017), contributions on deforestation in region are scant. Hund et al. (2017) and Abernethy et al. (2016) recognize that the mining sector is one of the main drivers of deforestation in the Democratic Republic

[4] The Extractive Industries Transparency Initiative

[5] Economic Community of West African States

[6] West African Economic and Monetary Union

[7] ECCAS: Economic Community of Central African States; SADC: Southern African Development Community

of Congo and in the Congo Basin. Hund et al. (2017) explore possibilities for the extractive sector to contribute to the Reduction of Emissions from Deforestation and forest Degradation and improving carbon stocks (REDD+). They do not assess the impact of mining on deforestation. To the best of our knowledge, our study is the first to estimate the extent to which mining affects deforestation in Africa while considering spatial spillovers across countries.

Second, we distinguish *de jure* and *de facto* environmental policies. *de jure* policy refers to country adherence to international environmental treaties. *de facto* environmental policy represents the actual environment control. The advantage of this distinction is that in poor institutional quality context and asymmetric power between states and foreign investors, a wide gap can exist between environmental policies on paper and in practice. This is important in environmental policy since the climate cost is global and relegated to future generations. Indeed, the effectiveness of the legal enforcement of environmental standards depends on the institutional environmental environment and the administrative capacity to implement these standards.

Finally, we account for regional economic communities in Africa. Taking into account regional economic communities allows not only comparison between regions but also it helps to evaluate environmental policy coordination within regions.

The rest of the paper is organized as follows. We discuss the related literature in section 4.2. Section 4.3 describes the data. We present the econometric specifications in section 4.4 and the results in section 4.5. Section 4.6 undertakes robustness checks of the results. Section 4.7 derives policy implications and future research prospects.

4.2 Related literature

Evidence suggests that deforestation contributes to climate change (Moutinho and Schwartzman, 2005; Shukla et al., 1990). Climate and vegetation coexist in a dynamic equilibrium such that a perturbation of either or both components could alter the equilibrium. In a simulated model, Shukla et al. (1990) show that deforestation of the Amazonian forest causes "a significant increase in surface temperature and a decrease in evapotranspiration and precipitation over Amazonia". Also, the authors predict that the forest chance of renewal is limited since the length of the dry season increases. Deforestation disrupts not only the ecosystem's natural ability to store carbon dioxide emissions; it also contributes to them.

From exploration to resource refinement, extractive activities disrupt the landscape and the environment. Deforestation is one of the main consequences of this disruption. Yet, the literature on the effects of mining on deforestation is still scant, especially in Africa. Most of the empirical studies on mining and deforestation are concentrated on the Amazonian forest and Brazil. However, the world's second-largest tropical forest is in Africa and the mining effect on deforestation might be particularly sizable in the context of weak enforcement capability and a weak institutional framework. Under the pollution haven hypothesis (PHH)[8], some empirical studies show that laxity in environmental regulation attracts highly-polluting industries (Dean et al., 2009; Xing and Kolstad, 2002).

According to Sonter et al. (2017), the effect of mining on deforestation is sizable and underestimated worldwide. Mining activities affect deforestation both directly and indirectly through different channels. Directly, processing and infrastructure development and extraction, particularly for strip mining removes the overburden on a significant area that may be forested. Indirectly, mining activities affect deforestation through three major channels (Sonter et al., 2017). First, toxins and solid metals released during mining operations might remain for a long time after the mining closure and cause soil erosion hence, significant forest loss in the surrounding area. The argument that mining companies occupy a small area (less than 1% of the world terrestrial land surface (Bridge, 2004)) may be delusional. Several studies show that adopting an ecosystem perspective, mining activities can have an impact on the forest on a large scale. Sonter et al. (2017) estimate that mining causes deforestation up to 70 km beyond the mining lease boundaries in the Amazonian forest. Using the propensity score matching method they found that mining activities cause 11.67 km^2 of deforestation between 2005 and 2015. This surface represents 9% of all Amazon and 12 times the deforestation that occurs within mining leases boundaries. Second, infrastructure establishment, both for extraction and transport might lead to forest loss. Third, mining affects population spatial distribution through displacement and urban expansion as a response to increasing labor demand and the development of other activities surrounding the mineral commodity supply chains.

Combes et al. (2015) use a sample of developing countries over the period 1990-2010 and find a positive relationship between mineral rents and deforestation. The authors argue that mineral extraction is space -consuming and might invade forest area. Bridge (2004) identifies tree major environmental impacts of mining: modifying physical landscape; waste pollution and driving regional and global environmental disruption. Waste pollution includes physical (ingress of particulates in the atmosphere, water and land) and chemical pollution (chemical products used during

[8]The "pollution haven hypothesis" is the idea that environmental policies could affect pollution-intensive activities location. See Kellogg (2006) for more details.

the mineral processing).

One common policy response to mining driven forest damage is setting protected areas. However, Durán et al. (2013) show that even protected areas (PA) are under threat. "7% of mines for four key metals directly overlaps with the protected area and a further 27% lies within 10 km of a PA boundary. Moreover, those PA with mining activity within their boundaries constitute around 6% of the total area coverage of the global terrestrial protected area system, and those with mining activity within or up to 10 km from their boundary constitute nearly 14% of the total area".

Overall, the literature emphasizes that mining activities disrupt the environment and weaken the ecosystem's natural ability to mitigate climate change.

Summing up, the literature on the effect of mining on deforestation in African remains limited. The role of environmental policy and spatial interactions are neglected. This study aims to fill this gap.

4.3 Data and variables

The dataset covers 35 African countries over the period 2001-2017. The list of countries is provided in Table 4.A1. Deforestation data availability limited the period to 2001-2017. We gather the data from different sources. In the following subsection, we describe the data and presents some descriptive analyses. Data sources and variables' definition are given in Table 4.A2.

4.3.1 Deforestation

Deforestation is "stand-replacement disturbance or a change from a forest to a non-forest state" (Hansen et al., 2013). We measure deforestation using the forest cover loss at different thresholds of three cover (greater than 20%; 30% and 50% capony cover) compiled by Hansen et al. (2013). Hansen et al. (2013) data are given by geographic coordinates that we convert into country-level data. The authors use earth observation satellite imagery data at a spatial resolution of 30 meters to quantify gross forest cover loss. Using different canopy covers allows us to take into account the sensitivity of forest measurement to different three cover thresholds (Grainger, 2008). The type of forest is classified following the canopy cover thresholds in percentage. The higher percentages correspond to the closed forest while lower correspond to open forest. Since the measurement methodology of forest loss and forest gain differ, the net cover loss cannot be used (Combes et al., 2018). These data are more reliable compared to the FAO forest cover data (Combes et al., 2018;

Grainger, 2008). Using the FAO dataset, Grainger (2008) shows that it is difficult to construct a reliable trend and "evidence for a decline is unclear". Deforestation data consider forest loss induced by both natural and economic activities.

The average forest loss is 0.66, 0.74 and 0.57 thousand of km^2 for canopy cover greater than 20%, 30% and 50% respectively. The minimum forest loss is zero for all canopy cover.The maximum are respectively 14.9, 14.65 and 13.77 thousand of km^2 in the sample. The standard deviations are respectively 1.49, 1.74 and 1.54.

4.3.2 Environmental policy

By contrast to developed countries where environmental policy data exist for quite a long period (OECD environmental policy dataset for instance), measuring environmental policy in Africa is challenging. To the best of our knowledge, there is no dataset on environmental policy in Africa over a significant period. The environmental performance index dataset is released biennially in even-numbered over the period 2006-2018 (Wendling et al., 2018) and cannot be assembled into a panel data because of methodological change. Also, the World Bank CPIA environmental sustainability rating started in 2005. The challenge is how to proxy environmental policy in Africa in a context of lack of data. To deal with these issues, we refer to two different measures of environmental policy in Africa: domestic environmental commitment which is a *de facto* measure of country environmental policy and international environmental commitment which is a *de jure* measure.

We follow the same methodology as Combes et al. (2016) to compute a *de facto* environmental policy measure. The authors build an indicator called "domestic efforts for climate mitigation (DECM)" which is the residuals of the regression of per capita CO_2 emissions over a set of control variables (GDP per capita, openness to trade, population, foreign direct investment and foreign aid). They argue that the error term provides a *de facto* measure of domestic effort to climate mitigation because the regression controls exogenous factors that predict the "structural emissions". Therefore, the residuals catch the autonomous climate policy (Combes et al., 2016).

We estimate a dynamic panel model estimated with a System-GMM (Blundell and Bond, 2000) as in Combes et al. (2016). We then normalize the residuals from -10 (lax environmental policy) to +10 (stringent environmental policy). See Table 4.A3 in Appendix for further details.

The *de jure* environmental policy is a count of country adhesion to international treaties. Although international treaties may not be binding, they are deemed to be more contingent than the domestic laws. Also, country commitment to international enforcement is a good signal of their environmental policy. We expect country environmental commitments to reduce deforestation.

4.3.3 Mineral resources rent

Because we are interested in mining activities we do not consider the other extractive resources such as oil and natural gas. Mining is more prevalent in forest areas than oil and gas extraction (Hund et al., 2017). The increasing weight in African economies of the mining sector comes with substantial environmental issues. We use mineral resource rents as % of GDP as our measure mining activities. Some alternative measures could be the subsoil wealth computed by the World Bank, and mining concession. However, these datasets are limited in terms of time and country coverage. The subsoil dataset is not available yearly while the dataset on mining concession data cover only a few countries. Subsequently, we resort to resource rents. The data are from the World Bank World Development Indicators.

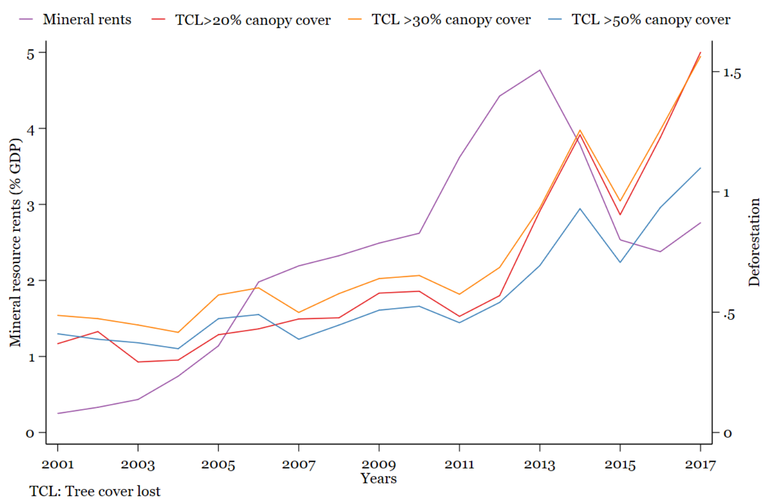

Figure 4.1: Mining and deforestation

Figure 4.1 displays the evolution of the sample average of mineral resource rents as a percent of GDP and deforestation (tree cover loss greater than 20%, 30% and 50% canopy cover). It shows a clear co-movement between mineral rents and deforestation over the period 2001-2017.

Figure 4.2 present the maps of the country average over the period 2001-2017 of deforestation (tree cover loss at canopy cover >20%) and mineral resource rents. Except for Mali, we observe spatial correlation between the mineral resource rents of the countries in the sample and their deforestation. Countries with high mineral resource rents display greater forest loss.

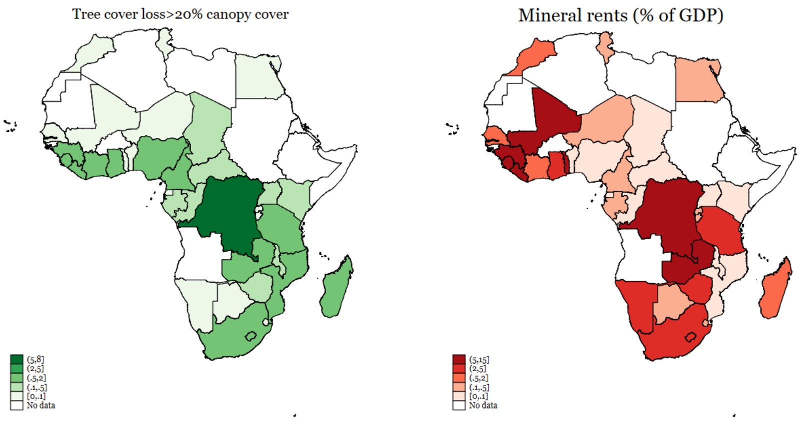

Figure 4.2: Average deforestation and mineral resource rents

4.3.4 Other control variables

Temperature and precipitation shocks: to control for the effect of climate shocks we use the absolute value of the deviation of the temperature, respectively precipitation, to its long-run average. Temperature (precipitation) shocks are natural events that can exacerbate deforestation. Data on temperature and precipitation are from the University of East Anglia Climatic Research Unit.

GDP per capita: We control for both GDP per capita and GDP per capita square. The intuition is that the level of economic development affect deforestation. Including the square allows us to test the environmental Kuznets Curve hypothesis. In the early stage of economic development, deforestation increases and starts to decrease since the country reaches a certain level of development. In this sense, we expect an inverted U-shape relation between deforestation and GDP per capita.

EITI membership: the Extractive Industries Transparency Initiative "is a global standard for the good governance of oil, gas and mineral resources. It seeks to address the key governance issues in the extractive sectors". The EITI membership is a dummy variable equal to 1 if the country is a member of EITI and 0 otherwise. 16 countries out of 35 of our sample are members of EITI. We expect EITI membership to decrease deforestation since the EITI promotes good practices in the extractive sector. However, the EITI membership is also a signal of extractive resource endowment. As compared to other countries, deforestation may be higher in those countries. The data on country status are extracted from the EITI website.[9]

Population density: The population density is the number of inhabitants per km^2. Higher population density is expected to be associated with higher deforestation. Population density data are from WDI.

[9] https://eiti.org/countries Membership status in February 2020

Regional economic community in Africa: Based on our sample, eight regional economic communities across Africa can be defined: The Arab Maghreb Union (AMU); the Common Market for Eastern and Southern Africa (COMESA); the Economic Community of Central African States (ECCAS); the Economic Community of West African States (ECOWAS); the Southern African Development Community (SADC); The West African Economic and Monetary Union (WAEMU); the Economic and Monetary Community of Central Africa (CEMAC) and the West African Monetary Zone (WAMZ). Regional economic communities capture the regional-level effort in environmental regulation. The effect of a given region compared to the others will depend on environmental the existence of regional enforcement. The WAEMU has established a regional mining code since 2003. In 2009 the ECOWAS adopted in 2009 a mining directive. For these two regions where the enforcement at the regional-level exist we expect to have less deforestation compared to the other countries. See Table 4.A1 bellow for details of country membership.

Foreign Direct Investment (FDI):[10] is the annual FDI net inflows to the country. The direction of the relationship between FDI and deforestation is theoretically ambiguous. While lax environmental policies might attract FDI and increase deforestation, foreign investors might bring environmentally friendly technology or align with the environmental standards of the home countries. See Table 4.1 and 4.A2 in the Appendix for respectively the descriptive statistics and more details in the variables and data sources.

Aid per capita: is the net official development assistance per capita. We use this variable only as a control in the computation of *de facto* policy indicator.

Forest rents: "Forest rents are roundwood harvest times the product of average prices and a region-specific rental rate" (WDI, 2019). This variable account for logging since the data on logging covering our sample is unavailable. Higher forest rents are expected to induce deforestation.

Control of corruption: "Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests" (WGI,2019). Weaker control of corruption leads to environmental degradation.

[10]We would have preferred using the FDI of the mining sector, but unfortunately these data are not available. However, aggregated FDI should not bias the results.

Table 4.1: Descriptive statistics on the pooled data

Variables	mean	st. dev.	min	max
Three cover loss (>20% canopy cover)	0.66	1.49	0.00	14.90
Three cover loss (>30% canopy cover)	0.74	1.74	0.00	14.65
Three cover loss (>50% canopy cover)	0.57	1.54	0.00	13.77
GDP growth	4.68	5.67	-36.04	63.38
Mineral resource rents	2.28	4.56	0.00	46.62
Temperature shocks	2.07	1.77	0.00	15.90
de facto environmental policy	0.91	4.76	-10	10
de jure environmental policy	79.66	29.66	0.00	132
CO_2 emissions per capita	0.98	1.78	0.02	9.84
Population density	72.64	86	2.22	485.65
GDP per capita (in thousands of USD)	2.26	3.7	0.21	20.51
Total population (millions)	22.4	29.6	0.63	191
Aid per capita	53.24	43.19	-8.27	393.50
Openness to trade	73.01	33.69	20.72	311.35
Foreign Direct Investment (inflows)	4.98	9.52	-4.85	103.34
Control of corruption	-0.67	0.56	-1.83	1.22
Forest rents	6.07	6.06	0	40.43

Notes: Number of countries (N) =35; Waves (T)=17; NT=595

4.4 Empirical strategy

We consider a spatial panel-data error model:

$$F_{it} = \mathbf{x}'_{it}\boldsymbol{\beta} + \mathbf{z}'_{i(r)}\boldsymbol{\theta} + a_i + u_{it} \quad (4.1)$$

$$a_i = \phi \sum_{j=1}^{N} \omega_{ij} a_j + \eta_i$$

$$u_{it} = \lambda \sum_{j=1}^{N} m_{ijt} u_{jt} + v_{it}, \quad i = 1, \cdots, N;\ t = 1, \cdots, T;\ r = 1, \cdots, R; (j \neq i) \in R$$

where F_{it} is a measure of deforestation by type of canopy cover in country i at time t, a_i are country fixed effects; m_{ijt} is the time variant weight assigned to country j by country i, $(j \neq i)$; ω_{ij} are time invariant weight assigned to country j by country i, $(j \neq i)$; $\mathbf{x}$ is a vector of time variant controls including among others temperature and precipitation shocks,[11] mining rents, countries' environmental commitment, GDP per capita and its square; $\mathbf{z}$ denotes the vector of time invariant regional dummies,

[11]While climate shocks may raise endogeneity concern, due to reverse causality between deforestation and climate shocks, we presume that this feedback effect takes time to occur.

$\boldsymbol{\beta}$ and $\boldsymbol{\theta}$ are vector of parameters of interest to be estimated, ϕ and λ are spatial parameters to be estimated, u_{it} and v_{it} represent idiosyncratic shocks uncorrelated across countries and over time.

Equation 4.1 is a generalization of the spatial error model, in which the panel effects, represented by the vector $\mathbf{a} = (a_1, \cdots, a_i, \cdots, a_n)'$, are spatially correlated. The vectors $\mathbf{a}$ and $\mathbf{v} = (v_{i1}, \cdots, v_{it}, \ldots, v_{nT})'$ are assumed to be independently normally distributed errors, so the model is necessarily an random effect specification with $\mathbf{a} = (I - \phi W)^{-1}\eta$ with $W \ni \omega_{ij}$ and $\mathbf{u} = (I - \lambda M)^{-1}\mathbf{v}$, with $M \ni m_{ijt}$. In this setting, two spatial matrices were used: the inverse distance W which is a geographic distance, and the population matrix M which account for the size of the country.

Algebraically, an element w_{ij} of W, the geographic distance weighting matrix, takes the following form:

$$\omega_{ij} = \begin{cases} \frac{1/d_{ij}}{\sum_j 1/d_{ij}} & \text{if} \quad j \neq i \\ 0 & \text{otherwise} \end{cases}$$

with d_{ij} being the Euclidean distance between the capitals of countries i and j. The components m_{ijt} of the population matrix M are computed as:

$$m_{ijt} = \begin{cases} \frac{(|POP_{it} - POP_{jt}|)^{-1}}{\sum_j (|POP_{it} - POP_{jt}|)^{-1}} & \text{if} \quad j \neq i \\ 0 & \text{otherwise} \end{cases}$$

where POP denotes the population. The elements of M are based on the absolute difference in population between countries i and j. We take the inverse of the absolute difference so that the weighting matrix attributes a higher weight to countries that have a smaller absolute difference in population.

This specification emphasizes spatial interactions to which environmental quality indicators are subject, in particular deforestation. Brown (2000) stressed the importance of spatial dimension (spatial heterogeneity and externality) in the management of renewable resources. In the case of forest resource management, taking into account heterogeneities of this type such as spatial interdependence, irreversibility, different practices concerning the use of the forest surface and uncertainty may lead to optimal management of the forest surface (Albers, 1996).

While within countries, we may expect deforestation to be spatially dependent, it is hard to defend a spatial correlation across borders. Countries are unlikely to follow each other in deforestation behavior (activities). However, natural drivers of deforestation including unobserved climatic characteristics that influence deforestation may exhibit spatial dependence. For these reasons, we specify a generalized spatial panel random effects (GSPRE) model for the determinants of deforestation (Equations 4.1). This specification is estimated using the Quasi-Maximum Likelihood Estimator (QMLE).

The likelihood function of Equation 4.1, Generalized Spatial Panel Random Effects model (GSPRE) model adapted from Baltagi et al. (2013) is given by:

$$\begin{aligned} L(\beta,\theta) &= -\frac{NT}{2}\ln 2\pi - \frac{1}{2}\ln\det\left[T\sigma_\mu^2(A'A)^{-1} + \sigma_\upsilon^2(B'B)^{-1}\right] \\ &- \frac{T-1}{2}\ln\det\left[\sigma_\upsilon^2(B'B)^{-1}\right] - \frac{1}{2}(F-X\beta)'\Omega_u^{-1}(F-X\beta), \end{aligned} \qquad (4.2)$$

where $\theta = (\sigma_\upsilon^2, \sigma_\mu^2, \phi, \lambda)$, $A = I_n - \phi W$ and $B = I_n - \lambda M$

We refer the reader to Baltagi et al. (2013) for more details on the properties of the function and the underlying assumptions.

4.5 Results

4.5.1 Deforestation, climate shocks and mining rent

Tables 4.2a, 4.2b and 4.2c report the results of the regression of the determinants of deforestation for tree cover loss at canopy cover greater than 20%, 30% and 50% respectively. From column (1) to (8) in each table, we control for different regional economic communities across Africa (AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ). Because some countries are member of more than one regional economic zone we estimate separate equations to avoid overlapping.

The spatial autocorrelation coefficients in the error terms (ϕ for the spatial fixed effect and λ for the idiosyncratic spatial effect) are in most estimates (depending on regional clusters) positive and significant except for canopy cover$>$ 50% for which lambda is not significant (Table 4.2c). This result globally confirms the existence of spatial heterogeneity. Countries behave similarly when they share similar unobserved characteristics or unobservable institutional environment. Even though we control for some of these institutional environments by including regional clusters, there are still some factors (fixed and variable) such as the climatic zones that are captured in the spatial autocorrelations of the error terms.

Our variables of interest are mineral resource rents, temperature shocks and environmental policies.

4.5.2 Mineral resources rent

Mining rents increase deforestation in Africa as we presumed. The coefficient vary from 0.0421 (Table 4.2c column 2) to 0.0573 (Table 4.2a column 4) and are statistically significant at 1% level. On average, an increase in mining rent by 1% of GDP increases deforestation by 50 km^2. The size of the effect decreases with the canopy cover. We observe that the effect of mining on deforestation is more marked at the canopy cover greater than 20% than it is at canopy cover greater than 30% and 50%. This is expected because the higher the canopy cover the dense the forest, and forest protection policies might come at play for dense forests. Mining activities are space consuming and contribute directly to deforestation (Combes et al., 2015). Moreover, mining can also induce deforestation in the surrounding area (Sonter et al., 2017). The indirect effects may also include mining-induced infrastructures, urbanization and toxic releases (Bridge, 2004). These results are consistent with previous findings that mining activities are among the leading causes of deforestation (Combes et al., 2015).

4.5.3 Climate shocks

To control for climate variability, we use yearly average temperature shocks which is the absolute value of the difference between the yearly temperature (precipitation) and its mean. Temperature and precipitation shocks have a positive impact on deforestation as expected but nonsignificant statistically. Combes et al. (2018) find similar results in several specifications. A plausible explanation is that deforestation may be less sensitive to the yearly variation in climate conditions.

4.5.4 Environmental policy

The effect of environmental policies is statistically nonsignificant whether it is *de jure* (country international environmental treaties participation) or *de facto* ("domestic effort to climate mitigation"). However, the coefficients associated to EITI are positive and significant implying that deforestation is higher in EITI member States than non-EITI member States. This result might be a signal than mining resources increase deforestation since the members are those endowed with natural resources. In these countries both *de facto* and *de jure* environmental policies are effective in reducing deforestation in terms of the size of the coefficients. The coefficients of the interaction term between environmental policy and EITI membership are negative and statistically significant at 1% level. Moreover, within EITI members, *de facto* environmental policy is more effective than *de jure* environmental policy. The coefficients associated with the interaction between EITI and *de jure* environmental policy vary from -0.0405 (Table 4.2a column 2) to -0.0645 (Table 4.2b column 1). For *de facto* policy, the coefficients of the interactive term are ten times bigger. They are between -0.609 (Table 4.2a column 5) -0.443 (Table 4.2c column 1). These results support that, what matters the most is not that countries engage in international treaties but their actual efforts. Being members of EITI brings more transparency to the extractive sector and contributes to effective government policy in the mining sector regulation. EITI invest the past decade on empowering civil society in its State members. These interventions may contribute to enforcing environmental policy in these countries than in the others. Moreover, existing literature shows that EITI membership improves governance (Villar and Papyrakis, 2017) and revenue mobilization (Mawejje, 2019).

4.5.5 Regional clusters

African countries are engaged in regional economic communities in the last three decades. In these organizations, some policy harmonization has been put into place including the mining sector regulation. We capture these supranational regulations controlling for these regional dummies. Tables 4.2a, 4.2b, and 4.2c report similar pattern with regard to our regional dummies. The coefficients of AMU are negative but not statistically significant. Also, those associated with COMESA are positive and not significant. Similarly, the coefficient of ECCAS is positive but significant at 10% level only in Table 4.2c (canopy cover >50%). Being members of these three regions does not affect significantly deforestation as compared to other regions. The coefficients associated with the SADC region is positive and significant. The coefficients vary from 1.1 (Table 4.2a) to 1.6 (Table 4.2b). This means that deforestation is higher in SADC member states compared to others. Indeed, since 1990, Southern Africa experienced the highest rate of forest cover loss in Africa.[12]

The effect of ECOWAS membership on deforestation is negative and significant. One might think that this negative and significant effect stems from common environmental policies. ECOWAS set a mining directive since 2009 as a guideline for its member States. To the best of our knowledge, there is no similar coordination in the mining sector in Africa. This might induce countries to raise their environmental standards specifically in the mining sector. However, a closer look shows that the negative and significant coefficient is driven by the WEAMU members. When we divide ECOWAS into WAEMU and Non-WAEMU members (WAMZ), we observe

[12] https://www.sadc.int/themes/meteorology-climate/climate-change-mitigation/

Table 4.2a: Determinants of deforestation

	Dependent variable: Tree cover loss >20% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0565*** **	**0.0543*** **	**0.0561*** **	**0.0573*** **	**0.0551*** **	**0.0560*** **	**0.0564*** **	**0.0555*** **
	(0.00946)	(0.00946)	(0.00944)	(0.00940)	(0.00941)	(0.00935)	(0.00946)	(0.00942)
Temperature shocks	0.00523	0.00525	0.00600	0.00532	0.00498	0.00603	0.00515	0.00563
	(0.0169)	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0169)	(0.0168)
Precipitation shocks	0.000625	0.000601	0.000620	0.000612	0.000620	0.000603	0.000627	0.000615
	(0.000440)	(0.000440)	(0.000440)	(0.000439)	(0.000440)	(0.000439)	(0.000440)	(0.000440)
de jure environmental policy	0.00213	-0.00263	0.00120	-0.000523	0.00146	-0.00458	0.00109	-0.00258
	(0.0121)	(0.0115)	(0.0117)	(0.0104)	(0.0116)	(0.0105)	(0.0117)	(0.0118)
De faco environmental policy	0.00644	0.0221	0.0112	0.0319	0.0482	0.0368	0.00772	0.0270
	(0.0681)	(0.0643)	(0.0661)	(0.0609)	(0.0668)	(0.0620)	(0.0680)	(0.0663)
EITI membership	**6.038*** **	**5.604*** **	**5.778*** **	**6.303*** **	**5.770*** **	**5.786*** **	**5.963*** **	**5.646*** **
	(1.286)	**(1.314)**	**(1.302)**	**(1.244)**	**(1.282)**	**(1.222)**	**(1.280)**	**(1.344)**
***de jure* environmental policy x EITI**	**-0.0462*** **	**-0.0405*** **	**-0.0449*** **	**-0.0437*** **	**-0.0444*** **	**-0.0436*** **	**-0.0448*** **	**-0.0424*** **
	(0.0142)	**(0.0140)**	**(0.0138)**	**(0.0129)**	**(0.0137)**	**(0.0131)**	**(0.0140)**	**(0.0143)**
***de facto* environmental policy x EITI**	**-0.572*** **	**-0.579*** **	**-0.574*** **	**-0.597*** **	**-0.608*** **	**-0.597*** **	**-0.571*** **	**-0.588*** **
	(0.0851)	(0.0817)	(0.0834)	(0.0793)	(0.0834)	(0.0802)	(0.0852)	(0.0834)
GDP per capita (log)	2.518*	2.573*	2.780**	2.356*	2.509*	2.594*	2.521*	2.639*
	(1.337)	(1.359)	(1.350)	(1.351)	(1.353)	(1.343)	(1.335)	(1.352)
GDP per capita square (log)	-0.172*	-0.164*	-0.189**	-0.164*	-0.167*	-0.176**	-0.172*	-0.175*
	(0.0891)	(0.0905)	(0.0900)	(0.0889)	(0.0899)	(0.0888)	(0.0891)	(0.0899)
FDI	-0.00620*	-0.00600*	-0.00645*	-0.00625*	-0.00627*	-0.00646*	-0.00616*	-0.00621*
	(0.00344)	(0.00344)	(0.00344)	(0.00342)	(0.00343)	(0.00342)	(0.00344)	(0.00343)
ϕ	2.388***	-0.629	0.208	-1.565*	-0.0607	-1.329	2.398***	0.159
	(0.335)	(1.089)	(0.550)	(0.891)	(0.690)	(1.028)	(0.339)	(0.733)
λ	0.397***	0.387***	0.398***	0.408***	0.398***	0.412***	0.399***	0.399***
	(0.0697)	(0.0700)	(0.0688)	(0.0670)	(0.0686)	(0.0673)	(0.0694)	(0.0690)
σ_μ	1.519***	1.439***	1.411***	1.201***	1.400***	1.253***	1.516***	1.476***
	(0.218)	(0.196)	(0.197)	(0.180)	(0.192)	(0.182)	(0.217)	(0.202)
σ_e	0.648***	0.648***	0.648***	0.648***	0.648***	0.647***	0.648***	0.647***
	(0.0198)	(0.0197)	(0.0198)	(0.0198)	(0.0198)	(0.0197)	(0.0198)	(0.0197)
AMU	-0.0495							
	(1.321)							
COMESA		1.047						
		(0.698)						
ECCAS			0.950					
			(0.608)					
ECOWAS				-1.610***				
				(0.370)				
SADC					1.082**			
					(0.550)			
UEMOA						-2.083***		
						(0.579)		
CEMAC							-0.396	
							(0.882)	
WAMZ								-0.231
								(0.981)
Constant	-9.175*	-9.871*	-10.15**	-7.871	-9.486*	-8.566*	-9.066*	-9.344*
	(5.095)	(5.162)	(5.146)	(5.109)	(5.124)	(5.078)	(5.073)	(5.131)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-674.4	-672.3	-672.0	-668.4	-671.5	-669.1	-674.3	-673.1

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

that the WAEMU membership has a negative and significant effect on deforestation while the WAMZ membership is not significant. In fact, since 2003 the WEAMU member States establish a community mining code. Moreover, the WAEMU mining code, in its articles 11 and 18, explicitly enforces environmental regulation including environmental impact evaluation, encourages "set up a monitoring plan as well as a rehabilitation program for the environment" (Art.18).[13] Policy harmonization is advanced in the WAEMU compared to the other regions.

Overall, we find evidence that mining increases deforestation in Africa and environmental policy matters at least in EITI member countries. Moreover, the results

[13] http://www.droit-afrique.com/upload/doc/WAEMU/WAEMU-Code-minier-communautaire-2003.pdf

Table 4.2b: Determinants of deforestation

	Dependent variable: Tree cover loss >30% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0513*** **	**0.0495*** **	**0.0515*** **	**0.0516*** **	**0.0499*** **	**0.0509*** **	**0.0513*** **	**0.0514*** **
	(0.00972)	(0.00975)	(0.00973)	(0.00966)	(0.00965)	(0.00962)	(0.00972)	(0.00971)
Temperature shocks	0.00534	0.00584	0.00554	0.00618	0.00514	0.00674	0.00546	0.00554
	(0.0171)	(0.0171)	(0.0171)	(0.0171)	(0.0171)	(0.0171)	(0.0171)	(0.0171)
Precipitation shocks	0.000708	0.000685	0.000713	0.000689	0.000696	0.000680	0.000707	0.000706
	(0.000454)	(0.000454)	(0.000454)	(0.000453)	(0.000453)	(0.000453)	(0.000454)	(0.000454)
de jure environmental policy	0.0216	0.00726	0.0222*	0.00774	0.0136	0.00400	0.0180	0.0177
	(0.0134)	(0.0140)	(0.0127)	(0.0121)	(0.0129)	(0.0122)	(0.0128)	(0.0126)
De faco environmental policy	-0.0225	-0.0172	-0.0275	-0.00960	0.0205	-0.00518	-0.0184	-0.0202
	(0.0704)	(0.0690)	(0.0703)	(0.0656)	(0.0689)	(0.0655)	(0.0704)	(0.0704)
EITI membership	**7.253*** **	**5.939*** **	**7.157*** **	**6.519*** **	**6.200*** **	**5.974*** **	**7.102*** **	**7.187*** **
	(1.419)	**(1.617)**	**(1.384)**	**(1.424)**	**(1.443)**	**(1.437)**	**(1.423)**	**(1.419)**
***de jure* environmental policy x EITI**	**-0.0645*** **	**-0.0506*** **	**-0.0630*** **	**-0.0522*** **	**-0.0551*** **	**-0.0519*** **	**-0.0612*** **	**-0.0625*** **
	(0.0157)	**(0.0167)**	**(0.0149)**	**(0.0149)**	**(0.0152)**	**(0.0152)**	**(0.0154)**	**(0.0153)**
***de facto* environmental policy x EITI**	**-0.565*** **	**-0.559*** **	**-0.562*** **	**-0.576*** **	**-0.597*** **	**-0.576*** **	**-0.570*** **	**-0.568*** **
	(0.0864)	(0.0871)	(0.0861)	(0.0830)	(0.0847)	(0.0833)	(0.0864)	(0.0865)
GDP per capita (log)	2.490*	2.700*	2.529*	2.640*	2.520*	2.816**	2.481*	2.468*
	(1.413)	(1.420)	(1.410)	(1.410)	(1.418)	(1.411)	(1.414)	(1.412)
GDP per capita square (log)	-0.172*	-0.176*	-0.178*	-0.181*	-0.169*	-0.189**	-0.171*	-0.170*
	(0.0942)	(0.0946)	(0.0940)	(0.0936)	(0.0944)	(0.0938)	(0.0942)	(0.0942)
FDI	-0.00667*	-0.00635*	-0.00681*	-0.00657*	-0.00656*	-0.00666*	-0.00661*	-0.00659*
	(0.00358)	(0.00357)	(0.00358)	(0.00355)	(0.00356)	(0.00355)	(0.00357)	(0.00357)
ϕ	1.437***	-0.492	1.472***	-1.286	-0.498	-1.367	1.444***	1.477***
	(0.294)	(1.445)	(0.300)	(0.899)	(0.868)	(1.100)	(0.294)	(0.290)
λ	0.280***	0.278***	0.280***	0.292***	0.285***	0.295***	0.283***	0.284***
	(0.0763)	(0.0773)	(0.0762)	(0.0759)	(0.0762)	(0.0761)	(0.0764)	(0.0764)
σ_μ	1.709***	1.769***	1.664***	1.567***	1.633***	1.597***	1.745***	1.729***
	(0.234)	(0.233)	(0.228)	(0.214)	(0.214)	(0.222)	(0.235)	(0.234)
σ_e	0.668***	0.667***	0.668***	0.666***	0.667***	0.666***	0.667***	0.668***
	(0.0203)	(0.0202)	(0.0203)	(0.0202)	(0.0202)	(0.0201)	(0.0202)	(0.0203)
AMU	-1.269							
	(1.458)							
COMESA		0.910						
		(1.064)						
ECCAS			1.462					
			(0.914)					
ECOWAS				-1.706***				
				(0.483)				
SADC					1.591***			
					(0.573)			
UEMOA						-2.239***		
						(0.728)		
CEMAC							0.165	
							(0.977)	
WAMZ								0.746
								(1.004)
Constant	-10.39*	-10.62**	-10.91**	-9.322*	-10.32*	-9.786*	-10.15*	-10.20*
	(5.342)	(5.360)	(5.354)	(5.307)	(5.322)	(5.287)	(5.341)	(5.335)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-691.7	-691.2	-690.8	-688.1	-688.6	-688.7	-692.1	-691.8

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

support that *de facto* environmental policy is more effective than *de jure* environmental policy when countries are EITI members. The results are robust regarding different canopy.

Table 4.2c: Determinants of deforestation

	Dependent variable: Tree cover loss >50% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0439*** **	**0.0421*** **	**0.0442*** **	**0.0444*** **	**0.0424*** **	**0.0433*** **	**0.0440*** **	**0.0429*** **
	(0.00892)	(0.00894)	(0.00892)	(0.00880)	(0.00886)	(0.00882)	(0.00892)	(0.00888)
Temperature shocks	0.00226	0.00273	0.00241	0.00346	0.00217	0.00354	0.00243	0.00286
	(0.0156)	(0.0155)	(0.0156)	(0.0155)	(0.0155)	(0.0156)	(0.0156)	(0.0156)
Precipitation shocks	0.000683	0.000658	0.000685	0.000637	0.000671	0.000651	0.000680	0.000667
	(0.000423)	(0.000422)	(0.000423)	(0.000422)	(0.000422)	(0.000422)	(0.000422)	(0.000422)
de jure environmental policy	0.0178	0.00457	0.0187*	0.00105	0.0104	0.00243	0.0148	0.00657
	(0.0119)	(0.0124)	(0.0113)	(0.00985)	(0.0116)	(0.0108)	(0.0115)	(0.0121)
De faco environmental policy	-0.0695	-0.0646	-0.0764	-0.0568	-0.0338	-0.0499	-0.0661	-0.0562
	(0.0645)	(0.0628)	(0.0644)	(0.0545)	(0.0633)	(0.0594)	(0.0646)	(0.0633)
EITI membership	**6.187*** **	**5.038*** **	**6.086*** **	**5.378*** **	**5.324*** **	**5.141*** **	**6.070*** **	**5.244*** **
	(1.273)	**(1.430)**	**(1.233)**	**(1.286)**	**(1.301)**	**(1.286)**	**(1.279)**	**(1.400)**
***de jure* environmental policy x EITI**	**-0.0574*** **	**-0.0450*** **	**-0.0561*** **	**-0.0433*** **	**-0.0493*** **	**-0.0467*** **	**-0.0548*** **	**-0.0474*** **
	(0.0142)	**(0.0151)**	**(0.0134)**	**(0.0131)**	**(0.0139)**	**(0.0138)**	**(0.0140)**	**(0.0148)**
***de facto* environmental policy x EITI**	**-0.453*** **	**-0.448*** **	**-0.448*** **	**-0.460*** **	**-0.482*** **	**-0.470*** **	**-0.458*** **	**-0.461*** **
	(0.0792)	(0.0789)	(0.0787)	(0.0708)	(0.0775)	(0.0750)	(0.0792)	(0.0781)
GDP per capita (log)	2.040	2.181	2.061	2.280*	2.060	2.305*	2.026	2.215*
	(1.318)	(1.327)	(1.314)	(1.301)	(1.325)	(1.316)	(1.319)	(1.324)
GDP per capita square (log)	-0.156*	-0.155*	-0.162*	-0.166*	-0.151*	-0.166*	-0.155*	-0.161*
	(0.0878)	(0.0885)	(0.0875)	(0.0856)	(0.0882)	(0.0873)	(0.0879)	(0.0881)
FDI	-0.00652*	-0.00612*	-0.00671**	-0.00624*	-0.00635*	-0.00637*	-0.00646*	-0.00628*
	(0.00338)	(0.00338)	(0.00338)	(0.00335)	(0.00337)	(0.00336)	(0.00338)	(0.00338)
ϕ	1.439***	-0.495	1.461***	-3.800***	-0.326	-1.408	1.442***	0.0269
	(0.296)	(1.320)	(0.302)	(0.176)	(0.821)	(1.092)	(0.296)	(0.868)
λ	0.0732	0.0692	0.0737	0.0796	0.0705	0.0789	0.0743	0.0737
	(0.0869)	(0.0875)	(0.0869)	(0.0865)	(0.0872)	(0.0870)	(0.0870)	(0.0873)
σ_μ	1.497***	1.542***	1.438***	1.220***	1.460***	1.396***	1.527***	1.564***
	(0.205)	(0.203)	(0.198)	(0.160)	(0.191)	(0.193)	(0.206)	(0.204)
σ_e	0.627***	0.625***	0.627***	0.625***	0.625***	0.625***	0.626***	0.625***
	(0.0189)	(0.0188)	(0.0189)	(0.0188)	(0.0188)	(0.0188)	(0.0189)	(0.0188)
AMU	-1.136							
	(1.276)							
COMESA		0.763						
		(0.822)						
ECCAS			1.440*					
			(0.786)					
ECOWAS				-1.497***				
				(0.329)				
SADC					1.244**			
					(0.534)			
UEMOA						-1.927***		
						(0.624)		
CEMAC							0.249	
							(0.857)	
WAMZ								-0.379
								(1.034)
Constant	-7.680	-7.789	-8.133	-7.112	-7.662	-7.314	-7.486	-7.552
	(4.956)	(4.968)	(4.960)	(4.878)	(4.953)	(4.916)	(4.959)	(4.966)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-647.3	-646.6	-646.1	-648.7	-644.8	-644.1	-647.6	-646.9

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

4.6 Robustness checks

We analyze the sensitivity of the estimates of the determinants of deforestation by adding additional control variables and by using alternative weighting matrices. In fact, spatial regression can be sensitive to the choice of weight matrices. In our baseline models we use inverse distance and population as weighting matrices. Hence, we check the sensitivity of the estimates to the weighting matrices.

4.6.1 Additional controls

Tables 4.A4a, 4.A4b and 4.A4c report the results of the estimates of the determinants of deforestation with control of corruption and forest rents as additional controls. The coefficients associated to both variables are statistically not significant. However, the results are in line with the previous findings. Mining increases deforestation while environmental policies (both *de jure* and *de facto*) are effective in EITI member countries. African regional economic communities have heterogeneous effects on deforestation as shown previously.

4.6.2 Alternative weighting matrices

We replace the inverse distance matrix with a contiguity matrix and the population weighting matrix with the GDP weighting matrix. The contiguity matrix is based on Rook contiguity. We use the same formula, as for the population matrix, to compute the GDP weighting matrix. This matrix captures the economic distance between countries. As shown in the Tables 4.A5a, 4.A5b and 4.A5c, our main results still hold. Comparing the results of Tables 4.A5a, 4.A5b and 4.A5c also shows that our estimates is not sensitive to the choice of the canopy cover. Mining increases deforestation. From Table 4.A6 to Table 4.A8, we use trade as weighting matrices for canopy cover >20%, >30% and >50% respectively. The results are also consistent with the previous findings. We observe an Environmental Kuznets Curve in accordance to the previous literature (Combes et al., 2015, 2018). The effects of climate shocks remain nonsignificant while the conclusion on regional economic communities still holds.

4.7 Conclusion

In the context of climate change, Africa is caught between a double imperative: mobilizing domestic revenue for financing development and protecting the environment. While the mining sector constitutes an opportunity for domestic revenue mobilization (Collier, 2010), it poses at the same time enormous environmental issues (Edwards et al., 2014). Deforestation is one of the environmental costs of mining activities. Indeed, mining activities are the fourth driver of forest landscape loss after industrial agriculture, infrastructure and urban expansion (Hosonuma et al., 2012; Potapov et al., 2017). However, the role of forest in mitigating climate change cannot be overstated according to the Intergovernmental Panel on Climate Change (Netz et al., 2007).

In this paper, we investigate how mining affects deforestation and environmental policies. We use two environmental policy measures for this purpose. A *de jure* environmental policy, which is the adherence of countries to international environmental treaties and a *de facto* measure which is the country's commitment to climate change mitigation proposed by Combes et al. (2016). Relying on a sample of 35 African countries over the period 2001-2017, we show that mining activity increases deforestation in Africa. An increase in mineral rent by a one-point percentage of GDP leads to forest loss of about 50 km^2. However, environmental policy contributes to reducing deforestation in resource-rich countries (member countries of the EITI).

Three main policy recommendations emerge from these results. First, international environmental treaties must be more binding. As African countries increasingly engage in environmental treaties, their actual commitment to mitigate climate change are slackening. Imaginative solutions that involve setting up clearly defined environmental rating systems (as the notations in finance) can motivate countries to strengthen their environmental standards due to the reputation stakes involved. Such notations have the advantage, not only for putting countries in a virtuous circle of environmental competition but also; they can be used to allocate funding in the Green Climate Fund (GCF) framework for instance.

Second, the coordination of environmental policies is imperative to avoid a race to the bottom. Regional economic communities are appropriate frameworks for such coordination. This coordination can be done by following the example of WAEMU and ECOWAS. However, it must be done through concrete actions and with monitoring and evaluation mechanisms to avoid free-riding. Such coordination can also help avoiding "Prisoner's Dilemma" while designing policies to attract foreign investment. Zhang et al. (2018) support that in China, central coordination enforces local environmental policy.

Third, at the country level, mining is an environmental cost often left to the affected local populations. Countries need to be much more careful about environmental aspects and put in place mechanisms that limit the effects of mining activity on deforestation.

We draw two future research prospects from our findings. First, there is no environmental policy data in developing countries for long period. Moreover, existing institutional quality data weakly document the environmental aspects of governance in developing countries specifically in Africa. Country international environmental treaty participation and domestic effort to climate mitigation are limited environmental policy measures. Future research focusing on developing world governance indicators (WGI) type dataset on environmental governance for developing countries is an important step for sound climate mitigation policies. Second, this study focuses on a sample of countries level analysis of deforestation. However, local case studies can give detailed insights on the extent to which mining activities affect deforestation and how to mitigate it.

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Appendix

Table 4.A1: Regional Economic Communities in Africa

Regional Economic Community	Offical State members	Member in the sample	Frequence
AMU	Algeria, Libya, Mauritania, Morocco, Tunisia	Morocco, Tunisia	6%
COMESA	Angola, Burundi, Comoros, D. R. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia, Zimbabwe	Burundi, D. R. Congo, Kenya, Madagascar, Malawi, Rwanda, Uganda, Zambia, Zimbabwe	31%
ECCAS	Burundi, Cameroon, C. Afr. Rep., Chad, D.R.Congo, Equatorial Guinea, Gabon, Rep. Congo, Rwanda, S. Tomé and Princ.	Burundi, Cameroon, C. Afr. Rep., Chad, D.R.Congo, Equatorial Guinea, Gabon, Rep. Congo, Rwanda	26%
ECOWAS	Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo	Benin, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo	31%
SADC	Angola, Botswana, D.R. Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe	Botswana, D.R. Congo, Malawi, Mozambique, Namibia, South Africa, Eswatini, Tanzania, Zambia, Zimbabwe	29%
UEMOA	Benin, Burkina Faso, Côte d'Ivoire, Guinea Bissau Mali Niger Senegal Togo	Benin, Côte d'Ivoire, Mali Niger Senegal Togo	17%
CEMAC	Cameroon, Chad, Congo Republique, Centrale Africa Republique, Equatorial Guinea, Gabon	Cameroon, Chad, Congo Republique, Centrale Africa Republique, Equatorial Guinea, Gabon	17%
WAMZ	Cape Verde, the Gambia, Ghana, Guinea, Liberia, Nigeria, Sierra Leone	Ghana, Guinea, Liberia, Nigeria, Sierra Leone	14%

Table 4.A2: Data sources and variables description

Variables	Definition	Type[a]	Sources
Deforestation	Three cover loss at different canopy cover (greater than 20%; 30% 50%)	Cont.	Hansen et al. (2013)
Temperature (Precipitation) shocks	Absolute value of the yearly average temperature (precipitation) deviation to its long-run trend	Cont.	University of East Anglia Climatic Research Unit
Mining rents	Mineral rents are the difference between the value of production for a stock of minerals at world prices and their total costs of production. Minerals included in the calculation are tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	Cont.	WDI (2019)
de facto environmental policy	An index of environmental policy build upon domestic effort for climate mitigation	Int.	Authors' computation based on Combes et al. (2016)
de jure environmental policy	A count of country adhesion to international environmental treaties	Cont.	Environmental Treaties and Resource Indicators dataset
Population	Population is the midyear estimate of the total population based on the *de facto* definition of population, which counts all residents regardless of legal status or citizenship.	Cont	WDI (2019)
Openness to trade	Openness to trade is the sum of exports and imports of goods and services (in % of GDP)	Cont.	WDI (2019)
Aid	Aid is the Net official development assistance (ODA) per capita. It consists of disbursements of loans made on concessional terms and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries.	Cont.	WDI (2019)
EITI membership	A dummy variable equal 1 if the country of a member of EITI and 0 otherwise.	Dum.	EITI website
Foreign Direct Investment	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP.	Cont.	WDI (2019)
GDP per capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes.	Cont.	WDI (2019)
Population density	Population density is midyear population divided by land area in square kilometers. The population is based on the *de facto* definition of population, which counts all residents.	Cont.	WDI (2019)
CO_2 emissions per capita	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Cont.	WDI (2019)
Control of corruption	"Control of corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as 'capture' of the state by elites and private interests."	Cont.	WGI(2019)
Forest rents	"Forest rents are roundwood harvest times the product of average prices and a region-specific rental rate."	Cont.	WDI(2019)

[a] Cont.: continuous; Int.: integer.; Dum.: dummy

Table 4.A3: System-GMM estimation of *de facto* environmental policy

Dependent variable: Log of CO_2 emissions per capita			
	(1)	(2)	(3)
L.CO2 emissions per capita (log)	0.874***	0.869***	0.880***
	(0.0792)	(0.0807)	(0.0895)
GDP per capita (log)	0.180*	0.215**	0.214*
	(0.0956)	(0.107)	(0.113)
Total population (log)	0.0510**	0.0700**	0.0739**
	(0.0243)	(0.0318)	(0.0342)
Openness to trade (log)	0.139*	0.197***	0.207**
	(0.0724)	(0.0762)	(0.0813)
Foreign Direct Investment (log)		-0.00190	-0.000535
		(0.00957)	(0.00993)
Aid per capita (log)			-0.000790
			(0.0214)
Constant	-2.804***	-3.643***	-3.714***
	(1.010)	(1.343)	(1.334)
Time fixed effects	Yes	Yes	Yes
# Observations	560	537	535
Number of countries	35	35	35
AR(1) p-value	0.000	0.000	0.000
AR(2) p-value	0.510	0.555	0.532
Hansen test p-value	0.142	0.220	0.283
Number of instruments	26	29	32

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$ Residuals from the complete specification (column 3) is used to compute the index of *de facto* policy.

Robustness of the estimates of the determinants of deforestation

Table 4.A4a: Determinants of deforestation with additional controls

	Dependent variable: Tree cover loss >20% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0565*****	**0.0542*****	**0.0560*****	**0.0575*****	**0.0552*****	**0.0559*****	**0.0564*****	**0.0556*****
	(0.00953)	**(0.00950)**	**(0.00950)**	**(0.00949)**	**(0.00949)**	**(0.00941)**	**(0.00952)**	**(0.00949)**
Temperature shocks	0.00570	0.00581	0.00646	0.00599	0.00594	0.00672	0.00561	0.00638
	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0169)	(0.0169)
Precipitation shocks	0.000614	0.000582	0.000608	0.000612	0.000627	0.000588	0.000615	0.000612
	(0.000442)	(0.000441)	(0.000441)	(0.000440)	(0.000441)	(0.000439)	(0.000442)	(0.000441)
de jure environmental policy	0.00189	-0.00320	0.000843	-0.000752	0.00186	-0.00503	0.000698	-0.00267
	(0.0121)	(0.0115)	(0.0118)	(0.0104)	(0.0116)	(0.0105)	(0.0117)	(0.0118)
De faco environmental policy	0.00798	0.0292	0.0161	0.0329	0.0533	0.0432	0.00920	0.0302
	(0.0685)	(0.0647)	(0.0665)	(0.0624)	(0.0670)	(0.0630)	(0.0684)	(0.0666)
EITI membership	**5.981*****	**5.511*****	**5.734*****	**6.279*****	**5.854*****	**5.737*****	**5.885*****	**5.665*****
	(1.307)	**(1.322)**	**(1.317)**	**(1.269)**	**(1.298)**	**(1.245)**	**(1.303)**	**(1.355)**
***de jure* environmental policy x EITI**	**-0.0462*****	**-0.0404*****	**-0.0451*****	**-0.0441*****	**-0.0458*****	**-0.0440*****	**-0.0445*****	**-0.0432*****
	(0.0143)	**(0.0140)**	**(0.0139)**	**(0.0130)**	**(0.0138)**	**(0.0132)**	**(0.0141)**	**(0.0143)**
***de facto* environmental policy x EITI**	**-0.562*****	**-0.573*****	**-0.570*****	**-0.591*****	**-0.606*****	**-0.595*****	**-0.559*****	**-0.584*****
	(0.0881)	(0.0821)	(0.0846)	(0.0808)	(0.0846)	(0.0811)	(0.0884)	(0.0849)
GDP per capita (log)	2.841**	2.893**	3.005**	2.576*	2.705*	2.779**	2.868**	2.880**
	(1.410)	(1.416)	(1.409)	(1.400)	(1.411)	(1.396)	(1.408)	(1.413)
GDP per capita square (log)	-0.190**	-0.183*	-0.203**	-0.177*	-0.176*	-0.188**	-0.192**	-0.188**
	(0.0929)	(0.0934)	(0.0932)	(0.0917)	(0.0932)	(0.0917)	(0.0928)	(0.0933)
Population density	-0.000601	-0.000796	-0.000536	5.05e-05	0.000678	-0.000390	-0.000702	1.43e-05
	(0.00224)	(0.00192)	(0.00198)	(0.00168)	(0.00193)	(0.00175)	(0.00225)	(0.00203)
FDI	-0.00599*	-0.00575*	-0.00625*	-0.00612*	-0.00599*	-0.00622*	-0.00593*	-0.00598*
	(0.00345)	(0.00345)	(0.00345)	(0.00343)	(0.00345)	(0.00343)	(0.00345)	(0.00344)
Control of corruption	-0.123	-0.134	-0.101	-0.110	-0.167	-0.113	-0.128	-0.137
	(0.152)	(0.150)	(0.153)	(0.146)	(0.152)	(0.147)	(0.152)	(0.151)
Forest rents	-0.000855	-0.00416	-0.00359	-3.84e-05	-0.000192	-0.00673	-0.00103	-0.00159
	(0.0158)	(0.0156)	(0.0157)	(0.0155)	(0.0156)	(0.0155)	(0.0158)	(0.0158)
ϕ	2.379***	-0.825	0.224	-1.550*	-0.178	-1.364	2.387***	0.166
	(0.330)	(1.159)	(0.547)	(0.888)	(0.745)	(1.033)	(0.333)	(0.745)
λ	0.407***	0.403***	0.409***	0.411***	0.394***	0.424***	0.410***	0.404***
	(0.0744)	(0.0739)	(0.0740)	(0.0726)	(0.0741)	(0.0731)	(0.0743)	(0.0748)
σ_μ	1.511***	1.420***	1.411***	1.203***	1.395***	1.248***	1.504***	1.477***
	(0.223)	(0.201)	(0.202)	(0.186)	(0.194)	(0.186)	(0.223)	(0.206)
σ_e	0.647***	0.647***	0.647***	0.647***	0.647***	0.646***	0.647***	0.647***
	(0.0198)	(0.0198)	(0.0198)	(0.0198)	(0.0198)	(0.0197)	(0.0198)	(0.0198)
AMU	-0.0337							
	(1.316)							
COMESA		1.173*						
		(0.703)						
ECCAS			0.918					
			(0.624)					
ECOWAS				-1.594***				
				(0.372)				
SADC					1.157**			
					(0.543)			
UEMOA						-2.094***		
						(0.576)		
CEMAC							-0.466	
							(0.879)	
WAMZ								-0.199
								(1.010)
Constant	-10.54*	-11.16**	-11.02**	-8.820*	-10.62**	-9.206*	-10.49*	-10.44*
	(5.404)	(5.431)	(5.403)	(5.337)	(5.366)	(5.329)	(5.378)	(5.400)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-674.0	-671.8	-671.7	-668.1	-670.8	-668.7	-673.9	-672.7

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A4b: Determinants of deforestation with additional controls

	Dependent variable: Tree cover loss >30% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0511*** **	**0.0491*** **	**0.0512*** **	**0.0512*** **	**0.0496*** **	**0.0503*** **	**0.0511*** **	**0.0511*** **
	(0.00979)	**(0.00981)**	**(0.00979)**	**(0.00974)**	**(0.00973)**	**(0.00968)**	**(0.00979)**	**(0.00977)**
Temperature shocks	0.00577	0.00626	0.00584	0.00654	0.00586	0.00715	0.00591	0.00601
	(0.0172)	(0.0171)	(0.0172)	(0.0171)	(0.0171)	(0.0171)	(0.0172)	(0.0172)
Precipitation shocks	0.000705	0.000672	0.000704	0.000691	0.000708	0.000670	0.000706	0.000699
	(0.000456)	(0.000456)	(0.000456)	(0.000454)	(0.000455)	(0.000454)	(0.000456)	(0.000456)
de jure environmental policy	0.0213	0.00673	0.0220*	0.00769	0.0134	0.00386	0.0177	0.0175
	(0.0134)	(0.0141)	(0.0128)	(0.0121)	(0.0128)	(0.0123)	(0.0129)	(0.0127)
De faco environmental policy	-0.0195	-0.0137	-0.0247	-0.0103	0.0210	-0.00280	-0.0151	-0.0169
	(0.0708)	(0.0692)	(0.0707)	(0.0672)	(0.0689)	(0.0668)	(0.0709)	(0.0707)
EITI membership	**7.260*** **	**5.901*** **	**7.149*** **	**6.582*** **	**6.306*** **	**6.020*** **	**7.120*** **	**7.195*** **
	(1.428)	**(1.662)**	**(1.395)**	**(1.443)**	**(1.441)**	**(1.455)**	**(1.436)**	**(1.428)**
***de jure* environmental policy x EITI**	**-0.0648*** **	**-0.0506*** **	**-0.0631*** **	**-0.0527*** **	**-0.0561*** **	**-0.0524*** **	**-0.0616*** **	**-0.0629*** **
	(0.0157)	**(0.0171)**	**(0.0150)**	**(0.0150)**	**(0.0152)**	**(0.0153)**	**(0.0155)**	**(0.0153)**
***de facto* environmental policy x EITI**	**-0.565*** **	**-0.559*** **	**-0.562*** **	**-0.578*** **	**-0.598*** **	**-0.580*** **	**-0.571*** **	**-0.568*** **
	(0.0884)	(0.0886)	(0.0879)	(0.0844)	(0.0853)	(0.0843)	(0.0885)	(0.0885)
GDP per capita (log)	2.571*	2.796*	2.603*	2.583*	2.457*	2.762*	2.541*	2.568*
	(1.494)	(1.502)	(1.490)	(1.479)	(1.486)	(1.478)	(1.497)	(1.493)
GDP per capita square (log)	-0.176*	-0.181*	-0.182*	-0.177*	-0.163*	-0.186*	-0.174*	-0.176*
	(0.0983)	(0.0985)	(0.0981)	(0.0974)	(0.0981)	(0.0975)	(0.0985)	(0.0983)
Population density	0.000154	-0.000160	-9.73e-05	0.000537	0.00129	0.000244	0.000301	4.81e-05
	(0.00214)	(0.00215)	(0.00214)	(0.00180)	(0.00188)	(0.00182)	(0.00216)	(0.00218)
FDI	-0.00648*	-0.00612*	-0.00664*	-0.00643*	-0.00630*	-0.00644*	-0.00642*	-0.00638*
	(0.00359)	(0.00359)	(0.00359)	(0.00357)	(0.00358)	(0.00357)	(0.00359)	(0.00359)
Control of corruption	-0.0741	-0.0667	-0.0527	-0.0367	-0.108	-0.0417	-0.0762	-0.0806
	(0.160)	(0.159)	(0.160)	(0.158)	(0.159)	(0.158)	(0.160)	(0.159)
Forest rents	-0.00306	-0.00616	-0.00420	-0.00353	-0.00203	-0.00802	-0.00292	-0.00414
	(0.0162)	(0.0162)	(0.0162)	(0.0159)	(0.0160)	(0.0159)	(0.0162)	(0.0162)
ϕ	1.436***	-0.572	1.471***	-1.257	-0.629	-1.369	1.443***	1.476***
	(0.294)	(1.593)	(0.300)	(0.901)	(0.894)	(1.100)	(0.295)	(0.290)
λ	0.283***	0.285***	0.284***	0.287***	0.275***	0.296***	0.284***	0.288***
	(0.0792)	(0.0803)	(0.0792)	(0.0800)	(0.0797)	(0.0806)	(0.0796)	(0.0797)
σ_μ	1.720***	1.777***	1.675***	1.583***	1.628***	1.610***	1.757***	1.739***
	(0.239)	(0.240)	(0.233)	(0.219)	(0.217)	(0.226)	(0.240)	(0.238)
σ_e	0.667***	0.666***	0.668***	0.666***	0.666***	0.665***	0.667***	0.667***
	(0.0203)	(0.0202)	(0.0203)	(0.0202)	(0.0202)	(0.0201)	(0.0203)	(0.0203)
AMU	-1.246							
	(1.469)							
COMESA		0.966						
		(1.174)						
ECCAS			1.449					
			(0.929)					
ECOWAS				-1.698***				
				(0.491)				
SADC					1.667***			
					(0.563)			
UEMOA						-2.251***		
						(0.737)		
CEMAC							0.132	
							(0.992)	
WAMZ								0.778
								(1.022)
Constant	-10.77*	-10.98*	-11.20**	-9.175	-10.35*	-9.543*	-10.47*	-10.65*
	(5.692)	(5.731)	(5.695)	(5.601)	(5.609)	(5.584)	(5.689)	(5.685)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-691.6	-691.0	-690.8	-688.0	-688.2	-688.5	-691.9	-691.6

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A4c: Determinants of deforestation with additional controls

	Dependent variable: Tree cover loss >50% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0433******	**0.0413******	**0.0435******	**0.0433******	**0.0415******	**0.0421******	**0.0434******	**0.0421******
	(0.00897)	**(0.00899)**	**(0.00897)**	**(0.00886)**	**(0.00891)**	**(0.00887)**	**(0.00897)**	**(0.00893)**
Temperature shocks	0.00219	0.00265	0.00223	0.00305	0.00224	0.00342	0.00237	0.00283
	(0.0156)	(0.0155)	(0.0156)	(0.0155)	(0.0155)	(0.0155)	(0.0155)	(0.0155)
Precipitation shocks	0.000676	0.000644	0.000673	0.000631	0.000674	0.000637	0.000676	0.000663
	(0.000424)	(0.000423)	(0.000424)	(0.000422)	(0.000422)	(0.000422)	(0.000423)	(0.000422)
de jure environmental policy	0.0175	0.00441	0.0188*	0.00119	0.00961	0.00210	0.0146	0.00574
	(0.0121)	(0.0124)	(0.0114)	(0.00990)	(0.0116)	(0.0108)	(0.0116)	(0.0123)
De faco environmental policy	-0.0673	-0.0624	-0.0751	-0.0617	-0.0361	-0.0510	-0.0641	-0.0560
	(0.0650)	(0.0633)	(0.0648)	(0.0584)	(0.0635)	(0.0609)	(0.0651)	(0.0637)
EITI membership	**6.208******	**5.056******	**6.105******	**5.531******	**5.381******	**5.211******	**6.113******	**5.246******
	(1.283)	**(1.440)**	**(1.242)**	**(1.300)**	**(1.306)**	**(1.285)**	**(1.291)**	**(1.408)**
***de jure* environmental policy x EITI**	**-0.0573******	**-0.0448******	**-0.0560******	**-0.0432******	**-0.0492******	**-0.0465******	**-0.0550******	**-0.0470******
	(0.0143)	**(0.0152)**	**(0.0135)**	**(0.0131)**	**(0.0140)**	**(0.0138)**	**(0.0141)**	**(0.0149)**
***de facto* environmental policy x EITI**	**-0.464******	**-0.460******	**-0.460******	**-0.466******	**-0.489******	**-0.481******	**-0.471******	**-0.472******
	(0.0810)	(0.0800)	(0.0802)	(0.0747)	(0.0785)	(0.0766)	(0.0810)	(0.0794)
GDP per capita (log)	1.751	1.916	1.772	1.858	1.684	1.908	1.693	1.854
	(1.392)	(1.397)	(1.386)	(1.361)	(1.388)	(1.377)	(1.396)	(1.393)
GDP per capita square (log)	-0.140	-0.140	-0.146	-0.141	-0.129	-0.143	-0.137	-0.140
	(0.0914)	(0.0917)	(0.0911)	(0.0891)	(0.0914)	(0.0906)	(0.0916)	(0.0917)
Population density	0.000466	0.000203	0.000168	0.000614	0.00123	0.000588	0.000679	0.000829
	(0.00187)	(0.00181)	(0.00186)	(0.00134)	(0.00164)	(0.00152)	(0.00188)	(0.00173)
FDI	-0.00653*	-0.00607*	-0.00676**	-0.00623*	-0.00624*	-0.00628*	-0.00648*	-0.00623*
	(0.00340)	(0.00340)	(0.00340)	(0.00337)	(0.00339)	(0.00338)	(0.00340)	(0.00339)
Control of corruption	0.0701	0.0662	0.0948	0.106	0.0324	0.0807	0.0709	0.0631
	(0.151)	(0.150)	(0.151)	(0.143)	(0.151)	(0.148)	(0.152)	(0.151)
Forest rents	-0.00748	-0.0104	-0.00853	-0.00725	-0.00764	-0.0121	-0.00727	-0.00854
	(0.0147)	(0.0147)	(0.0147)	(0.0144)	(0.0146)	(0.0145)	(0.0147)	(0.0147)
ϕ	1.437***	-0.497	1.455***	-3.800***	-0.393	-1.484	1.439***	-0.0507
	(0.297)	(1.319)	(0.303)	(0.176)	(0.840)	(1.065)	(0.298)	(0.917)
λ	0.0684	0.0664	0.0695	0.0673	0.0621	0.0718	0.0681	0.0663
	(0.0881)	(0.0886)	(0.0881)	(0.0883)	(0.0885)	(0.0885)	(0.0883)	(0.0886)
σ_μ	1.520***	1.562***	1.453***	1.228***	1.476***	1.405***	1.549***	1.587***
	(0.211)	(0.209)	(0.203)	(0.163)	(0.196)	(0.196)	(0.212)	(0.208)
σ_e	0.626***	0.624***	0.626***	0.624***	0.624***	0.624***	0.625***	0.624***
	(0.0189)	(0.0188)	(0.0189)	(0.0188)	(0.0188)	(0.0187)	(0.0189)	(0.0188)
AMU	-1.129							
	(1.299)							
COMESA		0.750						
		(0.873)						
ECCAS			1.506*					
			(0.803)					
ECOWAS				-1.522***				
				(0.332)				
SADC					1.276**			
					(0.536)			
UEMOA						-1.979***		
						(0.622)		
CEMAC							0.312	
							(0.877)	
WAMZ								-0.430
								(1.045)
Constant	-6.374	-6.542	-6.802	-5.442	-6.117	-5.570	-6.039	-5.956
	(5.299)	(5.320)	(5.289)	(5.125)	(5.242)	(5.196)	(5.301)	(5.295)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-647.0	-646.3	-645.7	-648.2	-644.3	-643.5	-647.3	-646.5

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A5a: Determinants of deforestation with different matrices

	Dependent variable: Tree cover loss >20% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0461***** **(0.00930)**	**0.0451***** **(0.00929)**	**0.0465***** **(0.00931)**	**0.0482***** **(0.00931)**	**0.0460***** **(0.00928)**	**0.0470***** **(0.00926)**	**0.0461***** **(0.00931)**	**0.0461***** **(0.00928)**
Temperature shocks	0.00733 (0.0168)	0.00667 (0.0168)	0.00745 (0.0168)	0.00695 (0.0168)	0.00657 (0.0168)	0.00737 (0.0169)	0.00737 (0.0168)	0.00727 (0.0168)
Precipitation shocks	0.000722 (0.000451)	0.000703 (0.000451)	0.000720 (0.000451)	0.000730 (0.000451)	0.000739 (0.000451)	0.000716 (0.000451)	0.000722 (0.000451)	0.000728 (0.000451)
de jure environmental policy	0.00300 (0.0129)	0.00185 (0.0118)	0.00468 (0.0119)	0.00399 (0.0111)	0.00724 (0.0117)	0.00103 (0.0113)	0.00168 (0.0119)	0.00167 (0.0118)
De faco environmental policy	0.0515 (0.0695)	0.0549 (0.0679)	0.0436 (0.0691)	0.0675 (0.0649)	0.0721 (0.0698)	0.0713 (0.0676)	0.0522 (0.0694)	0.0563 (0.0690)
EITI membership	**6.346***** **(1.419)**	**6.031***** **(1.422)**	**6.328***** **(1.378)**	**6.575***** **(1.332)**	**6.544***** **(1.335)**	**6.289***** **(1.391)**	**6.282***** **(1.401)**	**6.229***** **(1.396)**
***de jure* environmental policy x EITI**	**-0.0484***** **(0.0155)**	**-0.0432***** **(0.0151)**	**-0.0485***** **(0.0146)**	**-0.0462***** **(0.0140)**	**-0.0499***** **(0.0143)**	**-0.0471***** **(0.0146)**	**-0.0472***** **(0.0149)**	**-0.0459***** **(0.0149)**
***de facto* environmental policy x EITI**	**-0.640***** (0.0862)	**-0.634***** (0.0838)	**-0.633***** (0.0861)	**-0.657***** (0.0831)	**-0.657***** (0.0860)	**-0.656***** (0.0846)	**-0.641***** (0.0865)	**-0.646***** (0.0860)
GDP per capita (log)	2.155 (1.493)	2.039 (1.491)	2.251 (1.487)	1.713 (1.478)	1.931 (1.480)	1.894 (1.481)	2.122 (1.489)	2.069 (1.490)
GDP per capita square (log)	-0.128 (0.0984)	-0.116 (0.0983)	-0.139 (0.0982)	-0.109 (0.0968)	-0.115 (0.0975)	-0.116 (0.0973)	-0.125 (0.0980)	-0.123 (0.0981)
Population density	0.00244 (0.00200)	0.00187 (0.00194)	0.00213 (0.00200)	0.00286 (0.00179)	0.00289 (0.00194)	0.00242 (0.00191)	0.00249 (0.00203)	0.00278 (0.00199)
FDI	-0.00598* (0.00363)	-0.00577 (0.00363)	-0.00625* (0.00364)	-0.00622* (0.00362)	-0.00599* (0.00363)	-0.00614* (0.00363)	-0.00594 (0.00364)	-0.00596 (0.00363)
Control of corruption	-0.0522 (0.161)	-0.0571 (0.160)	-0.0210 (0.163)	-0.0357 (0.157)	-0.0850 (0.162)	-0.0349 (0.159)	-0.0528 (0.163)	-0.0553 (0.161)
Forest rents	0.00173 (0.0161)	0.000684 (0.0161)	0.000384 (0.0161)	0.00361 (0.0160)	0.00352 (0.0161)	-0.00126 (0.0161)	0.00183 (0.0161)	0.00313 (0.0162)
ϕ	0.0288 (0.246)	-0.265 (0.327)	-0.0123 (0.250)	-0.426 (0.273)	-0.00787 (0.278)	-0.265 (0.311)	0.0239 (0.253)	-0.0769 (0.290)
λ	0.140* (0.0822)	0.143* (0.0820)	0.143* (0.0821)	0.157* (0.0816)	0.143* (0.0809)	0.165** (0.0835)	0.141* (0.0823)	0.138* (0.0818)
σ_μ	1.581*** (0.224)	1.521*** (0.217)	1.537*** (0.220)	1.345*** (0.204)	1.468*** (0.210)	1.419*** (0.209)	1.584*** (0.224)	1.581*** (0.221)
σ_e	0.667*** (0.0201)	0.667*** (0.0201)	0.667*** (0.0201)	0.667*** (0.0202)	0.667*** (0.0201)	0.667*** (0.0201)	0.667*** (0.0201)	0.666*** (0.0201)
AMU	-0.349 (1.336)							
COMESA		1.147 (0.737)						
ECCAS			0.808 (0.645)					
ECOWAS				-1.581*** (0.434)				
SADC					1.313** (0.617)			
UEMOA						-1.728*** (0.626)		
CEMAC							0.0219 (0.856)	
WAMZ								-0.616 (0.944)
Constant	-9.091 (5.746)	-9.146 (5.716)	-9.504* (5.722)	-6.727 (5.659)	-8.984 (5.654)	-7.394 (5.689)	-8.911 (5.715)	-8.639 (5.718)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-683.8	-682.8	-683.1	-679.7	-681.5	-680.9	-683.8	-683.6

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A5b: Determinants of deforestation with different matrices

	Dependent variable: Tree cover loss >30% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0430***** **(0.00944)**	**0.0424***** **(0.00945)**	**0.0433***** **(0.00944)**	**0.0440***** **(0.00940)**	**0.0428***** **(0.00940)**	**0.0434***** **(0.00939)**	**0.0431***** **(0.00944)**	**0.0430***** **(0.00942)**
Temperature shocks	0.00744 (0.0168)	0.00735 (0.0168)	0.00760 (0.0168)	0.00752 (0.0168)	0.00666 (0.0168)	0.00786 (0.0168)	0.00763 (0.0168)	0.00752 (0.0168)
Precipitation shocks	0.000781* (0.000457)	0.000770* (0.000457)	0.000779* (0.000457)	0.000782* (0.000457)	0.000798* (0.000457)	0.000773* (0.000457)	0.000782* (0.000457)	0.000784* (0.000457)
de jure environmental policy	0.0169 (0.0144)	0.0101 (0.0135)	0.0153 (0.0135)	0.0104 (0.0126)	0.0162 (0.0133)	0.00902 (0.0130)	0.0117 (0.0135)	0.0106 (0.0134)
De faco environmental policy	-0.00242 (0.0719)	-0.00228 (0.0712)	-0.00881 (0.0721)	0.00650 (0.0691)	0.0260 (0.0709)	0.0110 (0.0701)	0.00171 (0.0718)	0.00344 (0.0714)
EITI membership	**6.897***** **(1.603)**	**6.389***** **(1.668)**	**6.818***** **(1.564)**	**6.745***** **(1.521)**	**6.724***** **(1.526)**	**6.551***** **(1.616)**	**6.670***** **(1.606)**	**6.531***** **(1.597)**
***de jure* environmental policy x EITI**	**-0.0616***** **(0.0170)**	**-0.0533***** **(0.0171)**	**-0.0587***** **(0.0161)**	**-0.0536***** **(0.0158)**	**-0.0579***** **(0.0161)**	**-0.0553***** **(0.0165)**	**-0.0570***** **(0.0165)**	**-0.0547***** **(0.0166)**
***de facto* environmental policy x EITI**	**-0.610***** (0.0868)	**-0.607***** (0.0869)	**-0.607***** (0.0868)	**-0.627***** (0.0848)	**-0.634***** (0.0853)	**-0.628***** (0.0854)	**-0.616***** (0.0869)	**-0.617***** (0.0866)
GDP per capita (log)	2.275 (1.529)	2.213 (1.531)	2.314 (1.528)	1.989 (1.520)	1.926 (1.523)	2.104 (1.523)	2.186 (1.530)	2.168 (1.529)
GDP per capita square (log)	-0.146 (0.101)	-0.139 (0.101)	-0.152 (0.101)	-0.133 (0.0999)	-0.124 (0.100)	-0.137 (0.100)	-0.140 (0.101)	-0.139 (0.101)
Population density	0.00168 (0.00199)	0.00154 (0.00202)	0.00150 (0.00201)	0.00226 (0.00185)	0.00251 (0.00189)	0.00198 (0.00191)	0.00197 (0.00200)	0.00209 (0.00198)
FDI	-0.00665* (0.00370)	-0.00639* (0.00369)	-0.00678* (0.00370)	-0.00668* (0.00369)	-0.00655* (0.00369)	-0.00659* (0.00369)	-0.00650* (0.00370)	-0.00649* (0.00369)
Control of corruption	-0.00484 (0.165)	-0.00656 (0.164)	0.0185 (0.166)	0.0146 (0.163)	-0.0438 (0.165)	0.00693 (0.164)	-0.00767 (0.166)	-0.01000 (0.165)
Forest rents	-0.000996 (0.0161)	-0.00167 (0.0161)	-0.00194 (0.0161)	0.000107 (0.0160)	0.00114 (0.0161)	-0.00285 (0.0161)	-0.000685 (0.0161)	2.13e-05 (0.0162)
ϕ	0.0720 (0.252)	-0.0908 (0.339)	0.0762 (0.250)	-0.281 (0.271)	-0.0917 (0.286)	-0.176 (0.303)	0.0576 (0.253)	-0.0208 (0.291)
λ	0.0552 (0.0840)	0.0575 (0.0847)	0.0569 (0.0843)	0.0625 (0.0844)	0.0623 (0.0834)	0.0672 (0.0855)	0.0571 (0.0846)	0.0562 (0.0844)
σ_μ	1.806*** (0.246)	1.839*** (0.243)	1.795*** (0.243)	1.694*** (0.226)	1.679*** (0.225)	1.747*** (0.231)	1.854*** (0.247)	1.853*** (0.244)
σ_e	0.677*** (0.0204)	0.676*** (0.0203)	0.677*** (0.0204)	0.676*** (0.0203)	0.677*** (0.0204)	0.676*** (0.0203)	0.676*** (0.0203)	0.676*** (0.0203)
AMU	-1.520 (1.509)							
COMESA		0.719 (0.937)						
ECCAS			0.985 (0.807)					
ECOWAS				-1.658*** (0.578)				
SADC					1.722*** (0.641)			
UEMOA						-1.770** (0.790)		
CEMAC							0.155 (0.978)	
WAMZ								-0.615 (1.087)
Constant	-9.619 (5.857)	-9.363 (5.867)	-9.850* (5.874)	-7.515 (5.809)	-8.933 (5.788)	-8.075 (5.833)	-9.103 (5.859)	-8.863 (5.867)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-696.4	-696.6	-696.1	-694.0	-693.7	-694.8	-696.9	-696.7

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A5c: Determinants of deforestation with different matrices

	Dependent variable: Tree cover loss >50% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0402*** **	**0.0397*** **	**0.0407*** **	**0.0410*** **	**0.0400*** **	**0.0405*** **	**0.0405*** **	**0.0402*** **
	(0.00865)	**(0.00867)**	**(0.00865)**	**(0.00861)**	**(0.00863)**	**(0.00861)**	**(0.00866)**	**(0.00863)**
Temperature shocks	0.00427	0.00422	0.00450	0.00426	0.00363	0.00468	0.00455	0.00438
	(0.0151)	(0.0151)	(0.0151)	(0.0151)	(0.0152)	(0.0152)	(0.0151)	(0.0151)
Precipitation shocks	0.000660	0.000650	0.000654	0.000657	0.000674	0.000649	0.000659	0.000660
	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000419)
de jure environmental policy	0.0123	0.00620	0.0113	0.00544	0.0115	0.00486	0.00750	0.00622
	(0.0129)	(0.0121)	(0.0119)	(0.0112)	(0.0121)	(0.0117)	(0.0120)	(0.0121)
De faco environmental policy	-0.0733	-0.0716	-0.0835	-0.0609	-0.0520	-0.0584	-0.0697	-0.0669
	(0.0657)	(0.0651)	(0.0653)	(0.0626)	(0.0654)	(0.0640)	(0.0654)	(0.0653)
EITI membership	**5.763*** **	**5.361*** **	**5.596*** **	**5.536*** **	**5.676*** **	**5.468*** **	**5.525*** **	**5.403*** **
	(1.408)	**(1.452)**	**(1.363)**	**(1.350)**	**(1.348)**	**(1.431)**	**(1.417)**	**(1.429)**
***de jure* environmental policy x EITI**	**-0.0542*** **	**-0.0471*** **	**-0.0512*** **	**-0.0457*** **	**-0.0512*** **	**-0.0483*** **	**-0.0502*** **	**-0.0478*** **
	(0.0152)	**(0.0152)**	**(0.0143)**	**(0.0142)**	**(0.0144)**	**(0.0149)**	**(0.0148)**	**(0.0151)**
***de facto* environmental policy x EITI**	**-0.474*** **	**-0.475*** **	**-0.468*** **	**-0.495*** **	**-0.495*** **	**-0.495*** **	**-0.482*** **	**-0.482*** **
	(0.0792)	(0.0789)	(0.0786)	(0.0768)	(0.0784)	(0.0776)	(0.0791)	(0.0789)
GDP per capita (log)	2.025	1.955	2.085	1.720	1.734	1.854	1.919	1.930
	(1.395)	(1.398)	(1.390)	(1.387)	(1.394)	(1.390)	(1.397)	(1.396)
GDP per capita square (log)	-0.153*	-0.145	-0.162*	-0.136	-0.135	-0.142	-0.146	-0.146
	(0.0918)	(0.0919)	(0.0915)	(0.0911)	(0.0917)	(0.0914)	(0.0917)	(0.0918)
Population density	0.000852	0.000792	0.000602	0.00147	0.00150	0.00120	0.00123	0.00122
	(0.00174)	(0.00176)	(0.00172)	(0.00159)	(0.00169)	(0.00165)	(0.00175)	(0.00174)
FDI	-0.00644*	-0.00619*	-0.00666*	-0.00640*	-0.00637*	-0.00633*	-0.00634*	-0.00626*
	(0.00340)	(0.00340)	(0.00340)	(0.00339)	(0.00340)	(0.00339)	(0.00340)	(0.00340)
Control of corruption	0.0766	0.0715	0.111	0.0820	0.0483	0.0785	0.0796	0.0688
	(0.150)	(0.150)	(0.152)	(0.148)	(0.151)	(0.149)	(0.152)	(0.150)
Forest rents	-0.00690	-0.00741	-0.00801	-0.00574	-0.00549	-0.00845	-0.00655	-0.00628
	(0.0144)	(0.0144)	(0.0144)	(0.0143)	(0.0144)	(0.0143)	(0.0144)	(0.0144)
ϕ	0.0977	-0.0336	0.0423	-0.313	0.0308	-0.155	0.0512	0.00288
	(0.251)	(0.316)	(0.254)	(0.277)	(0.278)	(0.305)	(0.259)	(0.314)
λ	-0.0728	-0.0694	-0.0726	-0.0649	-0.0651	-0.0625	-0.0711	-0.0702
	(0.0877)	(0.0882)	(0.0879)	(0.0880)	(0.0875)	(0.0888)	(0.0880)	(0.0880)
σ_μ	1.563***	1.597***	1.517***	1.462***	1.497***	1.514***	1.602***	1.609***
	(0.212)	(0.210)	(0.205)	(0.194)	(0.202)	(0.198)	(0.212)	(0.212)
σ_e	0.624***	0.624***	0.624***	0.624***	0.624***	0.624***	0.624***	0.624***
	(0.0188)	(0.0188)	(0.0188)	(0.0188)	(0.0188)	(0.0188)	(0.0188)	(0.0188)
AMU	-1.375							
	(1.316)							
COMESA		0.535						
		(0.775)						
ECCAS			1.199*					
			(0.666)					
ECOWAS				-1.484***				
				(0.493)				
SADC					1.324**			
					(0.634)			
UEMOA						-1.588**		
						(0.687)		
CEMAC							0.426	
							(0.855)	
WAMZ								-0.422
								(1.016)
Constant	-6.980	-6.698	-7.252	-4.925	-6.384	-5.597	-6.401	-6.310
	(5.327)	(5.338)	(5.319)	(5.281)	(5.285)	(5.300)	(5.336)	(5.350)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-646.0	-646.3	-645.0	-643.5	-644.4	-644.3	-646.4	-646.5

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ We estimate the same equation from column (1) to (8), controlling respectively AMU, COMESA, ECCAS, ECOWAS, SADC, WAEMU, CEMAC and WAMZ.

Table 4.A6: Robustness: With trade matrix

	Dependent variable: Tree cover loss >20% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0453*** **	**0.0434*** **	**0.0452*** **	**0.0465*** **	**0.0444*** **	**0.0454*** **	**0.0453*** **	**0.0456*** **
	(0.00923)	**(0.00917)**	**(0.00921)**	**(0.00922)**	**(0.00918)**	**(0.00916)**	**(0.00922)**	**(0.00923)**
Temperature shocks	0.00731	0.00707	0.00796	0.00772	0.00706	0.00831	0.00725	0.00747
	(0.0168)	(0.0168)	(0.0168)	(0.0169)	(0.0168)	(0.0169)	(0.0168)	(0.0168)
Precipitation shocks	0.000730	0.000707	0.000731	0.000728	0.000734	0.000722	0.000731	0.000729
	(0.000451)	(0.000450)	(0.000451)	(0.000451)	(0.000451)	(0.000451)	(0.000451)	(0.000451)
de jure environmental policy	0.00386	-0.00115	0.00295	0.00103	0.00307	-0.00281	0.00216	0.00285
	(0.0126)	(0.0117)	(0.0122)	(0.0109)	(0.0120)	(0.0110)	(0.0122)	(0.0119)
de facto environmental policy	0.00594	0.0274	0.0180	0.0467	0.0548	0.0513	0.00788	0.0100
	(0.0690)	(0.0646)	(0.0669)	(0.0620)	(0.0681)	(0.0632)	(0.0689)	(0.0678)
EITI membership	**6.166*** **	**5.741*** **	**5.941*** **	**6.447*** **	**5.904*** **	**5.918*** **	**6.065*** **	**6.324*** **
	(1.350)	**(1.348)**	**(1.359)**	**(1.307)**	**(1.339)**	**(1.283)**	**(1.345)**	**(1.337)**
***de jure* environmental policy x EITI**	**-0.0459*** **	**-0.0390*** **	**-0.0445*** **	**-0.0434*** **	**-0.0438*** **	**-0.0432*** **	**-0.0438*** **	**-0.0469*** **
	(0.0150)	**(0.0145)**	**(0.0146)**	**(0.0136)**	**(0.0144)**	**(0.0139)**	**(0.0148)**	**(0.0145)**
***de facto* environmental policy x EITI**	**-0.604*** **	**-0.615*** **	**-0.613*** **	**-0.643*** **	**-0.646*** **	**-0.643*** **	**-0.603*** **	**-0.608*** **
	(0.0856)	(0.0814)	(0.0838)	(0.0804)	(0.0842)	(0.0813)	(0.0856)	(0.0848)
GDP per capita (log)	3.052**	3.084**	3.338**	2.981**	3.075**	3.227**	3.044**	3.036**
	(1.396)	(1.413)	(1.407)	(1.409)	(1.410)	(1.402)	(1.395)	(1.399)
GDP per capita square (log)	-0.196**	-0.188**	-0.217**	-0.197**	-0.196**	-0.209**	-0.195**	-0.195**
	(0.0933)	(0.0941)	(0.0939)	(0.0929)	(0.0937)	(0.0930)	(0.0932)	(0.0932)
FDI	-0.00553	-0.00534	-0.00581	-0.00560	-0.00562	-0.00573	-0.00546	-0.00549
	(0.00358)	(0.00357)	(0.00357)	(0.00356)	(0.00357)	(0.00356)	(0.00358)	(0.00357)
ϕ	2.400***	-0.974	0.218	-1.511*	-0.0772	-1.372	2.405***	1.468***
	(0.342)	(1.062)	(0.544)	(0.915)	(0.699)	(1.075)	(0.343)	(0.291)
λ	0.194***	0.190***	0.200***	0.215***	0.202***	0.219***	0.197***	0.198***
	(0.0721)	(0.0715)	(0.0715)	(0.0706)	(0.0713)	(0.0709)	(0.0720)	(0.0718)
σ_{mu}	1.647***	1.514***	1.521***	1.304***	1.502***	1.352***	1.644***	1.551***
	(0.235)	(0.209)	(0.212)	(0.200)	(0.207)	(0.203)	(0.235)	(0.220)
σ_e	0.665***	0.664***	0.665***	0.665***	0.664***	0.665***	0.665***	0.665***
	(0.0201)	(0.0200)	(0.0201)	(0.0201)	(0.0201)	(0.0201)	(0.0201)	(0.0201)
AMU	-0.320							
	(1.419)							
COMESA		1.380**						
		(0.648)						
ECCAS			1.014					
			(0.654)					
ECOWAS				-1.643***				
				(0.403)				
SADC					1.139*			
					(0.585)			
UEMOA						-2.133***		
						(0.638)		
CEMAC							-0.396	
							(0.953)	
WAMZ								0.719
								(0.905)
Constant	-11.88**	-12.55**	-12.89**	-10.73**	-12.21**	-11.49**	-11.69**	-11.97**
	(5.291)	(5.330)	(5.342)	(5.320)	(5.323)	(5.281)	(5.280)	(5.308)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-684.5	-681.9	-682.2	-679.2	-681.7	-680.0	-684.5	-683.7

Notes: Estimates using trade and contiguity matrices. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4.A7: Robustness: With trade matrix

	Dependent variable: Tree cover loss >30% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0436*** **	**0.0416*** **	**0.0437*** **	**0.0439*** **	**0.0424*** **	**0.0433*** **	**0.0435*** **	**0.0436*** **
	(0.00936)	**(0.00934)**	**(0.00937)**	**(0.00933)**	**(0.00930)**	**(0.00930)**	**(0.00936)**	**(0.00936)**
Temperature shocks	0.00715	0.00751	0.00730	0.00807	0.00694	0.00860	0.00729	0.00741
	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0168)	(0.0168)
Precipitation shocks	0.000784*	0.000756*	0.000787*	0.000768*	0.000776*	0.000761*	0.000782*	0.000781*
	(0.000458)	(0.000457)	(0.000458)	(0.000458)	(0.000458)	(0.000458)	(0.000458)	(0.000458)
de jure environmental policy	0.0233*	0.00806	0.0236*	0.0103	0.0158	0.00683	0.0194	0.0192
	(0.0134)	(0.0135)	(0.0128)	(0.0122)	(0.0129)	(0.0124)	(0.0129)	(0.0127)
de facto environmental policy	-0.0208	-0.0166	-0.0254	0.000259	0.0257	0.00502	-0.0165	-0.0178
	(0.0705)	(0.0685)	(0.0705)	(0.0657)	(0.0696)	(0.0658)	(0.0706)	(0.0706)
EITI membership	**7.445*** **	**6.030*** **	**7.337*** **	**6.770*** **	**6.430*** **	**6.234*** **	**7.283*** **	**7.364*** **
	(1.452)	**(1.573)**	**(1.417)**	**(1.460)**	**(1.468)**	**(1.479)**	**(1.459)**	**(1.456)**
***de jure* environmental policy x EITI**	**-0.0652*** **	**-0.0496*** **	**-0.0634*** **	**-0.0532*** **	**-0.0560*** **	**-0.0531*** **	**-0.0615*** **	**-0.0627*** **
	(0.0161)	**(0.0166)**	**(0.0154)**	**(0.0153)**	**(0.0156)**	**(0.0156)**	**(0.0159)**	**(0.0158)**
***de facto* environmental policy x EITI**	**-0.594*** **	**-0.587*** **	**-0.592*** **	**-0.616*** **	**-0.632*** **	**-0.617*** **	**-0.600*** **	**-0.599*** **
	(0.0870)	(0.0865)	(0.0866)	(0.0833)	(0.0854)	(0.0835)	(0.0870)	(0.0870)
GDP per capita (log)	2.666*	2.862**	2.697*	2.843**	2.706*	3.030**	2.658*	2.654*
	(1.442)	(1.447)	(1.440)	(1.442)	(1.447)	(1.444)	(1.443)	(1.442)
GDP per capita square (log)	-0.177*	-0.179*	-0.183*	-0.188**	-0.175*	-0.197**	-0.176*	-0.175*
	(0.0962)	(0.0965)	(0.0960)	(0.0958)	(0.0963)	(0.0961)	(0.0963)	(0.0962)
FDI	-0.00661*	-0.00619*	-0.00678*	-0.00647*	-0.00648*	-0.00650*	-0.00652*	-0.00649*
	(0.00367)	(0.00367)	(0.00367)	(0.00365)	(0.00366)	(0.00365)	(0.00367)	(0.00367)
ϕ	1.434***	-0.826	1.475***	-1.214	-0.474	-1.285	1.442***	1.469***
	(0.294)	(1.361)	(0.300)	(0.903)	(0.859)	(1.139)	(0.294)	(0.291)
λ	0.0682	0.0699	0.0699	0.0814	0.0763	0.0836	0.0709	0.0712
	(0.0741)	(0.0743)	(0.0741)	(0.0744)	(0.0742)	(0.0746)	(0.0743)	(0.0743)
σ_{mu}	1.769***	1.804***	1.724***	1.636***	1.687***	1.669***	1.810***	1.796***
	(0.241)	(0.243)	(0.235)	(0.223)	(0.222)	(0.233)	(0.243)	(0.242)
σ_e	0.678***	0.677***	0.678***	0.677***	0.677***	0.677***	0.678***	0.678***
	(0.0204)	(0.0203)	(0.0204)	(0.0203)	(0.0203)	(0.0203)	(0.0204)	(0.0204)
AMU	-1.425							
	(1.496)							
COMESA		1.247						
		(0.906)						
ECCAS			1.552					
			(0.946)					
ECOWAS				-1.737***				
				(0.510)				
SADC					1.645***			
					(0.593)			
UEMOA						-2.250***		
						(0.792)		
CEMAC							0.143	
							(1.013)	
WAMZ								0.687
								(1.040)
Constant	-11.51**	-11.83**	-12.02**	-10.63**	-11.53**	-11.17**	-11.29**	-11.38**
	(5.437)	(5.433)	(5.449)	(5.408)	(5.418)	(5.388)	(5.440)	(5.436)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-697.4	-696.7	-696.5	-694.2	-694.5	-694.8	-697.8	-697.6

Notes: Estimates using trade and contiguity matrices. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4.A8: Robustness: With trade matrix

	Dependent variable: Tree cover loss >50% Canopy cover							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mineral resource rents	**0.0419*** **	**0.0402*** **	**0.0422*** **	**0.0420*** **	**0.0405*** **	**0.0414*** **	**0.0420*** **	**0.0410*** **
	(0.00858)	**(0.00859)**	**(0.00858)**	**(0.00853)**	**(0.00854)**	**(0.00851)**	**(0.00859)**	**(0.00855)**
Temperature shocks	0.00345	0.00388	0.00355	0.00426	0.00332	0.00478	0.00363	0.00403
	(0.0152)	(0.0152)	(0.0152)	(0.0152)	(0.0152)	(0.0152)	(0.0152)	(0.0152)
Precipitation shocks	0.000677	0.000651	0.000680	0.000652	0.000665	0.000646	0.000673	0.000662
	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000419)	(0.000418)	(0.000419)	(0.000419)
de jure environmental policy	0.0186	0.00538	0.0194*	0.00674	0.0115	0.00388	0.0156	0.00775
	(0.0118)	(0.0122)	(0.0112)	(0.0106)	(0.0114)	(0.0107)	(0.0114)	(0.0119)
de facto environmental policy	-0.0663	-0.0620	-0.0731	-0.0506	-0.0302	-0.0448	-0.0628	-0.0528
	(0.0642)	(0.0625)	(0.0641)	(0.0588)	(0.0630)	(0.0591)	(0.0643)	(0.0630)
EITI membership	**6.345*** **	**5.185*** **	**6.236*** **	**5.783*** **	**5.496*** **	**5.335*** **	**6.232*** **	**5.427*** **
	(1.281)	**(1.430)**	**(1.242)**	**(1.285)**	**(1.308)**	**(1.300)**	**(1.289)**	**(1.404)**
***de jure* environmental policy x EITI**	**-0.0586*** **	**-0.0459*** **	**-0.0571*** **	**-0.0480*** **	**-0.0506*** **	**-0.0482*** **	**-0.0559*** **	**-0.0488*** **
	(0.0143)	**(0.0151)**	**(0.0136)**	**(0.0136)**	**(0.0140)**	**(0.0139)**	**(0.0142)**	**(0.0148)**
***de facto* environmental policy x EITI**	**-0.470*** **	**-0.464*** **	**-0.465*** **	**-0.488*** **	**-0.500*** **	**-0.490*** **	**-0.476*** **	**-0.479*** **
	(0.0794)	(0.0789)	(0.0789)	(0.0744)	(0.0775)	(0.0749)	(0.0793)	(0.0781)
GDP per capita (log)	1.841	1.977	1.861	1.918	1.864	2.117	1.827	2.013
	(1.318)	(1.327)	(1.315)	(1.320)	(1.326)	(1.318)	(1.320)	(1.326)
GDP per capita square (log)	-0.141	-0.139	-0.146*	-0.142	-0.136	-0.152*	-0.140	-0.146*
	(0.0878)	(0.0884)	(0.0875)	(0.0874)	(0.0881)	(0.0874)	(0.0879)	(0.0881)
FDI	-0.00663*	-0.00619*	-0.00682**	-0.00639*	-0.00644*	-0.00643*	-0.00655*	-0.00635*
	(0.00340)	(0.00340)	(0.00340)	(0.00338)	(0.00339)	(0.00338)	(0.00340)	(0.00339)
ϕ	1.437***	-0.556	1.462***	-1.412	-0.331	-1.386	1.442***	0.0422
	(0.296)	(1.323)	(0.302)	(0.912)	(0.820)	(1.103)	(0.296)	(0.847)
λ	-0.0568	-0.0563	-0.0550	-0.0529	-0.0556	-0.0514	-0.0560	-0.0542
	(0.0802)	(0.0802)	(0.0803)	(0.0804)	(0.0803)	(0.0804)	(0.0803)	(0.0803)
σ_{mu}	1.509***	1.548***	1.450***	1.371***	1.468***	1.411***	1.540***	1.575***
	(0.206)	(0.205)	(0.198)	(0.188)	(0.192)	(0.195)	(0.207)	(0.204)
σ_e	0.626***	0.625***	0.627***	0.625***	0.625***	0.625***	0.626***	0.625***
	(0.0189)	(0.0188)	(0.0189)	(0.0188)	(0.0188)	(0.0188)	(0.0189)	(0.0188)
AMU	-1.166							
	(1.280)							
COMESA		0.828						
		(0.804)						
ECCAS			1.448*					
			(0.792)					
ECOWAS				-1.493***				
				(0.417)				
SADC					1.265**			
					(0.535)			
UEMOA						-1.938***		
						(0.637)		
CEMAC							0.253	
							(0.864)	
WAMZ								-0.377
								(1.035)
Constant	-7.124	-7.245	-7.567	-6.209	-7.135	-6.852	-6.942	-7.021
	(4.953)	(4.962)	(4.958)	(4.936)	(4.948)	(4.914)	(4.956)	(4.963)
# Observations	595	595	595	595	595	595	595	595
Number of countries	35	35	35	35	35	35	35	35
Log likelihood	-647.4	-646.7	-646.2	-643.6	-644.9	-644.3	-647.7	-647.1

Notes: Estimates using trade and contiguity matrices. Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

General Conclusion

5.1 Summary and main takeaway

The natural resources curse puzzle is one of the most debated topics in development literature over the last thirty years. Despite the interest shown in the subject by researchers and politicians alike, a number of grey areas remain. Firstly, as most of the rent is captured by the government, much of the literature focuses on the role of the government to the detriment of the private sector. Secondly, the context of climate change opens up another dimension to the resource curse literature. The energy transition is putting greater pressure on mineral resources. This pressure has consequences for both environmental policies and the environment in developing countries. This thesis contributes to both these areas of the literature. It is organized in two parts, each comprising two chapters.

Chapter 1 studies the effect of natural resource dependence on manufacturing firm productivity in 100 developing countries over the period 2008-2019. Using the World Bank Enterprises Survey data and multi-level mixed model, I find the following results: natural resource dependence deters firm productivity regardless of the firm's size and age. The effects operate through real exchange rate volatility and corruption. Oil and natural gas dependence has the most detrimental effect on productivity while the effect of mineral resource dependence is not statistically significant. The findings are robust to several robustness checks including alternative measures of productivity and alternative measures of resource wealth. Natural resources-dependent countries should consider reforms that create forward and backward linkages of domestic firms with the extractive sector to limit enclave economies and promote macroeconomic management.

Chapter 2 investigates the relationship between extractive resources and public capital in developing countries. We rely on the IMF public capital new database which distinguishes "full public provision" capital and Public-Private Partnership capital to assess the effect of extractive resources on public capital in a sample of 95 developing countries over the period 1996-2015 using instrumental variables approach. The results show that extractive resource exerts a negative effect on the full public provision of public capital while its effect on public-private partnership capital is positive. These effects are robust regardless of the type of extractive resources considered. Nevertheless, the negative effect of mineral resources is lower compared to energy resources (gas, coal and oil). A focus on the African region shows that both the adverse effect of extractive resources on public capital and its positive effect on public-private partnership capital are stronger. These findings shed some light on the fact that rent-seeking behavior (political or economic) might motivate public investment spending in resource-rich countries. However, "tying the hands" between the private sector and the public sector in investment projects helps to scale-up public capital. The paper calls for a closer look at the scaling up effect of natural resources on public investment in developing countries claimed in the literature specifically when institutions are weak.

Chapter 3 examines whether African countries are engaged in a strategic interaction in their environmental commitment using two measures: a *de jure* and a *de facto* environmental policy. Our results support that countries adopt a strategic behavior in response to the environmental policy of their neighbors. A 1% increase in neighbors' environmental commitment increases one's own environmental commitment by 0.3% and 0.8% for *de jure* and *de facto* respectively. We document that this strategic behavior leads to a race to the top for *de jure* environmental policy and a race to the bottom *de facto* environmental policy. As African countries increasingly engage in *de jure* environmental enforcement, their *de facto* efforts to mitigate climate change are slackening.

Chapter 4 studies the link between mining and deforestation in Africa using spatial econometrics framework on a panel of 35 African countries over the period 2001-2017. Our findings suggest that mining increases deforestation while environmental policy contributes to reduce deforestation in mineral resource-rich countries. An increase in mineral rent by a one-point percentage of GDP leads to forest loss of about 50 km^2. Moreover, regional economic community has heterogeneous effects on deforestation. Economic communities such as the Economic Community of West African States (ECOWAS) and the West African Economic and Monetary Union (WAEMU) are associated with lower deforestation while Economic Community of Central African States (ECCAS) and Southern African Development Community (SADC) are associated with higher deforestation.

5.2 Avenue for future research

The thesis paves the way for a research agenda based on certain the results and some limitations. Firstly, at country level, the research could be refined by investigating the local effects of extractive activities on both the private sector and the environment. The rapid growth of geo-referenced databases on both extractive activity and socio-economic and environmental indicators could help to advance future research agenda on this subject. Studies at local level could better capture the effects of mining activity on several dimensions of well-being and environmental quality, including water, air and soil. PPP projects also pose enormous problems in developing countries. They cannot, therefore, be seen as a panacea for governments' rent-seeking behavior. An in-depth study is needed to understand which type of project, which type of infrastructure, which PPP policy design is conducive to the accumulation of productive public capital. In addition, countries need to invest in the institutional and physical infrastructure to create upstream and downstream links between their extractive sector and the other sectors of their economies. This calls for case studies of local content policies, in order to learn from successes and failures.

Secondly, between countries, the thesis shows, on the one hand, that countries interact in environmental policy and, on the other, that this leads to de facto deregulation. The enthusiasm for international treaties on the environment is nothing more than lip service, which does not translate into concrete commitment in reality. This behavior is not without consequences for the environment, particularly deforestation. In the context of climate change and energy transition policies, strategic interaction is one of the key issues in the regulation of natural resources. Countries rich in mineral resources may face competition among themselves on the one hand, and pressure from major economic and diplomatic powers on the other. The analysis of the diplomatic, geopolitical and strategic positioning of economic powers in relation to resource-rich developing countries, and its consequences on regulation, remains an area for further research. To this end, it would be very useful to draw up comparable databases for developing countries in terms of *de facto* and *de jure* environmental policy. This work could be extended to labor market regulation.

Thirdly, Africa is one of the regions in the world paying the highest price for climate change, due to its exposure and lack of capacity to cope. The upcoming energy transition could prove even more costly if the trend continues. Despite its wealth of mineral resources, Africa is still lagging behind in the production of renewable energies. At this rate, mineral wealth could be used for the energy transition, but outside the continent. How to ensure that mineral resources contribute to bringing Africa's energy sector up to standard, while respecting the environment, remains an important area of research that is of great interest to policymakers. Research into the value chain of mining resources in relation to renewable energies could serve as a basis for further study.