University of Sussex

Gold-diggers and Where to Find Them:

The Political Economy of Natural Resources

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Declaration

I hereby declare that this thesis has not been and will not be submitted in whole or in part to another University for the award of any other degree.

This thesis consists of three chapters and I produced them under the guidance of my main supervisor Dr. Sambit Bhattacharyya and my second supervisor Prof. Richard Tol.

The first chapter (*Resource Discovery and the Political Fortunes of National Leaders*) is co-authored with my main supervisor Dr. Sambit Bhattacharyya. It is released as working paper and under review with a journal on the date of submission. I hereby declare that the entire analysis was carried out by me under the guidance of Dr. Sambit Bhattacharyya and I wrote the first draft independently. The first draft served as blueprint for Dr. Sambit Bhattacharyya to write the paper version. My contribution can be quantified at 80%.

The remaining two chapters of the thesis (*Resource Revenues and Domestic Taxation: Is there a crowding-out effect?* and *Wasted windfalls: Inefficiencies in health care spending in oil rich countries*) are single-authored. The entire analysis was carried out by myself under the guidance of my supervisors. I produced the first draft independently and included edits and amendments suggested by my supervisors.

For all three chapters I obtained valuable advice and feedback from my second supervisor Prof. Richard Tol.

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Doctor of Philosophy in Economics

Gold-diggers and Where to Find Them:
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Summary

This thesis analyses the political economy of natural resources and investigates how natural resources influence political survival, taxation and inefficiency in the health care sector.

The first chapter investigates the causal effects of giant and first oil and mineral discoveries on the political fortunes of national leaders using a large dataset of 1255 leaders from 158 countries over the period 1950 to 2010 in 'single risk' and 'competing risk' discrete time proportional hazard models. The results show that mineral discoveries reduce risk for the incumbent in a 'single risk model' especially in non-election years. In contrast, oil discoveries reduce risk disproportionately more in countries with weak political institutions. In a 'competing risk model', oil discovery significantly reduces the risk of departure via military coup while resource discovery reduces the risk of resignation. Non-resource tax and military expenditure appears to be two potent mechanisms through which oil discovery affects political survival.

The second chapter exploits the 2000s commodity price boom to identify the impact of resource revenues on domestic taxation in resource exporting countries. I estimate the average effect of resource revenues on non-resource taxation for 25 resource exporting countries using synthetic control methodology. Non-resource tax per capita is on average 11% lower in resource exporting countries because of the 2000s commodity price boom compared to a scenario without price shock. However, I also show that the effect is heterogeneous and occurs only in oil exporting countries but not in mineral or precious mineral exporting countries. Within the sample of oil exporting countries, the tax reducing effect persists only in countries with a low level of institutional quality, are highly oil dependent and prefer the use of tax instruments rather than non-tax instruments.

The third chapter uses stochastic frontier analysis (SFA) to determine whether oil rents drive inefficiency in the health care sector. SFA simultaneously estimates a production function for health outputs and the determinants of inefficiency in production. Using a sample of 119 countries covering the period 2000 to 2015, unexpectedly high oil revenues are shown to increase inefficiency. Oil rents hinder countries in reaching their potential life expectancy. Exploiting exogenous variation in the international oil price reveals that causality runs from oil rents to inefficiency in democratic countries. The effect varies with institutions, sex and age. The effect is more pronounced in democracies, and women and children are affected more than men and adults. Transparency and inequality are potential mechanisms.

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Chapter 1

Introduction

The oil embargo proclaimed by the Organization of Arab Petroleum Exporting countries on Israel supporters in 1973 that lead to car-free Sundays in the Netherlands and Germany and further fuelled inflation in western countries contributing to the defeats of left-wing governments in the US and the UK towards the end of the decade is just one example of how natural resources give some countries the power to influence other countries.

The influence of natural resources over politics is not restricted to international relations between resource rich and resource poor countries but is also present −on an even greater scale− at the national level of resource rich countries. Currently, over 1.5 billion people live in resource rich countries and in turn their lives are affected by resource influenced politics (Barma et al., 2012). The existing evidence describes a rather pessimistic outlook for the population in resource rich countries. Natural resources are associated with slow economic growth, corruption, conflict and authoritarianism.[1]

The experience in resource rich countries, such as Nigeria, Bolivia or Sierra Leone, coined the notion of a resource curse (Auty, 1993) and the question whether natural resources are a 'curse' or a 'blessing' has been at the core of the economic and political literature concerned with natural resources ever since (Auty, 2001; Gylfason, 2001; Sachs and Warner, 2001). However, the evidence is not conclusive and successful resource-led developments in countries, such as Norway and Botswana, prove that the resource curse is not carved out of stone (Mehlum et al., 2006; van der Ploeg, 2011).

More recently, the topic of natural resource windfalls regained importance due to the 2000s commodity price boom. This price boom allowed many primary commodity exporters to prosper, especially in Africa. Growth rates in resource rich countries increased, but even then per capita growth rates did not exceed growth rates in resource poor countries

[1] See Sachs and Warner (2001) for growth, Bhattacharyya and Hodler (2010) for corruption, Ross (2015) for authoritarianism and De Soysa and Neumayer (2007) for conflict.

(IMF, 2012b). This missed opportunity shows that we still lack in understanding the impact of natural resources and miss effective instruments and policies to avoid adverse effects of natural resources on development.

This thesis contributes to the knowledge about the political economy of natural resources in three areas by studying the impact of natural resources on political survival, taxation and health care spending inefficiency. Therefore, the thesis consists of three stand-alone papers organized in three empirical chapters.

The first empirical chapter (chapter 2) intends to answer the question whether natural resources prolong or shorten the time national leaders stay in office. Survival in office is one of the key objectives of national leaders and depends inter alia on the size of a leader's core constituency and the amount of available funds which are interlinked. Funds can be used to increase the core constituency and a broader core constituency provides more funds.

Natural resources in this context should increase the available funds for the incumbent, allowing to broaden the core constituency and therefore prolong the time a leader stays in office (Caselli and Cunningham, 2009; Robinson et al., 2006). However, natural resources could also fractionalize the core constituency in contest for access over natural resources, increasing political competition and therefore reducing the time a leader stays in office (Caselli, 2006).

To analyse which of the two effects dominates, chapter 2 explores the causal effect of giant and first resource discoveries on the political fortunes of national leaders. We construct a large dataset containing information about the timing of giant oil and mineral discoveries[2] and leaders' tenure for 1255 leaders in 158 countries. We apply duration models in the form of 'single risk' and 'competing risk' discrete time proportional hazard models to estimate the causal effect of giant and first resource discoveries on leaders' time in office.

We find that mineral discoveries reduce risk for the incumbent in a 'single risk model' in non-election years. In contrast, oil discoveries reduce risk disproportionately more in countries with weak political institutions. The effect appears to be induced by resource income rather than expectations, because the effect for oil discoveries needs 11 years to develop and around 5-8 years for mineral discoveries, which is around the time the discovery becomes operational and generates income. In a 'competing risk model', oil

[2] A mineral deposit is coded as giant if it has the capacity to generate at least US$ 0.5 billion of annual revenue for 20 years or more whereas an oil discovery is coded as giant if it contains at least 500 million barrels of ultimate recoverable oil or gas equivalent.

discovery significantly reduces the risk of departure via military coup while both oil and mineral discoveries reduce the risk of resignation.

In agreement with the rentier state theory, we find that oil discoveries decrease tax in the non-resource sector and increase military spending (Mahdavy, 1970; Ross, 2001). Through these channels resource discoveries could increases the chances of political survival for the incumbent.

The main result that giant resource discoveries reduce the risk of leaders leaving office are broadly in line with previous findings. Omgba (2008) finds similar results for African leaders, Wright et al. (2013) and Andersen and Aslaksen (2013) for regimes and Cuaresma et al. (2011) for autocratic leaders.

Our contribution to the literature consists of the confirmation of the overall findings using a plausibly exogenous resource shock and in the new results derived from the 'competing risk model'. We can attribute the risk-reducing effect of oil discoveries in countries with low institutional quality to a risk reduction of military coups and resignation. Further, our finding of a resignation-risk-reducing effect of giant mineral discoveries in non-election years contradict the risk increasing effect found in Andersen and Aslaksen (2013) and the zero result in Omgba (2008). Andersen and Aslaksen (2013) and Omgba (2008) use mineral rents as explanatory variable, which captures also small mineral deposits, while we focus only on giant deposits. The contrasting results could imply that there is a non-linear effect of minerals on political survival. Small deposits could be risk increasing, because they are easier captured by the opposition, while giant deposits benefit the incumbent.

A potential mechanism on how resource discoveries reduce the risk of a leader leaving office −reduced non-resource tax− was already mentioned in the first empirical chapter. Taxes are part of the fiscal contract between citizens and the government and any change to the fiscal contract can have severe effects on development apart from political survival. Hence, this mechanism deserves an analysis on its own.

Therefore, the second empirical chapter (chapter 3) analyses the relationship between natural resource income and domestic taxation. In particular, the chapter asks the question whether resource revenues crowd out domestic taxes.

Natural resources have the potential to interrupt the fiscal contract by providing the government with the financial means from an external source (Mahdavy, 1970; Ross, 2015). In most countries, resource revenues accrue directly to the government and even if most constitutions state that resources belong to the people they never go through their hands which diminishes the importance of their opinions.

In chapter 3, I empirically explore the relationship between resource revenues and domestic taxation by exploiting the 2000s commodity price boom as a positive income shock. Applying comparative case study analysis in the form of synthetic control method to a sample of 25 resource exporting countries allows to estimate the average treatment effect of resource revenues on non-resource taxation.

The results confirm the existence of a crowding-out effect. Due to the 2000s commodity price boom total tax per capita is on average 11% lower in resource exporting countries compared to a scenario without price boom. This translates roughly to a US$ 300 lower tax burden per capita. Nevertheless, the analysis also shows that the crowding-out effect is not a necessity and depends on certain country characteristics. The results for certain sub-samples reveal heterogeneity of the crowding-out effect across countries. For example, the crowding-out effect is only present in oil exporting countries, but not in mineral or precious mineral exporting countries. Within the sub-sample of oil exporting countries, the crowding-out effect is stronger in countries with a low level of institutional quality and high resource dependency. Government preferences play also a role. Governments preferring tax instruments over non-tax instruments to extract funds from the resource sector are more prone to a crowding-out effect. Furthermore, while the crowding-out effect can be observed in countries with private and state ownership structure of the oil sector, the effect is greater in countries with private ownership.

Additionally, I verify the results by analysing five new oil producing countries. This analysis confirms that the crowding-out effect is not a necessity and depends on certain country characteristics. Only two of the five new producers show signs of a crowding-out effect, while the other three increased their non-resource taxes after oil production started.

The chapter contributes to the literature connecting resource revenues with domestic taxation. The result for the full sample −confirming a crowding-out effect− is in line with previous findings in the literature (Bornhorst et al., 2009; Crivelli and Gupta, 2014; Ossowski and Gonzales, 2012; Thomas and Treviño, 2013). New results are derived from the application of synthetic control method to specific sub-samples. This heterogeneity analysis uncovered country characteristics and government preferences which promote the crowding-out effect and yield valuable information for policies attempting to mitigate it. For example, oil exporters could avoid the crowding-out effect by improving institutional quality, investing into tax administration and diversify their economy.

The impact of natural resources is not restricted to the economic and political sphere. In excess of and especially through their economic and political influence they also affect people's lives on a social level. The literature concerned with natural resources provide many models predicting a socially sub-optimal and inefficient use of resources. For example, Ebeke et al. (2015) show that oil creates incentives for university students to pursue a career enabling them to access rents in the future, instead of pursuing a career in a more productive area. Corruption, patronage spending or white elephants −all associated with natural resources− are other examples how natural resources can lead to inefficient use of natural resources which should lead to lower social development (Bhattacharyya and Hodler, 2010; Robinson and Torvik, 2005; Robinson et al., 2006).

The third empirical chapter (chapter 4) attempts to measure the impact of natural resources on social development by estimating the effect of oil dependency on inefficiency in the health care sector. Here I apply stochastic frontier analysis to a sample covering 119 countries between 2000 and 2015. Stochastic frontier analysis estimates coefficients of a health production function and inefficiency determinants simultaneously and therefore allows to make inferences about whether oil dependency drives inefficiency in the production of the health output (life expectancy).

The results of the stochastic frontier analysis confirm that oil dependent countries have on average a lower efficiency score than oil poor countries and that oil dependency is a significant determinant of inefficiency in the health care sector, i.e. higher oil rents lead to more inefficiency. Exploiting unexpected oil price changes shows that the inefficiency increasing effect of oil is causal for democratic countries. Furthermore, the results show that certain parts of the population are more affected by oil induced inefficiency than others. Women's health is adversely more affected than men's and the same is true for children compared to adults.

The results of chapter 4 are in line with other findings in the literature connecting natural resources and health outcomes. Edwards (2016); Carmignani and Avom (2010); Bulte et al. (2005) and Daniele (2011) find that natural resources have a negative impact on health outcomes. The contribution of the chapter lies in the application of stochastic frontier analysis and inclusion of the oil rents variable as an inefficiency determinant. This approach allows to explore one possible reason why oil rich countries underperform in terms of health outputs, namely that funds spend on health care are disproportionally wasted in countries with high oil revenues. Furthermore, the results for different parts of the population are new and provide valuable information for policy makers on how to target policies attempting to increase efficiency in the health care sector.

In summary, this thesis provides new insights on the political economy of natural resources by analysing the impact of natural resources on political survival, taxation and health care inefficiency. The rest of the thesis is organized as follows: Chapter 2 is dedicated to *Resource Discovery and the Political Fortunes of National Leaders*, chapter 3 to *Resource Revenues and Domestic Taxation: Is there a crowding-out effect?* and chapter 4 to *Wasted windfalls: Inefficiencies in health care spending in oil rich countries*. Finally, chapter 5 concludes the thesis by discussing limitations of each chapter and providing an outlook for future research.

Chapter 2

Resource Discovery and the Political Fortunes of National Leaders

2.1 Introduction

The extent to which national leaders shape the destiny of a country is widely debated by scholars. Some scholars view leaders as Great Men influencing the evolution of history through idiosyncratic causative influences (Carlyle, 1837, 1859; Jones and Olken, 2005). Others disagree and view leaders as either slaves of history (Tolstoy, 2007; Berlin, 1978) or substantial individuals acting within the confines of existing social norms and institutions (Marx, 1852; Weber, 1947).

As important as it is to investigate the role of leaders in shaping national history, an equally important issue is to investigate the destiny of national leaders. Survival in office is one of the key objectives of leaders (de Mesquita and Smith, 2002). However, political survival is not an easy task. Leaders can continue holding office if and only if they have enough political power. Political power is primarily derived from their access to resources and the support of their core constituency in the society. These two determinants of political power however are interlinked and somewhat locked in an interactive relationship. For example, access to a sizeable amount of resources provide the leader with sufficient economic power to buy support, increase the size of the core constituency, and suppress opposition (Robinson et al., 2006; Caselli and Cunningham, 2009).[1] Alternatively, a large

[1]This is commonly known as the *rentier state theory*. See Robinson et al. (2006) for a review of this theory.

pool of resources induces more competition among political elites for access which could in fact diminish the size of the core constituency of the incumbent national leader and shorten her duration in office (Caselli, 2006).

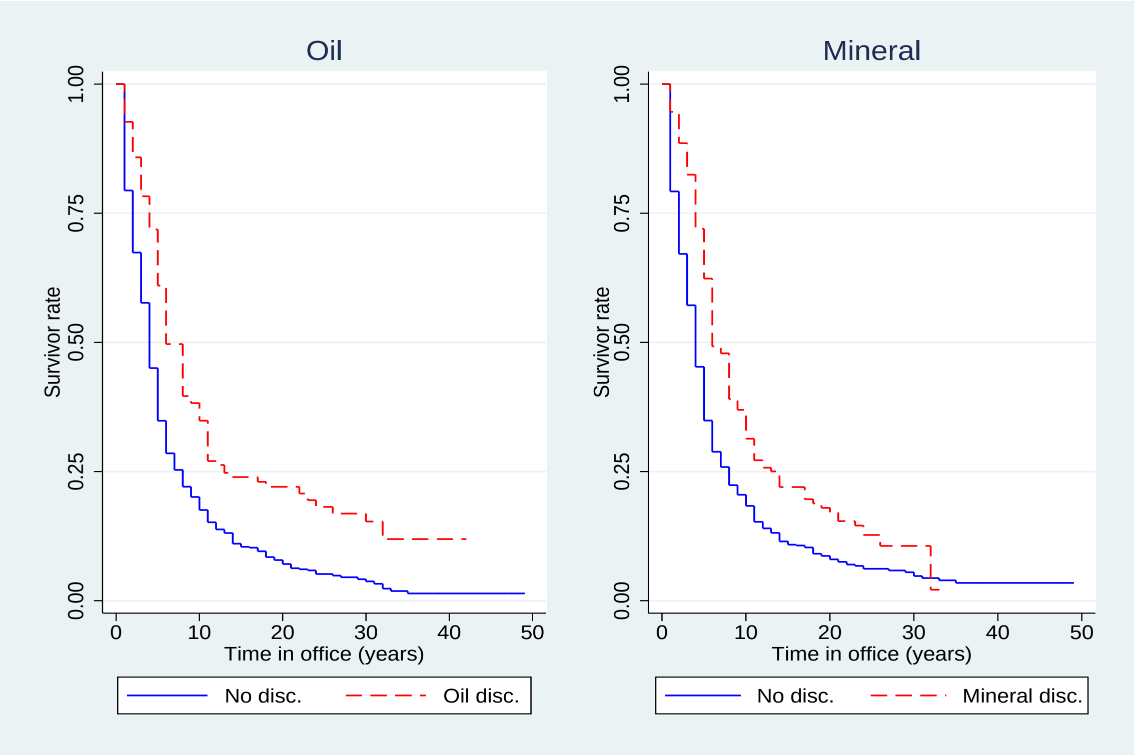
Resources that enhance or reduce political power of national leaders could take multiple forms. Some common examples are natural resource rents, foreign aid, lobbying contributions, and tax revenues. In fact, the existing literature on political survival of leaders studies the role of many of these factors. On the theory side, seemingly conflicting models highlight the role of natural resource rents induced patronage, rebel threats, and elite fragmentation in influencing the duration of a political leadership.[2] On the empirical side, several studies test the effect of resource wealth on political survival. However, they are heavily focused on certain country groups (Omgba, 2008), leader types (Cuaresma et al., 2011), and regimes (Wright et al., 2013; Andersen and Aslaksen, 2013). We observe some nuanced differences across studies. For example, Wright et al. (2013) focus on regime (authoritarianism and democracy) survival whereas Andersen and Aslaksen (2013) examine regime change only when the chief executive loses office along with her political party. de Mesquita and Smith (2010) use a global sample of leaders but they only estimate a 'single risk model'. Most of the existing studies use resource rent or primary products export as explanatory variables, thus making their estimates vulnerable to reverse causality (Ross, 2015).

In this study, we take a new approach towards the question of leader survival. We test the effect of giant oil[3] and mineral discovery news shocks on leader survival using a discrete time proportional hazard model with no restriction on the baseline hazard. The use of discovery news shocks offer a cleaner identification strategy than 'resource rent' or 'primary products export' variables typically used by the existing literature. Moreover, we also estimate our model using 'first discovery' which offers an even cleaner identification strategy. Unlike previous studies, we recognise that a leader faces multiple risks. Therefore, we estimate 'competing risk models' along with 'single risk models'. The existing literature solely relies on the 'single risk model'. We also recognise that the nature of risk faced by the leader during election and non-election years could very well be different. Furthermore, leaders with term limits face different type of risks relative to leaders without term limits. Therefore, we account for these nuances in our model using a large dataset of 1255 leaders distributed across 158 countries over the period 1950 to 2010.

[2]See Caselli and Cunningham (2009) for a review of this literature.
[3]Throughout this chapter 'oil and gas' is referred to as 'oil'. More on this in section 2.2.

We start with an observational plot of the raw data. Figure 2.1 plots the Kaplan-Meier survival function[4] comparing leaders with and without resource discoveries. We consider two types of resource discoveries: oil and minerals. We find that the average survival rate for incumbent leaders with resource discoveries is higher than the average survival rate for the same without resource discoveries at any given point in time. The Survival function plot is not informative about confounding factors and the baseline estimates (Andersen and Aslaksen, 2013). In particular, one might expect that the relationship between resource discovery and leaders' survival is conditional on the quality of institutions (Acemoglu et al., 2004; Robinson and Torvik, 2005). Hence we estimate discrete time proportional hazard models next.

Figure 2.1: Kaplan-Meier survival function by resource discovery



Notes: Figure 2.1 compares in the left graph the Kaplan-Meier survival function for leaders with oil discoveries (dashed line) with leaders without oil discoveries (solid line). The right graph compares the Kaplan-Meier survival function for leaders with mineral discoveries (dashed line) with leaders without mineral discoveries (solid line).

Using a 'single risk model' on a pooled sample of election as well as non-election years we find that a mineral discovery reduces risk for the incumbent. This result survives in

[4]The Kaplan-Meier survival function estimates the conditional probability of survival beyond time t, given survival up to time $t : S(t) = \prod_{j|t_j \leq t} \left(\frac{n_j - d_j}{n_j}\right)$,where n_j is the number of leaders in office at time t_j and d_j is the number of failures at time t_j (Andersen and Aslaksen, 2013).

the non-election year sample. In contrast, we do not observe any effect of an oil discovery on risk in an aggregate sample. However, interacting oil discovery with institutional quality reveals that the former reduces risk disproportionately more in countries with weak political institutions (low democracy score, low executive constraint, and low level of competition in the executive recruitment process).

A 'single risk model' as estimated by several existing studies aggregate the different reasons of leaving office. In contrast a 'competing risk model' accounts for the diversity of reasons behind a leader's exit. Hence, we account for the risk of resignation and military coup during non-election years and the risk of losing election during election years. We find that a resource discovery significantly reduces the risk of losing office via resignation and military coup. In particular, both oil and mineral discoveries appear to be 'resignation risk' reducing. However, a reduction in 'military coup risk' is exclusively associated with oil discovery shocks. The latter result perhaps reinforces the association between oil and authoritarianism under which military coups typically occur. Resource discovery does not seem to have any impact on the risk of election loss. We tackle the contentious issue of 'term limits' by excluding all term limit years from the non-election year sample for leaders with term limits.

Our result could be interpreted as high income induced political risk reduction for the incumbent leader following a resource discovery. We observe on average risk reduction takes effect 5-8 years after mineral discovery and 11 years plus after oil discovery. Therefore, by then these discoveries are likely to be operational as it takes 8-10 years to develop a deposit. In case of mineral discoveries, the risk reduction effect is uniform across regime type. In contrast, oil discoveries reduce risk in non-democratic countries. This is perhaps suggestive that minerals are better connected to the rest of the economy than oil. Therefore, it improves the income of both the incumbent and the challengers increasing the likelihood of cooperation in non-election years. Cooperation without doubt significantly reduces risks for the incumbent. Higher income in general could also create an atmosphere of optimism, good will, and national unity, which could also benefit the incumbent. In contrast, oil has more of an 'enclave' character which could disproportionately increase the income of the incumbent which then could be used to support coercion or patronage under an uncompetitive political system and reduce risk.

The theoretical literature discusses tax on the non-resource sector, military expenditure, conflict onset, government borrowing, and economic growth as potential mechanisms through which resource discovery affects leaders' survival. We test these mechanisms and find that in agreement with the rentier state hypothesis oil discovery decreases tax as a share of GDP from the non-resource sector. Oil discovery also increases military spending and thereby reducing risk for the incumbent. In contrast, mineral discovery appears to have no effect on military spending. It also appears to increase non-resource sector tax as a share of GDP. The latter is perhaps reflective of the relatively high level of connectedness of minerals to the rest of the economy.

We make the following contributions to the literature. First, to the best of our knowledge this is the first study to analyse the effect of resource discovery news shocks on the political fortunes of national leaders. In doing so we marry a novel dataset on resource discoveries with a dataset on national leaders. In contrast, existing empirical studies on the political fortunes of national leaders tend to focus on resource rent or resource income. Second, the dataset on resource discoveries is able to distinguish between minerals[5] and oil discoveries. This allows us to analyse the effects of oil and minerals on national leaders separately which yields new results of heterogeneous effects by resource type. Third, the existing literature estimates 'single risk models' whereas we estimate 'single risk' as well as 'competing risk models'. This creates new knowledge of the types of risk that respond to a resource discovery shock. Fourth, using data on non-resource sector tax, military expenditure, conflict onset, government borrowing, and economic growth we are able to explore potential mechanisms. Finally, establishing causality is a key motivation in this literature and this chapter offers a credible and cleaner identification strategy using the resource discovery variable.

Our identification strategy is similar to Cotet and Tsui (2013a), Bhattacharyya et al. (2017) and Arezki et al. (2017). It relies on the stochastic nature of the discovery dates of giant and supergiant mineral and oil discoveries. A mineral deposit is coded as giant if it has the capacity to generate at least US$ 0.5 billion of annual revenue for 20 years or more whereas an oil discovery is coded as giant if it contains at least 500 million barrels of ultimate recoverable oil or gas equivalent. A giant oil discovery has the capacity to generate an annual revenue stream of approximately US$ 0.4 billion under certain assumptions which will be discussed in section 2.2.1.

Our working argument is that accurately predicting the timing of a giant or supergiant discovery is almost impossible because it is a rare event. How about politicians and the government manipulating the announcement of the precise timing to gain political mileage? This is unlikely in our dataset as the reported dates are independently verified

[5]The minerals are gold, silver, platinum group elements (PGE), copper, nickel, zinc, lead, cobalt, molybdenum, tungsten, uranium oxide.

using multiple industry sources and not just government records. Nonetheless, we also use 'first discovery' as an exogenous shock which offers even cleaner identification.

This chapter is related to a literature on the political consequences of natural resources. The most prominent among them is the 'rentier state theory' dating back to Mahdavy (1970). The 'rentier state theory' stipulates three mechanisms through which resource wealth reduces democratic pressure on the incumbent and thereby extending her tenure. The first mechanism is the 'taxation effect' whereby the incumbent in a resource rich country is less reliant on her citizens for revenues. In return, the citizens demand less accountability from the incumbent. The second mechanism is the 'spending effect' whereby the incumbent could engage in the extension of patronage and strategic social spending using resource wealth to remain in power. The third mechanism is the 'coercion effect' whereby the incumbent engages in coercion using resource wealth to disrupt the formation of opposition political groups.

Several theoretical and empirical studies have used these mechanisms to explain political survival. Acemoglu et al. (2004) and Acemoglu et al. (2010) emphasize the coercion mechanism. The former argue that an incumbent would disrupt the formation of an opposition critical mass by using resource wealth funded coercion. The latter emphasize the role of the military as an agent of the incumbent to carry out coercion. Robinson and Torvik (2005), Robinson et al. (2006), and Cuaresma et al. (2011) are examples where the taxation and patronage mechanisms are used.

This chapter is also related to the resource curse literature. Auty (2001), Gylfason (2001) and Sachs and Warner (2001, 2005) note that resource rich countries on average grow much slower than resource poor countries. Subsequent studies have argued that natural resources may lower the economic performance because they strengthen powerful groups, weaken legal frameworks, and foster rentier-seeking activities (e.g. Tornell and Lanem (1999) and Besley (2006)). Others have argued whether natural resources are a curse or a blessing depends on country-specific circumstances especially institutional quality (e.g Mehlum et al. (2006); Robinson et al. (2006); Bhattacharyya and Hodler (2010, 2014); Bhattacharyya and Collier (2014)), natural resource type (Isham, 2005) and ethnic fractionalisation (Hodler, 2006).

The remainder of this chapter is structured as follows: Section 2.2 discusses the data and empirical strategy. Section 2.3 presents evidence on the effects of resource discovery on the political fortune of national leaders and discusses potential mechanisms. It separately examines the effect on different risk types (resignation, military coup, and election loss) using competing risk models. It also reports the heterogeneous effects of oil and minerals. Section 2.4 deals with robustness and section 2.5 concludes.

2.2 Data and Empirical Strategy

We create a large dataset covering 1255 leaders in 158 countries[6] over the period 1950 to 2010[7] by marrying the leaders' database with the database on natural resource discovery. In what follows, we illustrate the nature and source of our data which is followed by a description of the empirical strategy.

2.2.1 Data

Leader Duration

A key variable in our analysis is the duration of a national leader staying in power. We source this data from the Archigos dataset compiled by Goemans et al. (2009). The dataset provides information on the entry and exit dates of the effective leader of a country. An effective leader is defined as the person who *de facto* exercises power in the country. Hence, this definition covers for cases whereby one person holds a formal title but is not able to exercise power to make political decisions. For example, the tenure of Saudi Arabia's King Fahd is considered to have lasted 13 years from 1982 to 1995, when he suffered a stroke and wasn't able to govern the country any more, even though officially he remained the head of state till his death in 2005. The binary 'leader duration' variable takes the value 1 in the event of an exit and 0 otherwise.

A typical challenge with an analysis of this nature is right censoring whereby a leader leaves the study before an event occurs (Jenkins, 2005). For example, a leader could leave office because of health reasons or natural death. In the absence of illness or death she could have stayed longer in office. This is taken care of by right censoring where the leader leaves the sample on the death or illness year. The 'leader duration' variable takes the value 0 for the entire duration of such leaders including the death or illness year. We also right censor leaders who are in office in the year 2010, the final year in our sample. Note that leaders leaving office due to death by assassination is not right censored as we consider these assassinations politically motivated. Nevertheless, our results do not change even if we right censor the 8 assassinations that we have in our sample. We discuss this more in section 2.4.

[6] A list of all countries used in the analysis is shown in appendix A table A 1

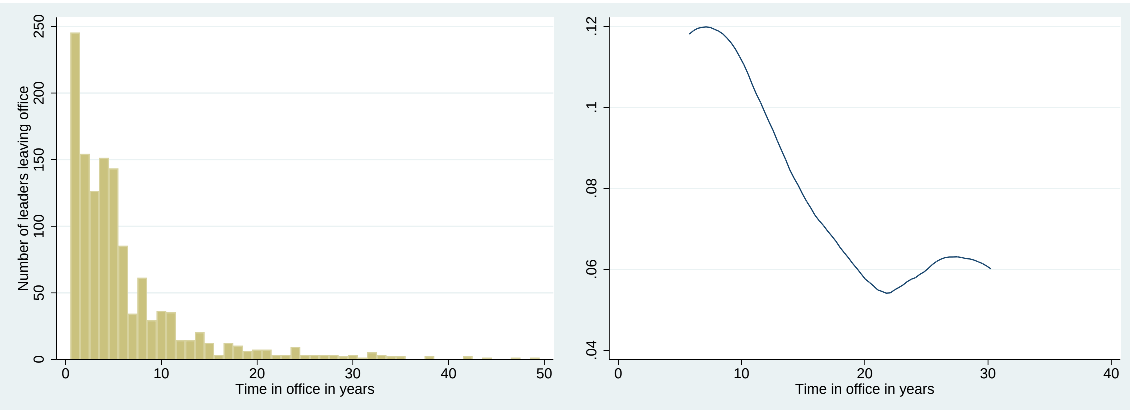
[7] The final year of the sample is dictated by our resource discovery data.

The tenure start date could be different for different leaders. Following Andersen and Aslaksen (2013) and Omgba (2008) we only count the years when the leader was in power as of the 1st of January. Using all the available information allows us to use the 'leader duration' variable in a discrete time survival model along with resource discovery.

In our dataset of 1255 leaders, the average time in office for a national leader is 6 years. Several leaders leave office after 1 year and the maximum duration is 49 years due to the Cuban leader Fidel Castro. Figure 2.2a depicts the distribution of leaders' duration. We note that around 20% of leaders leave office after 1 year and that number jumps to 53% after 4 years. The corresponding hazard rate is depicted in figure 2.2b. The distribution appears to be log-normal or log-logistic which have been used by the existing studies such as Andersen and Aslaksen (2013) and Omgba (2008) in their parametric survival models to determine the underlying baseline hazard. However, the spikes in years 4, 5, 8, 10 and 11 in figure 2.2a are not well accounted for by the conventional parametric method. These spikes are a reflection of 4 or 5 year election cycles in most countries. We therefore depart from the conventional parametric method by following a semi-parametric approach to estimate the baseline hazard. Furthermore, we divide the sample into election and non-election years which allows us to estimate separate hazard rates for the same.

Figure 2.2: Leaders' tenure distribution

(a) Distribution of leaders' time in office (b) Smoothed Nelson-Aalen Hazard function



Notes: The left panel shows the distribution of leaders' time in office for 1255 leaders from 1950-2010 and the right panel shows the estimated smoothed (Nelson-Aalen) hazard function for the same leaders and period.

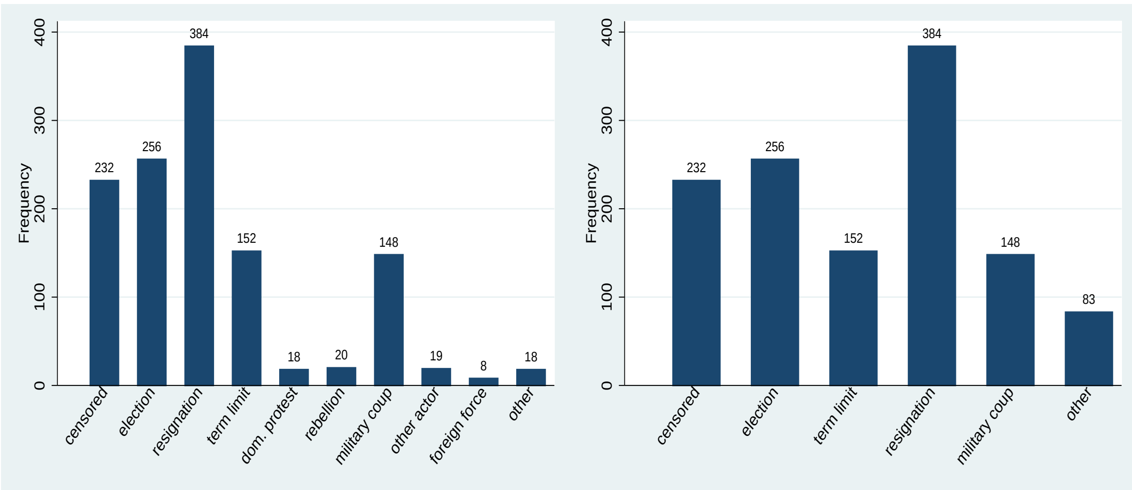
Reasons for Exit

In order to estimate the 'competing risk model', we would need to know why a leader leaves office. Archigos codes regular and irregular leader changes (Goemans et al., 2009).

A regular change is defined as a change in compliance with prevailing rules, provisions, conventions and norms of the country whereas an irregular change is defined as removal in contravention to explicit rules and conventions. The former includes resignation, term limits and lost elections. Note that the Archigos database do not differentiate between the causes of regular leader change. Hence we collect additional data from Lentz (1994), rulers.org, statesmen.org and the comparative constitution project[8] to code for resignation, elections or term limits.

Archigos differentiates irregular leader changes into six categories[9]: removal due to domestic popular protest, domestic rebels, military coups, other government actors, foreign force, and others. The left hand graph in figure 2.3 depicts the distribution of leaders exiting due to all possible causes. In the right hand graph we aggregate irregular leader changes. In particular, we pool domestic popular protest, domestic rebels, other government actors, foreign force, and other into one category and call it 'other'. The distribution appears to be as follows: 18% are censored, 20% lose elections, 12% hit term limits and leave, and 31% resign. The remaining leader changes are irregular out of which 12% are military coups and 7% 'others'. These represents the exit categories considered in the 'competing risk model'.

Figure 2.3: Failure distribution by reason



Notes: The left graph shows the number of leaders leaving office by all possible reasons. The right graph shows the number of leaders leaving office because of elections, term limits, resignation, military coup and other reasons. The category "other" in the right graph is the sum of domestic popular protest, domestic rebels, other government actors, foreign force and other in the left graph.

[8]Data available at: http://rulers.org, http://www.worldstatesmen.org and http://comparativeconstitutionsproject.org/

[9]Archigos provides an even more detailed coding for all irregular categories. Separating all categories into removal of leaders with or without foreign support. We do not take this fine coding into account because most irregular categories are very rare events and would not affect results.

Resource Discovery

We obtain the mineral discovery data from Minex Consulting (2014). Oil and gas discovery data come from Horn (2004). Both datasets provide geocoded information about the location and the year of discovery. A mineral deposit is coded as giant if it has the capacity to generate at least US$ 0.5 billion of annual revenue for 20 years or more accounting for fluctuations in commodity price. A giant oil or/and gas (including condensate) field is a deposit that contains at least a total of 500 million barrels of ultimate recoverable oil or gas equivalent. This would be able to generate an annual revenue stream of approximately US$ 0.4 billion under the assumptions that over the sample period the average gestation lag between production and discovery is 5 years, the average price of a barrel is US$ 25, and the average discount rate including the country specific risk premium is 10 percent.[10] Therefore, it is reasonable to assume that both the giant oil and mineral discovery shocks are approximately of the same size on average. However, it is important to note that the value of a discovery is an estimate and the projections rely on the estimation of the value at the time of the discovery. These estimates are often revised in subsequent years. The 'ultimate recoverable deposit' could also change if there was a major shift in technology. Therefore, discoveries are better treated as exogenous news shocks rather than projection based expected revenue shocks.

To capture the effect of resource discovery we construct a dummy variable which takes the value 1 in the year of discovery till the end of the incumbent leader's tenure. This approach of coding discovery offers a treatment control perspective over the entire post-discovery period of a leader's time in office. In other words, this approach compares leaders with discovery treatment with leaders without discovery treatment throughout their tenure.

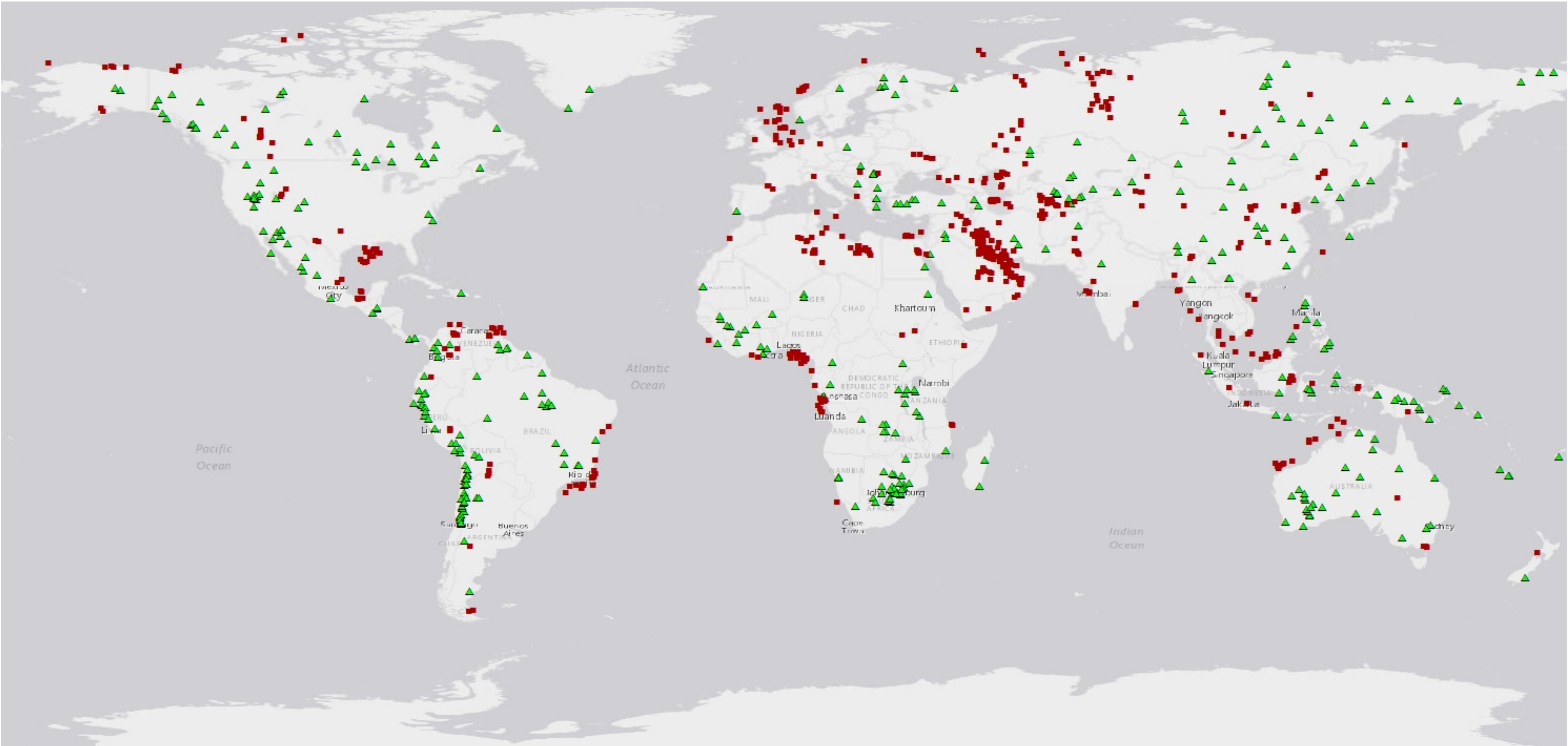
In addition to capturing the aggregate effect of discovery treatment, we also track the time path. Later in section 2.3 using alternative specifications we are able to track how many years it takes for the effect of discovery on leaders' tenure to kick in.

We code mineral and oil discoveries separately as they exhibit varying degrees of connectedness to the rest of the economy and thereby potentially heterogeneous political consequences for the incumbent (Andersen and Aslaksen, 2013).

Figure 2.4 shows the geographic distribution of oil and mineral discoveries covered in the dataset.

[10] Some studies claim that the risk premium augmented discount rate be as high as 14-15 percent. Arezki et al. (2017) presents a more sophisticated analysis of net present value of giant oil discoveries and find that the median size of a giant discovery is approximately 5-6 percent of GDP.

Figure 2.4: Resource discoveries 1950-2010



Notes: Green triangle = mineral discoveries; red squares = oil discoveries. All discoveries represent giant and supergiant resource discoveries. Information about oil discoveries are from Horn (2004) and for mineral discoveries from Minex Consulting (2014).

Overall the dataset covers 740 giant and supergiant oil discoveries in 63 countries and 453 giant and supergiant mineral discoveries in 61 countries. Table 2.1 reports the time distribution of resource discoveries and table A 2 and A 3 in appendix A lists the countries with the number of discoveries.

Table 2.1: Time distribution of resource discoveries

Years	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2010	**Sum**
Oil	58	166	203	94	94	125	**740**
Mineral	45	77	83	70	102	76	**453**

Institutions

The resource curse literature reports that the effect of natural resources on economic and political outcomes are conditional on the institutional quality (Mehlum et al., 2006; Bhattacharyya and Hodler, 2010; Andersen and Aslaksen, 2013). Therefore, it is worthwhile exploring any institution-based heterogeneity in the relationship between resource discovery and leaders' tenure. For this reason, we include component variables from the Polity index provided by Marshall and Jaggers (2014) in our regressions to look at interaction effects. Following Vreeland (2008) we use the adjusted *x-polity* index to measure the overall level of democracy or autocracy. The *x-polity* index is a combination of executive constraints (*xconst*), recruitment competition (*xrcomp*), and recruitment openness (*xropen*). The index ranges from 1 to 14 with 1 indicating an autocratic country and 14 a democratic country. We use the *x-polity* index as opposed to the Polity2 index because the former excludes component variables such as political hostility and turmoil. The degree of political hostility and turmoil could be influenced by the incumbent leader thereby creating endogeneity challenges for our specification (Vreeland, 2008).

We also use *xconst* which is a measure of the level of "institutional constraints on the decision-making powers of the chief executive" (Marshall and Jaggers, 2002, p.63). The index runs on a scale of 1 to 7, with 1 indicating unlimited power for the leader while 7 indicating maximum legislative constraints on the leader.

Finally, we use *xrcomp* which measures the competitiveness of executive recruitment, i.e. "how institutionalized, competitive and open are the mechanisms for selecting a political leader" (Marshall and Jaggers, 2002, p.49). This index ranges from 1 to 4, with 1 indicating no competition (for example, a leader is chosen by right of descent) while 4 indicating competitive elections. Between these two extremes are situations characterized by the forceful seizure of power and/or rigged elections.

Other Control Variables

We control for *log of population, entry age, first leader since independence, mineral* $discovery_{t-10}$ and *oil* $discovery_{t-10}$ in every regression. *Log of population* is included in every specification because it predicts to a certain extent the likelihood of a resource discovery. This issue is further discussed in section 2.3. Furthermore, *log of population* accounts for the size of a country which could influence leaders' tenure. Robinson (1960) and Cuaresma et al. (2011) argue that large countries are difficult to govern and longer tenure for national leaders in these locations provide economic stability. The *log of population* data is sourced from the Penn World Tables.

We control for leaders' *entry age* because younger leaders could potentially stay longer in power (Bienen and van de Walle, 1992). The *entry age* data is sourced from Archigos. In addition, every specification also includes a dummy variable taking the value 1 if the leader is the *first leader after independence*. The first leader post-independence is often viewed as the progenitor of the newly independent country coming out of the shackles of colonialism. Therefore, they typically enjoy high popularity and have an obvious advantage in terms of staying longer in power.[11]

Lei and Michaels (2014) and Bhattacharyya et al. (2017) argue that past discoveries influence the likelihood of current discoveries. Therefore, we include *mineral* $discovery_{t-10}$ and *oil* $discovery_{t-10}$ in all specifications to control for past giant and supergiant resource discoveries. These indicator variables take the value 1 for ten years if a deposit was discovered in the last ten years of the predecessor's term. Note that this definition takes into account past discoveries during the previous leader's tenure as well as spillover effects of past discoveries on the current leader.

We use information on elections from Archigos. Parliamentary and presidential election dates for every leader up to the year 2006 is sourced from Archigos. The remaining four years till 2010 is sourced from the website of the International Foundation for Electoral Systems.[12] Finally, the information on rules, changes and length of term limits is sourced from the Comparative Constitutions Project.[13]

2.2.2 Empirical Strategy

We aim to estimate the probability of a leader leaving office conditional on the same leader holding office up to that point in time. Hence, we focus on the time spent in office rather than the calendar time. Note that a leader's term in office is characterised by her staying

[11] This data is sourced from the website http://chartsbin.com/view/2295.
[12] Available at http://electionguide.org/
[13] available at http://comparativeconstitutionsproject.org/.

in office independently from the start of her term. Irrespective of the start date, our specification treats two leaders the same if they stay in power for the same number of years.

A basic survival model assumes that a failure could occur at any time. In contrast, this is not a given in our setting mainly due to the fact that a significant proportion of leaders leave office because of election defeats and term limits. Elections occur during election years and the probability of election defeat is zero in non-election years. Therefore, the underlying continuous time duration variable would have a distribution that is continuous between elections with probability mass points in election years. A similar logic also applies to term limits. Due to data limitations we do not deal with term limits in the main specification. The main specification deals with non-election and election years and exclude term limit years. We deal with term limit years separately in section 2.3.4.

To address the issue of elections we follow the approach of Narendranathan and Stewart (1993a) and use a discrete time survival model. The discrete time model estimates specific hazard rates for specific years and therefore could be used to estimate separate hazard rates for election and non-election years.

Finally, a leader could leave office due to resignation, rebellion, political protests, military coup or foreign invasion. The general assumption under a continuous time hazard model that the exit can occur at any time would be relevant here. We deal with these issues in section 2.3.3.

The Single Risk Model

We estimate both 'single risk' and 'competing risk models'. We start by describing the 'single risk model' first. The model follows Cox (1972) and Narendranathan and Stewart (1993a) and defines the conditional probability of leader i leaving office in year t, as

$$h_i(t) = \lambda(t) \exp(x'(t)\beta) \tag{2.1}$$

where $\lambda(t)$ is the baseline hazard representing the underlying risk for all leaders, $x'(t)$ is a vector of leader and country characteristics including *oil* and *mineral discovery, leader's entry age, log of population, first leader after independence, institutions, mineral discovery*$_{t-10}$ and *oil discovery*$_{t-10}$, and β is the vector of unknown coefficients. Note that the vector of leader and country characteristics do not include a constant.

The discrete-time model is estimated in a semi-parametric setting imposing no restrictions on the shape of the baseline hazard following Meyer (1990). This can be achieved by introducing time dummies for each recorded time interval avoiding to make an assumption about the shape of the baseline hazard. As discussed earlier, varying covariates are measured annually and therefore the duration of a leader's stay in office is recorded to the full year completed. A recorded duration of t whole years indicate duration on a continuous time scale between $t-1$ and t years. The probability of leaving office,q_{ne}, in a non-election[14] year t conditional on $x'(t)$ given that the leader is still in office at year $t-1$, is given by

$$q_{ne,i}(t|x(t)) = Prob(T_i < t|t-1 \leq T_i) = 1 - exp\left\{ - \int_{t-1}^{t} h_i(\tau)d\tau \right\}$$

$$= 1 - exp\left\{ - \int_{t-1}^{t} \lambda(\tau)exp(x'(t)\beta)d\tau \right\}$$

The above assumes that $x'(t)$ is constant between $t-1$ and t, i.e. changes in the time-varying variables occur at integer points. Therefore, the discrete time hazard could be written as

$$= 1 - exp[-exp\{x'(\beta) + \delta(t)\}] \quad where \quad \delta(t) = ln\left\{ \int_{t-1}^{t} \lambda(\tau)d(\tau) \right\}$$

The model has an extreme value form for the failure probability in discrete time with an unrestricted baseline hazard (Narendranathan and Stewart, 1993a,b)

As explained earlier, elections can only occur in election years. To account for the different circumstances in these years we assume that these point probabilities take the same extreme value form as before but with different coefficients. Hence, the probability of failure in an election year, $q_{e,i}$, is parameterized as

$$q_{e,i}(t|x(t)) = Prob(failing\, in\, election\, year|survival\, up\, to\, election\, year, x(t))$$

$$= 1 - exp[-exp\{x'(\alpha) + \delta(t)\}]$$

where $\delta(t)$ is defined as above and $x'(t)$ consists of the same control variable as explained before and α is the vector of unknown coefficients.

Let T_i be the time in years a leader i stays in office. The likelihood contribution for leader i in non-election years is then given by

$$L_i = q_{ne,i}(T_i) \prod_{t=1}^{T_i} \{1 - q_{ne,i}(t-1)\} \tag{2.2}$$

and the likelihood contribution by leader i in election years is then given by

[14] The subscript ne stands for non-election year and e for election year

$$L_i = q_{e,i}(T_i) \prod_{t=1}^{T_i} \{1 - q_{e,i}(t-1)\} \tag{2.3}$$

The first term on the right hand side of equations 2.2 and 2.3 is the probability of leaving office at time T and the second term represents the probability of staying in office up to time T. Equations 2.2 and 2.3 allow us to estimate separate hazards for election and non-election years.

The above model could be illustrated in a binary response model framework. In the case of non-election years ($q_{ne,i}$) the binary dependent variable is equal to 1 in the year the leader leaves office and equal to 0 in the remaining years. In the case of election years, ($q_{e,i}$), the model uses only the sub-sample of leaders who proceed to an election year. Here the binary dependent variable in an election year is equal to 1 if the leader leaves office and 0 if the leader proceeds to the next year. The 0 code here signifies election wins and no failures due to any other reason.

One advantage of the binary variable framework is that the extreme value assumption can be relaxed and coefficients can be estimated in a logit model (Arulampalam and Smith, 2004). The conditional probabilities $q_{ne,i}$ and $q_{e,i}$ can then be specified as

$$q_{ne,i}(t) = \frac{exp\{x'(\beta) + \delta(t)\}}{1 + exp\{x'(\beta) + \delta(t)\}}$$

and

$$q_{e,i}(t) = \frac{exp\{x'(\alpha) + \delta(t)\}}{1 + exp\{x'(\alpha) + \delta(t)\}}$$

which is used in equations 2.2 and 2.3 to estimate the hazard for election and non-election years.

The Competing Risk Model

The above model only considered a single risk of leaving office, but it can be expanded to a ‘competing risk model’. This is what we illustrate next which is a value addition to the existing literature.[15]

Consider K different reasons for a leader to leave office. In our case, the identified reasons to leave office are election, term limit, resignation, military coup and other irregular reasons. Each k relates to a $j^{th}(j = 1, 2, 3, ..., J)$ cause-specific hazard $h_{jt}(.)$ for leader i. Then the likelihood contribution of leader i with an observed duration T_i and failure type k is given by

[15] See Jenkins (2005) for a survey of competing risk models.

$$L_i = q_{k,i}(T_i) \prod_{t=1}^{T_i} \left[\prod_{j=1}^{J} \{1 - q_{k,i}(t-1)\} \right] \tag{2.4}$$

Similar to the 'single risk model' the sample is separated into election years, ($q_{e,k,i}$), and non-election years, ($q_{ne,k,i}$). We use a multinomial logit model and the above likelihood function (Equation 2.4) to estimate the different risk types simultaneously (Jenkins, 2005).

2.3 Evidence

2.3.1 How random are resource discoveries?

Our identification strategy relies on the exogeneity of giant and supergiant resource discoveries. Therefore, it is important to establish how random these discoveries are. In table 2.2 we test to what extent giant oil discoveries this year are predicted by social, political and economic factors of the previous year after controlling for country and year fixed effects. We do not find any evidence that pre-existing conditions affect the probability of giant oil discoveries. In table 2.3 we repeat the same exercise for giant mineral discoveries and find similar results. The only exception is the statistical significance of *log of population* which we include as a control in all models.

Table 2.2: How random are giant and supergiant oil discoveries?

Pr(Oil discovery=1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(log of) GDP pc $_{t-1}$	0.369								
	(0.319)								
Economic growth $_{t-1}$		-0.000							
		(0.008)							
x-Polity $_{t-1}$			-0.010						
			(0.039)						
Wildcat $_{t-1}$				0.056					
				(0.205)					
Int. crude oil price $_{t-1}$					0.008				
					(0.022)				
Trade (% of GDP) $_{t-1}$						-0.008			
						(0.005)			
Human capital $_{t-1}$							-0.889		
							(0.852)		
(log of) Population $_{t-1}$								-0.351	
								(0.475)	
Area (in 1000 sq. km)									0.000
									(0.000)
Observations	2,304	2,295	2,524	1,768	2,529	1,949	2,238	2,304	2,352
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: The table shows a logit model with country and year fixed effects, the dependent variable is giant and supergiant oil discovery in year t. The independent variable is measured in $t-1$ to see if an observable variable can predict oil discovery in the following year. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 2.3: How random are giant and supergiant mineral discoveries?

Pr(Mineral discovery=1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(log of) GDP pc $_{t-1}$	-0.380							
	(0.404)							
Economic growth $_{t-1}$		0.012						
		(0.021)						
x-Polity $_{t-1}$			0.015					
			(0.032)					
Metal pr. index $_{t-1}$				-0.007				
				(0.040)				
Precious metal pr. index $_{t-1}$				0.028				
				(0.024)				
Trade (% of GDP) $_{t-1}$					0.000			
					(0.007)			
Human capital $_{t-1}$						0.225		
						(0.760)		
(log of) Population $_{t-1}$							1.759**	1.417
							(0.864)	(0.882)
Area (in 1000 sq. km)								-0.000
								(0.000)
Observations	2,365	2,356	2,551	2,330	1,989	2,318	2,365	2,315
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES

Notes: The table shows a logit model with country and year fixed effects, the dependent variable is giant and supergiant mineral discovery in year t. The independent variable is measured in $t-1$ to see if an observable variable can predict mineral discovery in the following year. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

2.3.2 Single Risk Models

In table 2.4 we start by estimating the effect of a giant resource discovery on the hazard rate of a national leader while controlling for *x-polity, log of population, leader's entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. We use a 'single risk model' without interactions. The coefficient estimates here could be interpreted as follows. A positive coefficient implies an increase in the hazard rate and hence a leader is more likely to leave office earlier. Alternatively, a negative coefficient implies a leader is likely to stay longer in office. The magnitude of the coefficient is expressed by the hazard ratio $HR = exp(\beta)$ and $HR - 1$ represents the percentage change in the hazard rate (Jenkins, 2005).

Table 2.4: Resource Discovery and Political Survival:
Election vs. non-election years

	(1) all years	(2) non-election years	(3) election years
Oil discovery	−0.187	−0.281	−0.056
	(0.195)	(0.254)	(0.275)
Mineral discovery	−0.330**	−0.342**	−0.456
	(0.129)	(0.163)	(0.316)
x-polity	0.103***	0.059***	0.176***
	(0.015)	(0.017)	(0.028)
(log of) Population	0.026	0.032	−0.005
	(0.052)	(0.067)	(0.077)
Leader entry age	−0.025***	−0.027***	−0.029***
	(0.004)	(0.005)	(0.007)
First leader after independence	−0.650***	−0.461**	−1.860***
	(0.188)	(0.209)	(0.497)
Mineral discovery $_{t-10}$	−0.216	−0.248	−0.084
	(0.183)	(0.227)	(0.329)
Oil discovery $_{t-10}$	0.099	0.119	0.005
	(0.151)	(0.189)	(0.325)
Observations	6,034	5,211	823
# of leaders	1124	1053	526
# of countries	143	143	127
LL	-2172	-1598	-447

Notes: The table shows the impact of resource discoveries and institutions on the hazard of leaving office for the whole sample (Model 1), for non-election years (Model 2) and for election years (Model 3). The corresponding baseline hazard is semi-parametrically defined. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

In column 1, we use the full sample treating election and non-election years equally. We do not find any effect of *oil discovery* however *mineral discovery* appears to be risk reducing. A coefficient estimate of -0.33 translates into $exp(-0.33) = 0.72$ indicating a $(1-0.72)\times 100 = 28$ percent decline in hazard or risk. In columns 2 and 3, we distinguish between non-election years and election years respectively. We find that *mineral discovery* is risk reducing in non-election years while it does nothing to help or hinder the chances of an incumbent in elections.[16] *Oil discovery* does not seem to matter for the incumbent in both election and non-election years.

The political economy literature finds that the economic and political consequences of natural resources are often conditional on the quality of political institutions. Therefore, in table 2.5 we further examine the effect of giant resource discovery on political survival in non-election years conditional on the quality of institutions.

Table 2.5: Resource Discovery, Institutions and Political Survival: Single Risk Model in non-election years

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	-0.281	-1.584^{***}	-0.323	-1.715^{***}	-0.346	-2.569^{***}
	(0.254)	(0.437)	(0.259)	(0.512)	(0.265)	(0.699)
Mineral disc.	-0.342^{**}	-0.413	-0.326^{*}	-0.483	-0.283	-0.915
	(0.163)	(0.468)	(0.169)	(0.474)	(0.174)	(0.608)
Institution	0.059^{***}	0.040^{**}	0.084^{**}	0.048	-0.029	-0.100
	(0.017)	(0.017)	(0.036)	(0.036)	(0.070)	(0.071)
Oil # Inst.		0.159^{***}		0.337^{***}		0.811^{***}
		(0.039)		(0.094)		(0.211)
Mineral # Inst.		0.005		0.026		0.207
		(0.045)		(0.092)		(0.194)
Observations	5,211	5,211	5,211	5,211	5,211	5,211
# of leaders	1053	1053	1053	1053	1053	1053
# of countries	143	143	143	143	143	143
LL	-1598	-1584	-1605	-1591	-1611	-1593

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in non-election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

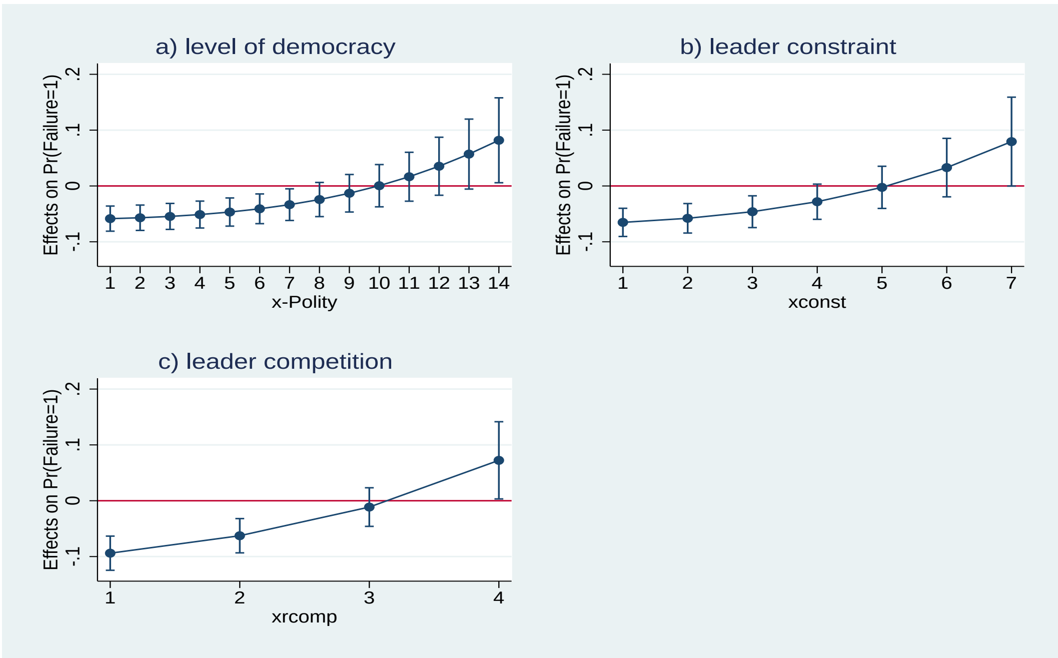
Column 1 is identical to column 2 of table 2.4. In column 2, we interact *oil discovery* and *mineral discovery* with the *x-polity* index which measures the overall level of demo-

[16] This is contrary to Andersen and Aslaksen (2013) finding that mineral rent increases risk.

cracy. *Oil discovery* appears to be risk reducing for leaders in countries with an average *x-polity* score under 8. Note that the average *x-polity* score in Qatar and Saudi Arabia is 2, in Romania it is 7, and in Norway it is 13. Our estimates predict that the probability of leaving office for a complete autocratic leader (*x-polity*=1) is reduced by 5.7 percent, while the same for a moderately autocratic leader with *x-polity* score of 7 is 3.3 percent.[17]

Columns 4 and 6 report interaction effects with executive constraints (*xconst*) and recruitment competition (*xrcomp*) which are measures of constraints on the chief executive and competitiveness in executive recruitment respectively. Similar to the *x-polity* result in column 2, we find *oil discovery* to be risk reducing for the incumbent in non-election years in states with weak *xconst* and *xrcomp*. Figure 2.5 plots the average marginal effects of *oil discovery*. We do not find any effect of *mineral discovery* once interacted with institutions.

Figure 2.5: Oil Discovery, Institutions and Political Survival in non-election years: Average Marginal effects with 95% CI



Notes: The graphs a, b, and c show the average marginal effect of oil discovery on leaders' time in office conditional on the level of democracy (*x-polity*), the constraints a leader faces (*xconst*) and the competition a leader faces (*xrcomp*). They correspond to Model 2, 4, and 6 in table 2.5 respectively.

The heterogeneous effects of minerals and oil is perhaps explained by their different levels of connectedness. Oil exhibits enclave characteristics which exclusively favours the incumbent. Oil revenue could be used by the incumbent for the purpose of coercion and patronage under weak political institutions which would reduce risk. In contrast, minerals

[17] The risk reduction percentages are calculated by the specific Sata command *margins*. The command calculates the marginal effect at each value of *x-polity*, *xconst* or *xrcomp*.

are better connected to the rest of the economy thereby empowering both the incumbent and the opposition. This could promote cooperation and reduce political risks for the incumbent.

Next, we ask the question whether the risk reducing effects are motivated by actual income or income expectations. To ascertain we need to observe how long it takes for a resource discovery to have an impact on risk. If the effect is instantaneous then it is most likely to be driven by expectations. Anything to the contrary would point towards actual income to be the driving force.

Table 2.6 finds that risk reduction takes effect 5-8 years after a mineral discovery. It typically takes 5-8 years post discovery to construct a mine and perhaps the incumbent reaps benefit during the construction phase from the new employment and infrastructure. However, this appears to be short-lived as it disappears over the 9-16 year period. The risk reducing effect returns again 16 years after discovery when the incumbent starts enjoying rent from the extracted deposits.

Table 2.6: The effect of mineral discovery over time

Institution:	(1) x-polity	(2) xconst	(3) xrcomp
Mineral discovery $_{1-4years}$	-0.285	-0.268	-0.239
	(0.184)	(0.185)	(0.180)
Mineral discovery $_{5-8years}$	-0.943^{**}	-0.914^{**}	-0.835^{*}
	(0.448)	(0.452)	(0.459)
Mineral discovery $_{9-12years}$	0.692	0.727	0.792^{*}
	(0.455)	(0.463)	(0.482)
Mineral discovery $_{13-16years}$	-0.916	-0.940	-0.915
	(0.656)	(0.661)	(0.666)
Mineral discovery $_{>16years}$	-0.971^{**}	-0.978^{**}	-0.934^{**}
	(0.464)	(0.463)	(0.456)
Oil discovery	-0.277	-0.317	-0.340
	(0.255)	(0.260)	(0.266)
Institution	0.059^{***}	0.083^{**}	-0.027
	(0.017)	(0.036)	(0.070)
Observations	5,211	5,211	5,211
# of leaders	1053	1053	1053
# of countries	143	143	143
LL	-1592	-1599	-1605

Notes: The table shows the impact of mineral discoveries over time on the hazard of leaving office in non-election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 2.7 focuses on oil. Since oil is risk reducing only in countries with weak political institutions, we restrict our sample here to *x-polity* < 8, *xconst* < 4 and *xrcomp* < 3.[18] We find that the risk reducing effect of oil appears 11-20 years after a giant or supergiant discovery. Unlike minerals the effects here is much delayed and appears only after a deposit is fully developed. Perhaps this is indicative that oil rig development is highly capital intensive and therefore creates very little employment during the construction phase (Karl, 2007). Once the deposit is fully developed 11-20 years after discovery, the incumbent mainly benefits from rent.[19]

Table 2.7: The effect of oil discovery over time

Institution:	(1) x-polity	(2) xconst	(3) xrcomp
Oil discovery $_{1-5years}$	-0.447	-0.306	0.144
	(0.382)	(0.374)	(0.423)
Oil discovery $_{6-10years}$	-0.358	-0.299	0.158
	(0.453)	(0.458)	(0.480)
Oil discovery $_{11-15years}$	-2.150^{**}	-2.160^{**}	-1.700
	(1.057)	(1.056)	(1.282)
Oil discovery $_{16-20years}$	-1.848^{**}	-1.770^{*}	-0.899
	(0.940)	(0.924)	(1.040)
Oil discovery $_{>20years}$	-1.329	-1.059	-0.102
	(0.949)	(0.869)	(0.718)
Mineral discovery	0.195	0.169	0.081
	(0.302)	(0.276)	(0.301)
Institution	-0.187^{**}	-0.648^{***}	-1.912^{***}
	(0.085)	(0.129)	(0.256)
Observations	2,550	2,550	2,550
# of leaders	353	353	353
# of countries	100	100	100
LL	-596	-607	-525

Notes: The table shows the impact of oil discoveries over time on the hazard of leaving office in non-election years for countries with *x-polity*<8, *xconst*<4 and *xrcomp*<3. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

So far we have used giant and supergiant resource discoveries as exogenous news shocks to identify the effect of resources on leaders' tenure. Next we use an even cleaner iden-

[18] These are the corresponding levels of institutional quality with significant marginal effects for *oil discovery*, see figure 2.5.

[19] This is consistent with the findings of Andersen and Aslaksen (2013) and de Mesquita and Smith (2010) who use oil rent as their explanatory variable.

tification strategy using first discovery in resource poor countries. Leaders in countries with a history of resource discoveries could expect giant discoveries in the future. In contrast, the first giant discovery in a resource poor country is unexpected and likely to be exogenous. We follow Smith (2015) in defining a resource poor country in 1950 and table A 5 in appendix A presents a list.[20] Table 2.8 reports the effects of first discovery shocks on tenure in a non-election year in a resource poor country and the results are similar to those of all discoveries (from table 2.5). Note that this time *oil discovery* is also significant at the 10% level in the specifications without interaction (column (1), (2) and (3)). However, the overall significant *oil discovery* coefficient is again driven by countries with weak institutional quality as can be seen in the marginal effects plot reported in figure 2.6.

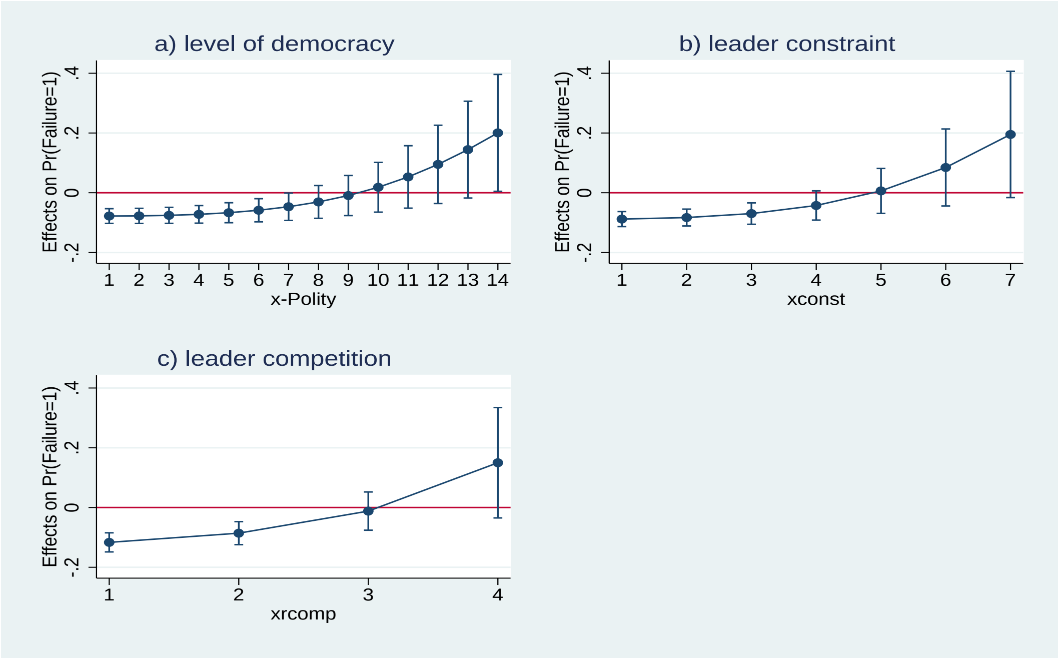
Table 2.8: First Resource Discovery, Institutions and Survival:
Single Risk Model in non-election years

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
F. oil discovery	−0.872*	−2.546***	−0.921*	−2.944***	−0.927*	−3.916***
	(0.477)	(0.708)	(0.478)	(0.869)	(0.474)	(1.228)
F. mineral disc.	−0.677**	−0.715	−0.671**	−0.645	−0.640**	−1.049
	(0.325)	(0.684)	(0.326)	(0.780)	(0.326)	(0.960)
Institution	0.050***	0.041**	0.069*	0.055	−0.060	−0.079
	(0.018)	(0.018)	(0.038)	(0.038)	(0.082)	(0.082)
F. oil # Institution		0.272***		0.601***		1.262***
		(0.067)		(0.172)		(0.393)
F. mineral # Inst.		0.009		−0.001		0.176
		(0.080)		(0.188)		(0.355)
Observations	3,670	3,670	3,670	3,670	3,670	3,670
# of leaders	745	745	745	745	745	745
# of countries	92	92	92	92	92	92
LL	-1187	-1176	-1191	-1181	-1193	-1184

Notes: The table shows the impact of first (F.) resource discoveries in initially resource poor countries on the hazard of leaving office for leaders in non-election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

[20] Smith (2015) defines a country as resource poor if annual oil and gas production per capita in 1950 was less than one oil barrel energy equivalent. He converts natural gas production to its oil barrel equivalent in terms of energy generation using the conversion rate of 0.00586152 oil barrels per terajoule. Countries that produced more than one barrel per capita at the start of the period, or already had significant mineral wealth are dropped from his sample as unsuitable comparison countries.

Figure 2.6: First Oil Discovery, Institutions and Political Survival in non-election years: Average Marginal effects with 95% CI



Notes: The graphs a, b, and c show the average marginal effect of first oil discovery in resource poor countries on leaders' time in office conditional on the level of democracy (*x-polity*), the constraints a leader faces (*xconst*) and the competition a leader faces (*xrcomp*). They correspond to Model 2, 4, and 6 in table 2.8.

Next, in table 2.9 we turn our attention to a single risk model in election years. The sample consists only of years in which an election took place and accounts therefore for the additional risk of election defeat. Columns 1 and 3 include the resource discovery variables and institutions without the interaction terms and columns 2 and 4 interacts *oil disocovery* and *mineral discovery* with *x-polity* and *xconst*. Executive recruitment competition (*xcomp*) is omitted here because it is endogenous in an election year. Countries with elections systematically score higher *xrcomp* than countries without elections. We find that *mineral discovery* and its interaction with institutions does not seem to have any effect on tenure in an election year. *Oil discovery* appears to be risk reducing for a leader in an election year in a country with less legislative control on the executive. In particular, the average marginal effect plot in figure 2.7 reveals that *oil discovery* reduces the risk of leaving office by 9.6% - 10.7% [21] for a leader with *xconst* score of less than 4. For example, Mexico and Mozambique have average *xconst* score of 4 while Myanmar has 2.

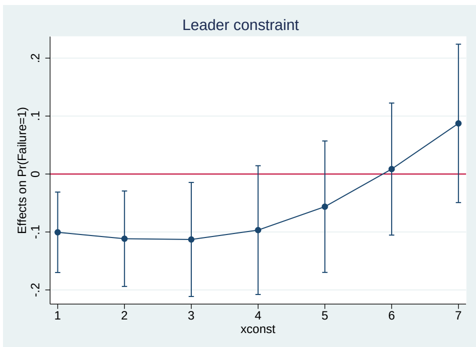
[21] Risk reduction of 9.7% corresponds to *xconst*=1 and 10.7% corresponds to *xconst* = 3.

Table 2.9: Resource Discovery, Institutions and Political Survival:
Single Risk Model in election years

	(1)	(2)	(3)	(4)
Institution:	x-polity	x-polity	xconst	xconst
Oil discovery	−0.056	−1.958	−0.091	−2.085*
	(0.275)	(1.374)	(0.273)	(1.086)
Mineral discovery	−0.456	−1.520	−0.481	−1.083
	(0.316)	(0.962)	(0.322)	(0.885)
Institution	0.176***	0.156***	0.314***	0.278***
	(0.028)	(0.028)	(0.056)	(0.057)
Oil # Institution		0.163		0.354**
		(0.106)		(0.172)
Mineral # Institution		0.094		0.110
		(0.080)		(0.150)
Observations	823	823	823	823
# of leaders	526	526	526	526
# of countries	127	127	127	127
LL	-447	-443	-452	-448

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Figure 2.7: Oil Discovery, Executive Constraint and Political Survival in election years:
Average Marginal effects with 95% CI



Notes: The graph shows the average marginal effect of oil discovery on leaders' time in office conditional on the constraints a leader faces (*xconst*) and corresponds to Model 4 in table 2.9.

Concluding the the 'single risk model' results: *mineral discovery* reduces risk generally in non-election years, but not in election years and *oil discovery* reduces risks only in countries with weak institutions in non-election years, the same is true but to a lesser extend in election years.

2.3.3 Competing Risk Models

The 'single risk models' discussed above show that resource discoveries influence the overall risk of a leader leaving office in non-election years. The effect is somewhat muted during election years. Using 'competing risk models' we investigate to what extent the effect of discoveries differ by risk types. In particular, we focus on the risk of resignation, military coups, and others[22] in non-election years and the risk of losing elections in election years. Furthermore, we also treat term limit years separately for leaders with and without term limit.

Table 2.10: Resource Discovery and the Risk of Resignation: Competing Risk Model in non-election years

Institution:	(1) x-polity	(2) x-polity	(3) xconst	(4) xconst	(5) xrcomp	(6) xrcomp
Oil discovery	−0.260	−2.292***	−0.342	−2.564***	−0.396	−4.030***
	(0.316)	(0.642)	(0.328)	(0.728)	(0.345)	(0.954)
Mineral disc.	−0.482**	−1.492**	−0.483**	−1.589**	−0.368	−2.380***
	(0.208)	(0.689)	(0.219)	(0.733)	(0.229)	(0.889)
Institution	0.162***	0.134***	0.298***	0.246***	0.328***	0.229**
	(0.026)	(0.026)	(0.051)	(0.053)	(0.104)	(0.106)
Oil # Inst.		0.211***		0.463***		1.203***
		(0.054)		(0.122)		(0.264)
Mineral # Inst.		0.093		0.203		0.616**
		(0.058)		(0.125)		(0.251)
Observations	5,211	5,211	5,211	5,211	5,212	5,213
# of leaders	1053	1053	1053	1053	1053	1053
# of countries	143	143	143	143	143	143
LL	-1957	-1957	-1957	-1957	-1940	-1906

Notes: The table shows the impact of resource discoveries and institutions on the hazard of leaving office because of resignation in non-election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 2.10 shows the impact of resource discoveries and institutions on the probability of resignation in a non-election year. Resignation here is defined as a leader leaving office in a regulated manner, but does not participate in an election. The reasons for resignation could be numerous ranging from satisfactory agenda fulfilment to being pushed out by her political party or cronies. *Oil discovery* appears to reduce resignation risk for leaders in

[22]The category others is an aggregated residual of leaders leaving office because of: domestic protest, domestic rebels, other government actors, foreign force and assassination by unsupported individuals.

countries with weak institutions. In particular, *oil discovery* reduces the risk of resignation by 2.3% - 3.1% for leaders with *x-polity* score between 1 and 8 and by 2.8% - 3.5% with *xconst* score between 1 and 4. Leaders in countries without any institutionalised regulation on executive selection ($xrcomp = 1$) face a 4% reduced risk of resignation following a giant *oil discovery*. *Mineral discovery* reduces resignation risk by approximately 38% percent in a non-election year independent of the institutional quality.

Table 2.11 examines the effect of discoveries on military coups in non-election years. Note that these are successful military coups that lead to leader changes. In addition to the military grabbing power, these transitions also include struggle within the military junta by irregular means (a coup within a coup). We find *mineral discovery* has no role in military coups. In contrast, *oil discovery* significantly reduces the risk of military coups especially in countries with weak political institutions. The risk is reduced by 1.3% - 5.5% for leaders in countries with *x-polity* score lower than 7. This is perhaps indicative of the link between oil and authoritarianism.

Table 2.11: Resource Discovery and the Risk of Military coups: Competing Risk Model in non-election years

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	-1.097^{**}	-1.794^{***}	-0.949^{**}	-1.463^{**}	-0.590	-0.145
	(0.426)	(0.548)	(0.422)	(0.737)	(0.391)	(1.279)
Mineral disc.	-0.120	0.177	-0.112	-0.020	-0.191	-1.085
	(0.320)	(0.618)	(0.314)	(0.608)	(0.317)	(0.823)
Institution	-0.198^{***}	-0.206^{***}	-0.552^{***}	-0.564^{***}	-1.464^{***}	-1.522^{***}
	(0.031)	(0.031)	(0.078)	(0.083)	(0.210)	(0.243)
Oil # Inst.		0.172^{***}		0.245		-0.306
		(0.062)		(0.264)		(0.707)
Mineral # Inst.		-0.062		-0.051		0.529
		(0.099)		(0.230)		(0.434)
Observations	5,211	5,211	5,211	5,211	5,212	5,213
# of leaders	1053	1053	1053	1053	1053	1053
# of countries	143	143	143	143	143	143
LL	-1957	-1957	-1957	-1957	-1940	-1906

Notes: The table shows the impact of resource discoveries and institutions on the hazard of leaving office because of military coups in non-election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

We also estimate the model with the 'others' (domestic protest, domestic rebels, other government actors, foreign force and assassination by unsupported individuals) risk category during non-election years and find no effect of resource discovery. These results are reported in appendix A table A 7.

Next, we turn to the risk of losing election in election years. In an election year, the risk of losing election dwarfs any other threats. There are only 8 resignations, 7 military coups and 3 leaders leaving for other reasons compared to 255 lost elections in election years. The small sample size of resignations, military coups and other reasons is insufficient for the estimation of separate models. Therefore, we focus only on the risk of election loss in an election year in table 2.12. Unsurprisingly, strong political institutions and checks and balances increase the risk of election loss for an incumbent but we do not find any direct effect of resource discovery nor one conditional on institutions.

Table 2.12: Resource Discovery and the Risk of losing elections: Competing Risk Model in election years

	(1)	(2)	(3)	(4)
Institution:	x-polity	x-polity	xconst	xconst
Oil discovery	−0.024	−1.526	−0.059	−1.761
	(0.294)	(1.473)	(0.289)	(1.162)
Mineral discovery	−0.520	−1.704	−0.555	−1.040
	(0.352)	(1.064)	(0.361)	(1.024)
Institution	0.212***	0.195***	0.372***	0.343***
	(0.027)	(0.028)	(0.058)	(0.058)
Oil # Institution		0.127		0.299
		(0.113)		(0.183)
Mineral # Institution		0.101		0.086
		(0.087)		(0.169)
Observations	823	823	823	823
# of leaders	526	526	526	526
# of countries	127	127	127	127
LL	-423	-421	-429	-427

Notes: The table shows the impact of resource discoveries and institutions on the hazard of leaving office because of losing an election. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

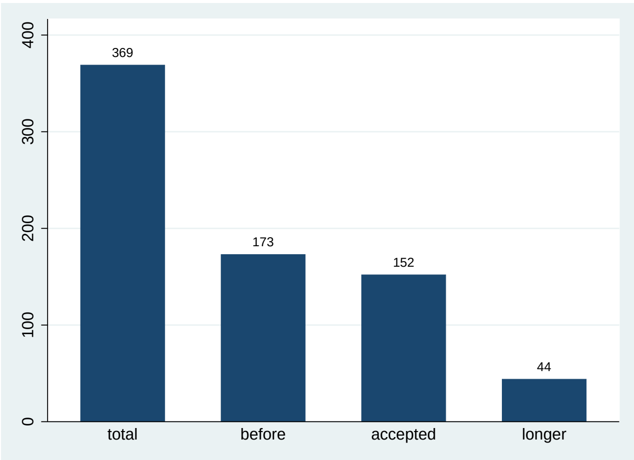
Concluding the results from the ‘competing risk model’ shows that the risk reducing effect of *mineral discovery* obtained in the single risk model is purely driven by a reduction of resignation risk in non-election years. *Mineral discovery* do not influence the risk of military coups, elections or other reasons of leaving office. The conditional risk reducing effect of *oil discovery* is slightly more widespread and reduces apart from the risk of resignation also the risk of losing office because of military coups.

2.3.4 Term Limits

So far we did not include term limit years in our analysis. This implies that in the non-election year specifications we include all the non-term limit years of leaders in countries with term limit but exclude the term limit years. This is because term limits represent a special case which requires exclusive treatment. This is what we intend to do next in table 2.13 by estimating a single risk model for leaders with term limit in their term limit year.

Figure 2.8 presents a breakdown on leaders with term limits. From the 369 leaders with term limits only 196 reach their term limit year, 173 leave office before, and 44 leaders stay longer. Table 2.13 shows that resource discovery does not seem to have any significant impact on the tenure of leaders with term limits in term limit years in a single risk model. Nonetheless, these results should be interpreted with caution as we have a sample size of only 206 observations.

Figure 2.8: Leaders with term limit



Notes: The graph shows leaders who face term limits and if they left office before, on or after the maximum term.

Table 2.13: Resource Discovery, Institutions and Political Survival: Single Risk Model in term limit years

Institution:	(1) x-polity	(2) x-polity	(3) xconst	(4) xconst
Oil discovery	0.214	1.805	0.150	1.693
	(0.699)	(1.315)	(0.600)	(1.331)
Mineral discovery	−1.149	0.486	−1.027	1.146
	(0.716)	(1.048)	(0.761)	(1.096)
Institution	0.387***	0.529***	0.789***	1.169***
	(0.068)	(0.102)	(0.158)	(0.243)
Oil # Institution		−0.216		−0.403
		(0.143)		(0.296)
Mineral # Institution		−0.200*		−0.565**
		(0.116)		(0.245)
Observations	206	206	206	206
# of leaders	196	196	196	196
# of countries	65	65	65	65
LL	-64	-61	-64	-61

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office for leaders in term limit years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

2.3.5 Mechanisms

Tax on the non-resource sector, military expenditure, conflict onset, government borrowing, and economic growth are potential mechanisms through which resource discovery could affect leaders' survival. The 'rentier state hypothesis' posits that governments receiving sufficient natural resource revenues are less likely to tax their citizens heavily and in return, the citizens demand less accountability from them (Mahdavy, 1970). The incumbent can also stay in power by using resource wealth to boost military spending, government borrowing and economic growth. Resource discoveries could increase the risk of armed conflict onset (Lei and Michaels, 2014) thereby increasing the risk for the incumbent (Caselli, 2006). In order for these variables to act as credible mechanisms, they must respond to mineral and oil discoveries. We estimate the following regression:

$$y_{it} = \alpha_i + \beta_t + \gamma_1(L)Discovery_{lit} + \gamma_2 X_{it} + \epsilon_{it}$$

where y_{it} is the dependent variable (non-resource tax, military expenditure, conflict onset, public debt, and economic growth) for country i in year t. α_i and β_t are country and year fixed effects. $Discovery_{lit}$ is a dummy variable equal one for two consecutive years, (L) years after the discovery $L \in \{1, 3, 5, 7, 9, 11, 13, 15, 17, 19\}$ for leader l. The coefficient γ_1 therefore measures the effect of a resource discovery 1-2, 3-4, 5-6, ..., 19-20 years after the discovery on the outcome variable (year 1 is the discovery year). X are control variables including past oil and mineral discovery in all specifications. Further, for regressions with the outcome variable measured as a share of GDP we include the log of GDP per capita as a control. ϵ_{it} is the error term. We analyse the impact of mineral and oil discoveries separately. The oil sample covers leaders from non-democracies only with x-polity score < 8 because the risk reducing effect of *oil discovery* is conditional on the level of institutional quality.

We find that *oil discovery* decreases non-resource sector tax as a share of GDP. *Oil discovery* also increases military spending and thereby reducing risk for the incumbent. In contrast, *mineral discovery* appears to have no effect on military spending. It also appears to increase non-resource sector tax as a share of GDP. The latter is perhaps reflective of the relatively high level of connectedness of minerals to the rest of the economy. We do not find any effect on conflict onset, public debt, and economic growth. The conflict onset result is in agreement with Cotet and Tsui (2013a).

Table 2.14: Mechanisms: Oil discoveries

Outcome in year:	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20
Panel A. Dependent variable: Non-resource tax (% of GDP)										
Oil discovery	0.217	0.880**	0.453	0.531	-0.788	-1.209*	-1.473**	-1.703**	0.428	-0.708
	(0.426)	(0.434)	(0.455)	(0.545)	(0.638)	(0.659)	(0.684)	(0.814)	(1.042)	(1.134)
Observations	1,192	1,192	1,192	1,192	1,192	1,192	1,192	1,192	1,192	1,192
Panel B. Dependent variable: Military expenditure (% of GDP)										
Oil discovery	0.319	0.710**	0.173	-0.0159	-0.00505	0.0469	0.182	0.686	1.185**	1.064*
	(0.261)	(0.276)	(0.287)	(0.327)	(0.362)	(0.416)	(0.422)	(0.461)	(0.587)	(0.587)
Observations	2,113	2,113	2,113	2,113	2,113	2,113	2,113	2,113	2,113	2,113
Panel C. Dependent variable: Conflict Onset										
Oil discovery	-0.00876	0.00779	0.0137	-0.00641	0.0156	-0.0242	-0.0178	-0.0207	0.0205	-0.0220
	(0.0123)	(0.0129)	(0.0139)	(0.0158)	(0.0173)	(0.0186)	(0.0202)	(0.0225)	(0.0251)	(0.0260)
Observations	3,403	3,403	3,403	3,403	3,403	3,403	3,403	3,403	3,403	3,403
Panel D. Dependent variable: Public debt (% of GDP)										
Oil discovery	3.662	6.997*	1.344	1.848	1.190	1.514	-1.865	-3.828	-4.921	-9.407
	(3.937)	(3.977)	(4.213)	(4.661)	(5.311)	(5.735)	(6.263)	(6.610)	(7.335)	(7.220)
Observations	1,958	1,958	1,958	1,958	1,958	1,958	1,958	1,958	1,958	1,958
Panel E. Dependent variable: Economic growth										
Oil discovery	-0.781	1.047	0.915	-1.121	-2.704**	2.101*	-3.018**	3.447**	2.217	0.577
	(0.830)	(0.874)	(0.936)	(1.020)	(1.144)	(1.252)	(1.364)	(1.488)	(1.696)	(1.697)
Observations	2,839	2,839	2,839	2,839	2,839	2,839	2,839	2,839	2,839	2,839
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All specifications include country and year fixed effects. The coefficients measure the effect of an oil discovery 1-2, 3-4, 5-6,. . . , 19-20 years after the discovery on the outcome variable. All specifications include past oil and mineral discoveries as controls. Regressions with outcome variable measured as a share of GDP (Panels A, B, & D) include log GDP per capita as a control. *Oil discovery* reduces risk in non-democratic countries, therefore, we run the regression for leaders in countries with x-polity score < 8. Standard errors in paranthesis; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 2.15: Mechanisms: Mineral discoveries

Outcome in year:	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20
Panel A. Dependent variable: Non-resource tax (% of GDP)										
Mineral discovery	0.228	0.148	0.373	0.790**	0.852*	0.398	1.535***	2.060***	3.001***	2.911***
	(0.256)	(0.297)	(0.344)	(0.393)	(0.447)	(0.603)	(0.589)	(0.663)	(1.019)	(1.012)
Observations	3,482	3,482	3,482	3,482	3,482	3,482	3,482	3,482	3,482	3,482
Panel B. Dependent variable: Military expenditure (% of GDP)										
Mineral discovery	-0.119	-0.187	-0.216	-0.243	-0.124	-0.0761	-0.104	0.0151	-0.731	-0.941
	(0.127)	(0.148)	(0.175)	(0.205)	(0.230)	(0.279)	(0.314)	(0.376)	(0.520)	(0.593)
Observations	5,451	5,451	5,451	5,451	5,451	5,451	5,451	5,451	5,451	5,451
Panel C. Dependent variable: Conflict onset										
Mineral discovery	0.000304	0.000351	0.000851	-0.00495	-0.0154	0.00790	-0.0278	0.00305	0.0230	-0.0341
	(0.00816)	(0.00954)	(0.0113)	(0.0130)	(0.0144)	(0.0178)	(0.0200)	(0.0235)	(0.0290)	(0.0342)
Observations	7,261	7,261	7,261	7,261	7,261	7,261	7,261	7,261	7,261	7,261
Panel D. Dependent variable: Public debt (% of GDP)										
Mineral discovery	-0.791	-1.403	-0.998	-0.0597	7.599	8.629	3.007	-1.258	-1.122	-1.303
	(3.001)	(3.470)	(4.112)	(4.639)	(5.250)	(6.868)	(7.512)	(8.800)	(11.09)	(13.09)
Observations	5,182	5,182	5,182	5,182	5,182	5,182	5,182	5,182	5,182	5,182
Panel E. Dependent variable: Economic growth										
Mineral discovery	0.536	0.0548	1.063	-0.190	-0.196	0.341	1.218	-2.264	-0.405	1.092
	(0.491)	(0.577)	(0.678)	(0.783)	(0.865)	(1.070)	(1.216)	(1.405)	(1.763)	(1.981)
Observations	6,493	6,493	6,493	6,493	6,493	6,493	6,493	6,493	6,493	6,493
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All specifications include country and year fixed effects. The coefficients measure the effect of a mineral discovery 1-2, 3-4, 5-6, . . . , 19-20 years after the discovery on the outcome variable. All specifications include past oil and mineral discoveries as controls. Regressions with outcome variables measured as a share of GDP (Panels A, B, & D) include log GDP per capita as a control. Standard errors in paranthesis; *, ** and *** stand for significant at the 10%, 5% and 1% level.

2.4 Robustness

We perform a battery of robustness tests of the empirical relationship between resource discovery and leaders tenure. They deal with nuanced issues relating to exploration effort, term limits, leaders who do not face elections, pre-election years, assassinated leaders, and resource dependence. Following is a discussion of these results.

Exploration effort could be the main driver of discoveries. Therefore a potent question is to what extent leaders' time in office influence exploration effort thereby influencing the likelihood of giant and supergiant discoveries? To take account of this issue we use data from Cotet and Tsui (2013a) on the number of *Wildcats* drilled in a country in a year. *Wildcats* are explorative boreholes drilled with the expectation of finding oil and therefore is a good proxy for exploration effort. Cotet and Tsui (2013a) provide *Wildcat* data for 57 countries for the period 1946 to 2003. This reduces the sample by about 60 percent. We re-estimate the baseline results with the observations for which *Wildcat* data is available and find little difference from original results in a 'single risk model'. Therefore, our results are robust to the inclusion of exploration effort. Table A 8 and A 9 in appendix A reports these results.

Our non-election year specifications include all the non-term limit years of leaders in countries with term limits along with non-election years of leaders without term limits. This could be a challenge if leaders with term limits systematically behave differently from leaders without term limits in non-election years. We therefore test the robustness of our results by dropping leaders with term limits from the non-election year sample and our results survive. Table A 10 in appendix A reports these results.

We estimate the probability of leaving office separately for election and non-election years but we do not distinguish between leaders who do or do not face elections. For example, a monarch who does not face the risk of an election could behave differently in a non-election year from a leader who does. Therefore, we drop leaders who do not face elections from the non-election year sample and re-estimate the 'single risk models'. The results are robust. Table A 11 in appendix A reports these results. Note that we do not run interaction with *xrcomp* here as the exclusion of non-election leaders from the sample creates endogeneity issues with regards to this variable.

Non-election years especially the year before election could have a disproportionate impact on the outcome variable in election years. For example, a leader could use certain policies in the year before election to influence election outcome. We test the potential of such spillovers in a 'single risk model' for election years using one year lagged covariates and the results are robust. Table A 12 in appendix A reports these results.

Recall that leaders leaving office due to death by assassination is not right censored in our sample as we treat these assassinations to be politically motivated. Next, we test the robustness of our results by right censoring the 8 assassinations that we have in the sample. The results are robust and table A 13 in appendix A reports them. The assassinated leaders are: Palme of Sweden, Verwoerd of South Africa, Rabin of Israel, Faisal of Saudi Arabia, Bandarcenaike S.W.R.D. of Sri Lanka, Kennedy of USA, Castillo Armas of Guatemala and Remon Cantera of Panama.

Our analysis includes countries which are resource dependent and therefore we could be picking up the effect of resource dependence rather than resource discovery. To check indeed we are picking up the effect of resource discovery, we follow Smith (2015) and use his sample of resource poor countries in 1950. Under this approach we are solely picking up the effect of resource discoveries[23] in resource poor countries thereby ruling out the confounding influence of 'resource dependence'. The results are robust with the additional feature of interaction between *mineral discovery* and institutions now statistically significant. Appendix A table A 5 lists the countries fitting Smith's definition of resource poor countries in 1950. Tables A 14 and A 15 report results of single risk models in non-election and election years respectively.

2.5 Conclusion

A large literature focuses on how leaders influence the economic and institutional performance of a country. However, surprisingly little is known about the link between natural resources and the political fortunes of a national leader. We take a fresh look here using a new dataset of giant oil and mineral discoveries. We combine this with a large dataset of 1255 leaders in 158 countries over the period 1950 to 2010 and empirically explore how leaders are affected by giant resource discoveries. We innovate by using both 'single risk' and 'competing risk' discrete time proportional hazard models. We find that mineral discoveries reduce risk for the incumbent in a 'single risk model' especially in a non-election year. In contrast, oil discoveries reduce risk disproportionately more for the incumbent in countries with weak political institutions.

The effects appear to be induced by actual income or rent rather than income expectations. We track the evolution of risk for the incumbent after a discovery news shock

[23]Note that these are all giant and supergiant discoveries in resource poor countries and not just first discoveries as in table 2.8.

and find that risk reduces significantly during the construction and extraction stages of a mine. The construction stage brings employment and new infrastructure and therefore is beneficial for the incumbent. In contrast, oil discovery reduces risk almost a decade after a giant discovery when the deposit is likely to be fully operational. Therefore, oil rents appears to be a powerful political tool for the incumbent in oil countries with weak political institutions.

We also observe that in a 'competing risk model' oil discovery significantly reduces the risk of losing office via military coup while resource (oil and mineral) discovery in general reduces the risk of resignation. Resource discovery does not seem to have any impact on the risk of election loss and on leaders with term limits.

We test potential mechanisms and find that oil discovery decreases tax as a share of GDP from the non-resource sector. Oil discovery also increases military spending and thereby reducing political risk for the incumbent. In contrast, mineral discovery appears to have no effect on military spending. It also appears to increase non-resource sector tax as a share of GDP which supports the thesis that minerals are better connected to the rest of the economy.

Chapter 3

Resource Revenues and Domestic Taxation: Is there a crowding-out effect?

3.1 Introduction

Low levels of government revenues are a major obstacle for development in many countries (Chaudhry, 1997). Government revenues average at 17% and 25% of GDP in low- and middle-income countries respectively compared to 32% in high-income countries (Knebelmann, 2017). At the same time, natural resources, such as oil, gas, and minerals contribute significantly to the government budget in many countries. They generate annually an estimated US$ 4 trillion in economic rents worldwide and the World Bank categorises currently over 50 countries as resource dependent. This massive amount of economic rents could eradicate poverty in those countries, improving the lives of over 1.5 billion people (Barma et al., 2012). Countries 'blessed' with an abundance of natural resources could use them to fill the revenue gap and lift resource-rich low- and middle-income countries on a better development trajectory. However, the reality often looks different.

Many scholars argue that resource revenues crowd out other forms of government revenues, especially domestic taxes (Bornhorst et al., 2009; Crivelli and Gupta, 2014; Mahdavy, 1970; Ossowski and Gonzales, 2012; Ross, 2001; Thomas and Treviño, 2013). Focusing on the resource sector and substituting resource revenues for other forms of taxation can be appealing for the government for several reasons. The potential gains in terms of rents is huge, outperforming in many countries the potential gains from traditional taxation (Barma et al., 2012). Collecting revenues from the resource sector is relatively easy because fewer stakeholders are involved. Fewer stakeholders and the resulting low visibility make it easier to hide income if desired (Lei and Michaels, 2014). Apart from lower effort, more waste and/or corruption, it could also be argued that governments substitute taxes with resource revenues intentionally to promote economic growth. Lower taxation of companies and individuals lead to lower production costs and higher disposable incomes. The former increases competitiveness of domestic businesses and the latter increases consumption (IMF, 2012b).

However, there are also arguments against a crowding-out effect, stating that resource revenues could increase tax income. The most obvious way for resource revenues to increase tax income would be if the government invests the resource revenues directly into tax administration (Besley and Mclaren, 1993; Besley and Persson, 2009, 2013). Higher wages for tax collectors, better training and technology should improve the tax administration and therefore governments' tax income. Further, to collect revenues from the resource sector the government needs a sophisticated tax administration division dealing with resource companies. If this division is not operating in isolation, it could be that they have positive spillovers on the rest of the tax administration (Knebelmann, 2017).

Resource revenues influence taxes positively or negatively and this chapter analyses if there is a prevailing direction. Exploiting the 2000s commodity price boom as a positive income shock for resource exporting countries and using comparative case study analysis in the form of the synthetic control method, I find a crowding-out effect of non-resource tax per capita through resource revenues. Due to the 2000s commodity price boom total tax per capita is on average 11% lower in resource exporting countries compared to what total tax per capita would have been without the price boom. The results confirm the finding of other scholars.[1] However, I also show that this effect is heterogeneous by resource type, institutional quality, resource dependence, the use of different fiscal instruments, and the ownership structure of the resource sector, which are new findings. Further, I conduct five case studies of new resource producers and the results indicate that the crowding-out effect is not a necessity. Only two new resource producers faced lower tax per capita while three of them actually increased their tax income per capita.

The existence of a crowding-out effect should be a concern for policymakers because resource revenues reliance can impede the planning of a sustainable state budget in several ways. Firstly, the market price of natural resources is unpredictable which makes revenues volatile (ECB, 2004; Loutia et al., 2016). Secondly, the life cycle of resource

[1] e.g. Bornhorst et al. (2009); Crivelli and Gupta (2014); Thomas and Treviño (2013); Ossowski and Gonzales (2012)

projects can span over several decades, which increases uncertainty. Fiscal policy decision regarding the resource project at the time of discovery could turn out to be sub-optimal and renegotiation of former mistakes come with high reputational costs, influencing future projects (Knebelmann, 2017). Thirdly, oil and minerals are non-renewable resources that will run out in the near future, hence, consuming the benefits is not sustainable (Auty, 1998; Barma et al., 2012).

Reliance on resource revenues can have further adverse political effects by reducing transparency. Political and economic research associates traditional taxation with improvements in transparency and governance, because tax compliance is only sustained through bargains and concessions between citizens and the government (Moore, 1966; North, 1990; Prichard, 2015). Resource revenues do not possess the same beneficial attributes (Ross, 2015). This argument represents also the first mechanism of the rentier effect in which according to Ross (2015) resource-rich governments use resource revenues to reduce taxation (taxation effect) to avoid demands from citizens to democratize.[2]

A further negative consequence of a crowding-out effect is that non-financial objectives become more difficult to accomplish. Apart of generating revenues taxes are also a fiscal policy instrument, which can stabilise the economy in turbulent times, redistribute income to reduce inequality, or reduce consumption of goods with negative externalities such as smoking. An underdeveloped tax system fails to provide these policy possibilities (Mahdavy, 1970; McLure et al., 2016).

The empirical literature so far has focused on the question how resource revenues influence tax or revenue effort, which is the tax or revenue to GDP ratio. Bornhorst et al. (2009) find in a sample of 30 hydrocarbon-producing countries in the period 1992 to 2005 that a one percentage point increase in hydrocarbon revenues reduces revenue effort by around 0.2 percentage points. Extending the Bornhorst et al. (2009) sample to 35 hydrocarbon-producing countries and an extended time period till 2009, Crivelli and Gupta (2014) find that a one percentage point increase in the resource revenues to GDP ratio leads to a 0.3 percentage point decrease in tax effort, mainly driven by a reduction in revenues from taxes on goods and services. Focusing on geographic sub-samples, Ossowski and Gonzales (2012) and Thomas and Treviño (2013) find similar results for Latin America and Sub-Saharan Africa respectively. In contrast, a recent paper by Knebelmann (2017) challenges those findings. She uses a sample of 31 oil-rich countries and exploits the 2000s

[2]The other two mechanisms are the spending effect and repression effect through which resource-rich governments increase public spending and suppress formation of political groups to avoid democratization (Ross, 2015).

oil price boom as an exogenous shock in resource revenues to measure the causal impact of resource revenues on domestic taxation. She does not find a negative effect of resource revenues on domestic tax effort, rather a weak positive effect.

This chapter contributes to the existing literature in several ways. First, I am using a novel methodology, which apart from estimating an average treatment effect, allows the analysis of sub-samples and inferences about heterogeneity across countries, a new advance. The synthetic control methodology developed by Abadie and Gardeazabal (2003) and Abadie et al. (2010) is based on comparative case studies and allows for a deeper insight into the crowding-out effect. Second, I focus on non-resource tax per capita instead of the non-resource tax to GDP ratio (tax effort). Using a ratio as dependent variable provides useful information, but it is not certain if the effect is triggered by a change in the numerator or denominator.[3] Further, total tax per capita allows seeing the issue from a distinct perspective.[4] Tax effort measures how important taxes are in an economy while per capita values show by how much an individual is affected by a resource price shock. It further allows calculating how much government revenues are foregone because of the price shock. Third, I also analyse different resource types. The literature about natural resources and their impact on an economy focuses on oil because it is strategically important and the most traded commodity worldwide (United Nations, 2016). I also include some mineral and precious mineral producers to see whether the 'resource curse' is actually an 'oil curse'. Fourth, I am exploiting the 2000s commodity price boom as an exogenous shock to determine the causal relationship between resource revenues and total tax per capita. Only Knebelmann (2017) used an identification strategy relying on exogenous variation of resource revenues. And finally, I analyse the existence of a crowding-out effect for five non-resource producers who became resource producers. Contrary to the main part of the study, in which the focus is on established resource producers, here I provide evidence and policy implications for countries who extract oil for the first time. These results can be of interest for countries who recently discovered natural resources, such as Uganda, Kenya and Ghana.

The identification strategy relies on the stochastic character of the 2000s commodity price boom from the perspective of resource exporting countries. The 2000s commodity price boom describes the rise of many physical commodities in the early 21st century (Hel-

[3]This could also hold for the tax per capita variable, particularly in countries with a large foreign work force. However, a t-test comparing the average population growth rate in resource exporting countries before and during the 2000s commodity boom did not reveal a significant difference, while average GDP growth is significantly greater during the price boom.

[4]Total tax per capita always refers to non-resource tax per capita throughout this chapter if not stated otherwise.

bling, 2012). The focus of this chapter is on non-renewable natural resources in particular oil, minerals, and precious minerals, because these commodities fulfil the requirements of the rentier state theory. They create rents and are mostly exported, which generates an external windfall for the government from outside of the domestic economy. This gives the government the possibility to substitute rents for taxes (Beblawi, 1990). Between 1999 and 2012 the international oil price, mineral price index and precious mineral price index increased by 450, 180 and 600 percent respectively. The price hike is associated with increasing demand from emerging economies, low interest rates set by the Federal Reserve resulting in a weak US$ and speculative investments (Carter et al., 2011; Hamilton, 2009, 2011). None of the reasons can be influenced by individual resource exporters in the sample and therefore the price shock qualifies as plausible exogenous allowing to analyse the causal relationship between resource revenues and non-resource tax income. More on the exogeneity and timing of the 2000s commodity price boom will be discussed in section 3.2.

The working argument is that the non-resource sector of a resource exporting economy is affected in the same way by a resource price shock as the non-resource sector of a non-resource producing country.[5] The only difference between resource exporting and non-resource producing country is that the government in a resource exporting country receives additional funds from the resource sector during the price boom. These additional funds can be saved (increasing reserves), stolen by members of the government (corruption) or transferred to the non-resource sector by increasing public expenditure or by reducing taxes. The latter is the focus of this chapter. Under the assumption that non-resource producers are affected in the same way as the non-resource sector in a resource exporting country, they can be used to construct synthetic control countries. The idea of the synthetic control methodology is to create a counterfactual country that behaves in the same manner as the resource producing country if the price shock would not have occurred. Comparing the resource producing country with the synthetic control country shows how tax per capita is affected because of a price shock. Identification and assumptions will be discussed further in section 3.3.

I find evidence for crowding-out. On average the treatment effect is negative supporting previous findings by indicating that the 2000s commodity price boom and the resulting increase in resource revenues lead to a decrease of about 11% in non-resource tax per capita in resource exporting countries. However, this average effect is heterogeneous and

[5] The non-resource sector of a non-resource producing country is the same as the whole economy.

the synthetic control analysis shows that the tax reducing effect is more prone in highly oil dependent countries with a low level of institutional quality and a preference to extract revenues from the resource sector via tax instruments. I do not find a significant effect for mineral or precious mineral exporting countries. The average treatment effect indicates that a person in an oil exporting country paid around US$ 300 less tax each year because of the price boom as compared to a scenario without price shock. For example, Saudi Arabia with an average population of around 24 million, lost US$ 7.7 billion each year. This foregone yearly tax income is only US$ 1.55 bn short of what the Saudi's tax authority expects to generate from the VAT introduced for the first time in Saudi Arabia's history in 2018.[6]

The results survive several robustness checks. Controlling for outliers by excluding the biggest oil exporter and potential swing producer (Saudi Arabia) and the country with the highest per capita taxes (Norway) does not alter the results. Further, the results are robust using different specifications controlling for additional predictor variables.

After providing evidence for a crowding-out effect for established resource exporting countries, I show results for five new resource producers. The results of the five new oil producers show that three countries have a tax increasing effect (Vietnam, Sudan, Equatorial Guinea), while two countries experience a tax decreasing effect (East Timor, Chad).

The remainder of the chapter is structured as follows: Section 3.2 describes the 2000s commodity price boom and explains why it can be considered as exogenous in this setting. Section 3.3 and 3.4 explains the methodology and data used to estimate the effect. Section 3.5 discusses the results and section 3.6 provides robustness checks. I then conduct five case studies in section 3.6 to see if the results change for new resource producers and section 3.8 concludes.

3.2 The 2000s commodity price boom

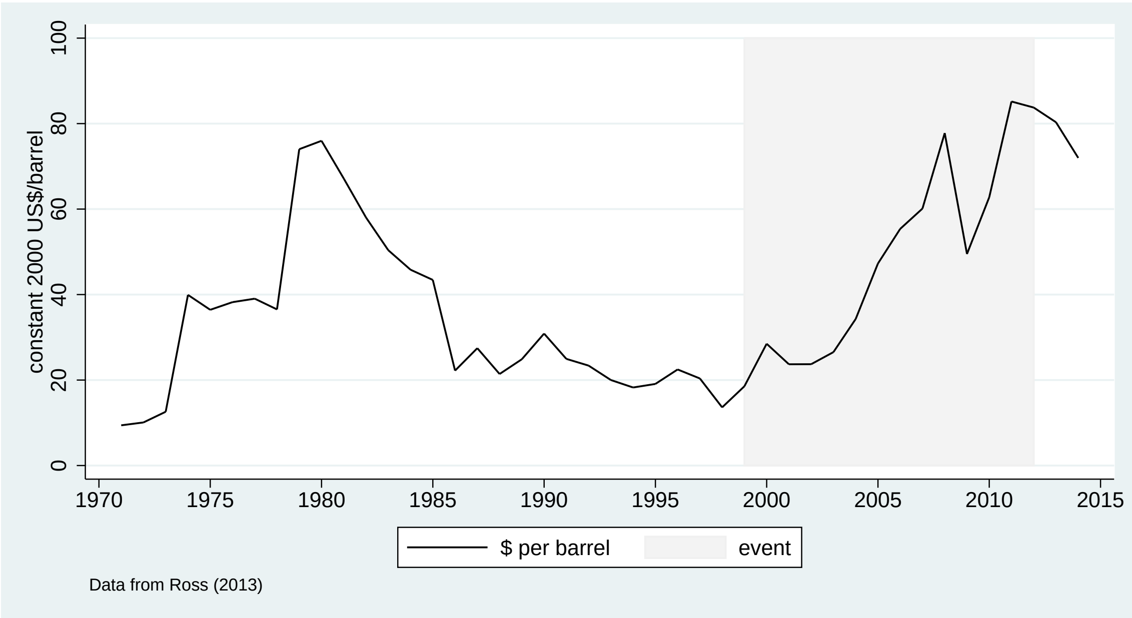
In this section, I describe the price behaviour of oil, minerals and precious minerals throughout the 2000s, the reasons for the commodity price boom as well as the timing and the exogeneity of the 2000s commodity price boom for resource exporting countries.

Following the 1973 and 1979 energy crisis the oil price plummeted from an all-time high above US$ 75 per barrel to US$ 22 in the mid-1980s (see Figure 3.1). The price

[6]The Saudi tax administration (General Authority of Zakat and Tax) estimates that the 5% VAT will generate US$ 9.35bn in 2018 (Arabian Business, 2018).

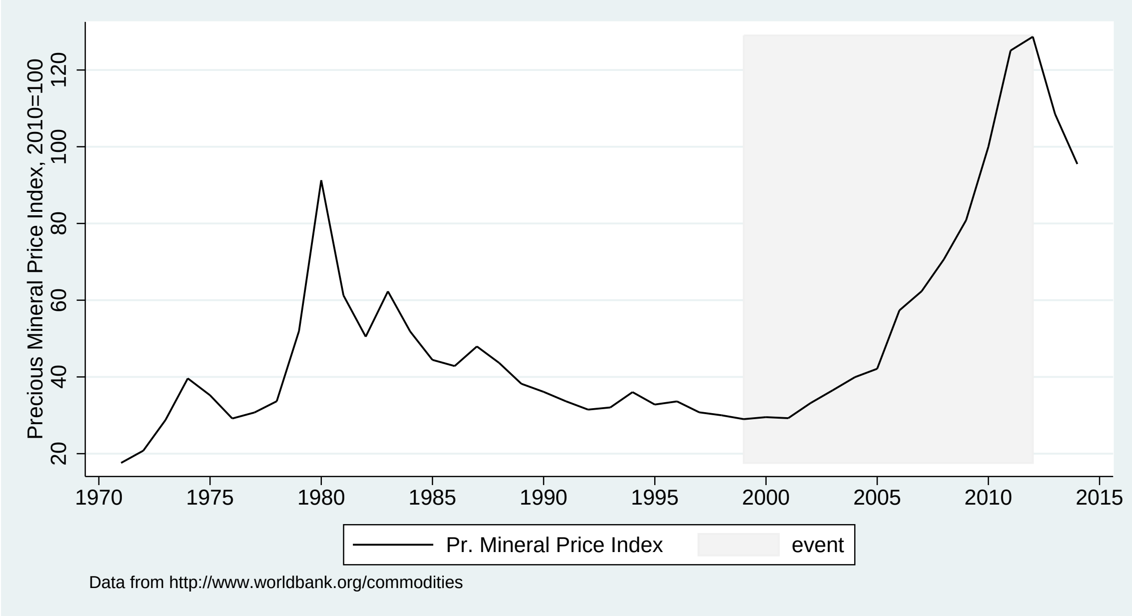
stayed low for the following years fluctuating between US$ 18 and US$ 30 per barrel with an average of US$ 22 until 1998. From 1999 on the oil price increased almost continuously up to a new all-time high of about US$ 85 in 2011 and stayed on a high level in 2012. Two short interruptions of the price boom occurred between 1999 and 2012. The first, between 2002 and 2003, was because of uncertainties created after the terrorist attack on 9/11 and the invasion of Iraq. The second downturn came because of the Great Recession in 2009. The overall increase between 1999 and 2012 was around 450%.

Figure 3.1: Oil price 1970-2015



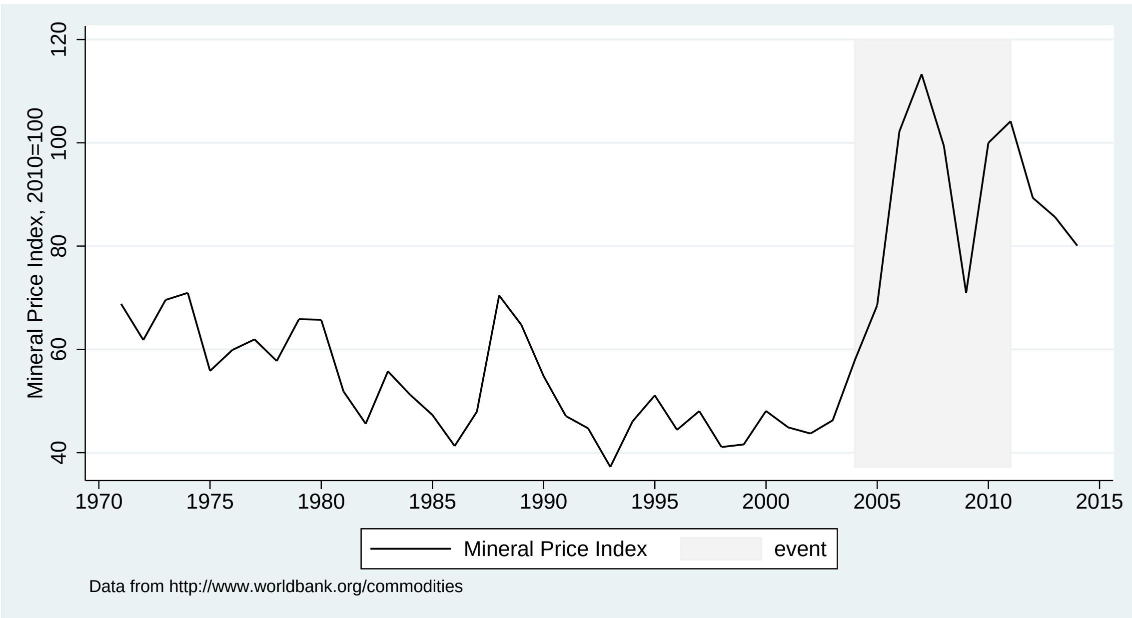
The precious mineral price index from the World Bank measures the price changes of Gold, Silver and Platinum. The base year is 2010 (=100) and the prices of the components are measured in constant 2005 US$. The precious mineral price index increased dramatically between 1999 and 2012 (see Figure 3.2). The index stood at around US$ 23 in 1999 and increased by almost 600% to just above US$ 138 in 2012. Contrary to the oil price the precious mineral price index increased continuously without interruption.

Figure 3.2: Precious mineral price index 1970-2015



The mineral price index shows the price of Aluminium, Copper, Iron Ore, Lead, Nickel, Tin and Zinc. The base year is again 2010 (=100) and the prices of the components are measured in constant 2005 US$. In comparison to oil and precious minerals, the mineral price boom was smaller and started later. The index stood at US$ 58 in 2004 and increased by almost 180% to just over US$ 104 in 2011 (see Figure 3.3). Similar to the oil price boom there was one interruption in 2009 because of the Great Recession.

Figure 3.3: Mineral price index 1970-2015



The reasons for the commodity price boom are still discussed and no single cause could be determined. The most prominent arguments include that the price boom was demand driven by high economic growth in China (Hamilton, 2009), the monetary policy of the Federal Reserves with low interest rates resulting in depreciation of the US$ (Carter et al., 2011; Frankel, 2008), and that speculative investment played a role (Masters, 2008). Most likely it was a mix of all these reasons. Important here to note is that contrary to past commodity price booms there was no significant supply reduction that triggered the price boom. World oil supply was remarkably stable despite events such as hurricanes in the Gulf of Mexico, turmoil in Nigeria and conflict in Iraq (Hamilton, 2009). The mentioned reasons of high demand, a weak US$ and speculation are likely not influenced by resource exporters which makes the period ideal to analyse the causal impact of a resource income shock.

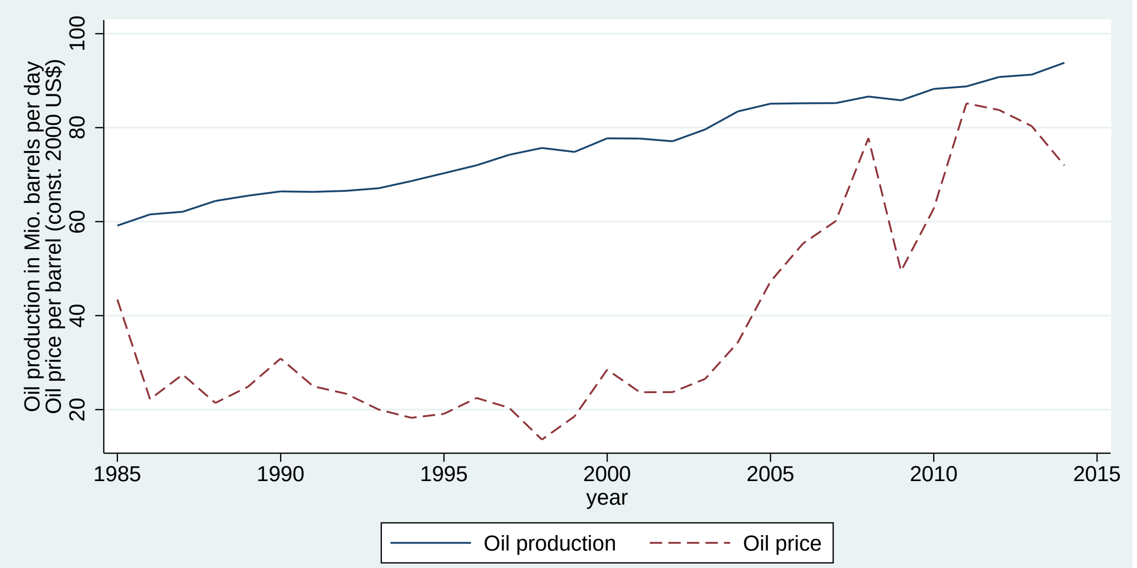
The timing of the commodity price boom is derived by econometric means. I regressed the price or price index for oil, minerals and precious minerals on its lagged value for the time between 1961 and 2015 and conduct a Wald-test for each year testing the null hypothesis of no structural break. The Wald statistics identifies structural breaks for the oil price coefficient from 1999 until 2012.[7] The precious mineral price index has significant structural breaks at the 10% level for the whole period 1999 to 2012 and the metal price index has structural breaks from 2004 until 2011. Those are the event periods considered as the commodity price boom in each country according to their primary exported commodity (see grey area in figures 3.1, 3.2 and 3.3). Note that this test does not indicate the direction of price changes. Special caution have to be taken when interpreting the results for the year 2008/2009 in which the Great Recession started and the oil price as well as the mineral price index declined significantly. Table B 2 in appendix B reports Wald test statistics.

To establish exogeneity in this setting it is necessary to understand that the price shock does not have to be stochastic. It suffices that the treatment assignment is merely orthogonal to the country's characteristics (Liou and Musgrave, 2014). This statement translates into two conditions that must be true to capture a causal effect. First, none of the treatment countries influenced the timing or the likelihood of the event and second, no country influenced their assignment to treatment, i.e. did not anticipate it. In other words, the event affects the treatment countries, but the treatment countries did not affect the event.

[7]The only exception is 2001. The oil price was affected in 2001 mainly through the 9/11 terrorist attacks but it only slowed down the oil price boom which speed quickly revived in the following years. The p-value in 2001 is 0.115 and only slightly above conventional significance level and will be included in the treatment period to avoid a gap in the sample.

A resource producer can influence the timing, likelihood or magnitude of a price shock only through the supply side by changing production levels. Overall, world oil production increased at an almost constant rate over the considered period (see figure 3.4). The average oil production growth rate for the sample period is 1.4%, before and after 1999 it was 1.6% and 1.3% respectively. Increasing supply should lead to a fall in prices assuming constant demand. However, oil consumption increased over the same period shifting demand up at a stronger rate than supply leading to a price increase.

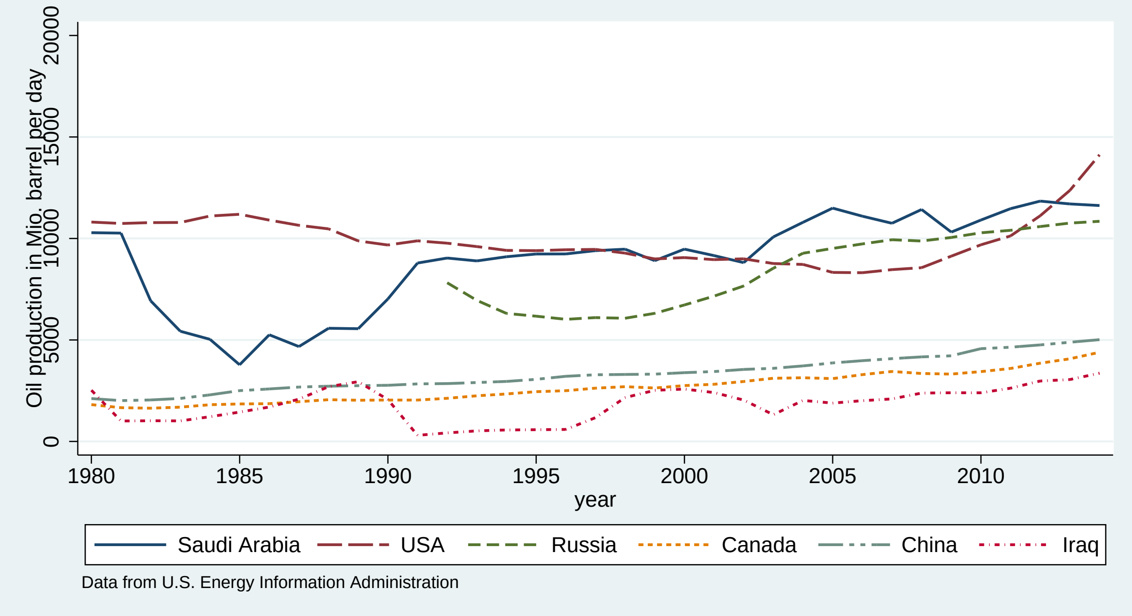
Figure 3.4: Oil price and world production 1985-2015



Oil price data from Ross (2013), oil production data from U.S. Energy Information Administration

For an individual country to be able to influence the oil price, it must have a big enough market share. Figure 3.5 shows oil production of the six biggest oil producers in the world. Out of the six countries, only Saudi Arabia deserves a further discussion because the remaining five are net-oil importer (USA, China) or have no data available (Iraq, Russia, Canada) to be part of the sample.

Figure 3.5: Top six oil producers 1980-2015



Saudi Arabia is considered a swing producer. The favourable oil fields on the Arabic peninsula and estimated reserves of around 260 billion barrels allow Saudi Arabia to change production level at will and influence the oil price (Fattouh and Mahadeva, 2013). However, the kingdom is part of OPEC and therefore decisions are made under concessions and discussions with other members. Saudi Arabia's oil production was almost constant from the beginning of the 1990s till 2002 at around 9 million barrels per day. In 2003, production increased to 10 million barrels per day and stayed above this level ever since (see figure 3.5). The increase in production should lead to a price decrease but the production increase was not enough and prices continued to rise. However, given the market power of Saudi Arabia I also test all specifications excluding Saudi Arabia from the sample (see section 3.6).

Saudi Arabia is part of OPEC and if Saudi Arabia on its own could be capable to influence the oil price then OPEC should also be discussed. OPEC members produce 40% of world's crude oil and their exports represent about 60% of traded oil internationally (Fattouh and Mahadeva, 2013; Loutia et al., 2016). The impact of OPEC's production decisions on the international oil price is highly debated in the economic literature but no consent has been achieved. Some scholars find that OPEC can influence the oil price while others find contradicting results. Other scholars argue in favour of a compromise that OPEC's power differs according to the period considered.[8]

[8]see Fattouh and Mahadeva (2013) and Loutia et al. (2016) for an overview of the related literature.

Considering the period at hand, the 2000s, two facts give confidence that OPEC could not manipulate the oil price boom. First, in the year 2000 Ali Rodriguez, Venezuela's oil minister and OPEC's president introduced a new price band mechanism to keep oil within a price band between US$ 22 and US$ 28 per barrel. Member quotas were supposed to be adjusted automatically in the instance the oil price exceeded or undercut the price band. The mechanism was tacitly abandoned in 2005 and since then OPEC is more quiet about price aims (Piotrowski, 2015). However, the automatic mechanism for once shows that OPEC worked against a possible price boom. Second, OPEC's spare capacity[9] was low for the 2003-2008 period. Saudi Arabia alone usually holds a spare capacity between 1.5 and 2 million barrels. In the period 2003-2008 the spare capacity of all OPEC members combined barely reached 2 million barrels, which represents less than 3% of global supply (EIA, 2018). Therefore, for most of the considered time period OPEC worked against the price boom or did not have the possibility to do anything about it which makes the 2000s commodity price boom plausibly exogenous also for OPEC members.

The inability of OPEC members to influence the price boom can also be seen in statements from Algerian Oil minister Chakib Khelil who said "there is not much we can do [about rising prices]," in 2005 or Qatar Oil Minister Abdullah al-Attiyah who stated, "This is out of the control of OPEC."[10]

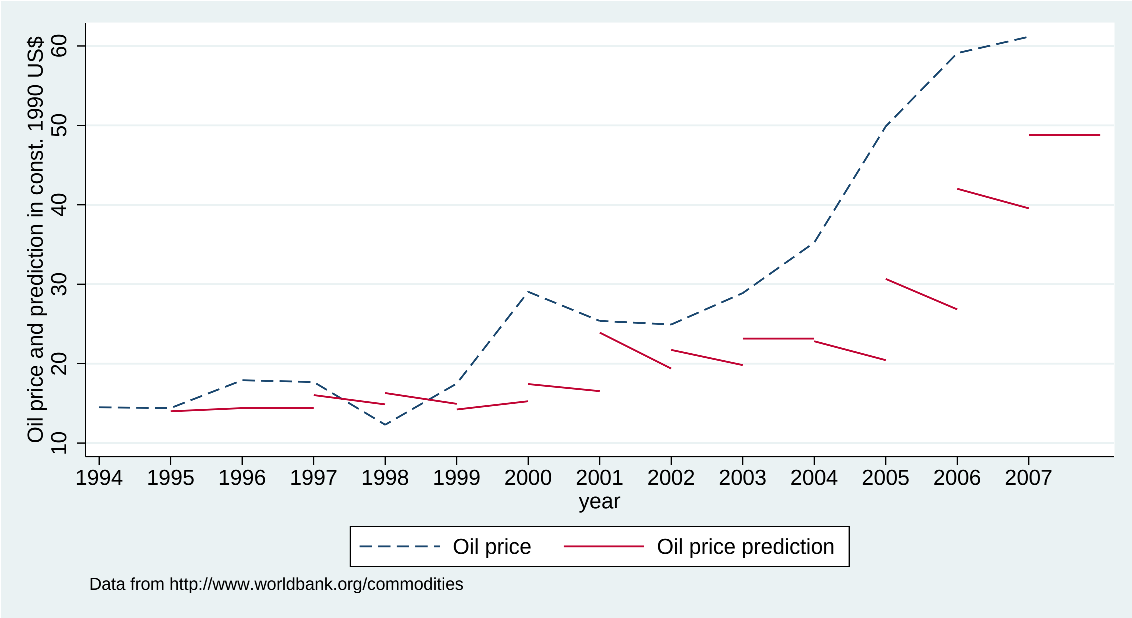
One remaining point before exogeneity can be established is the predictability of the price shock. Did oil exporters anticipate the price shock and adjust their behaviour? This is unlikely because predicting the future oil price is difficult up to the point that financial institutions such as the IMF assume that the oil price follows a random walk, i.e. the best possible prediction of next year's oil price is this year's oil price (ECB, 2004). Figure 3.6 compares the actual oil price with forecasts from World Bank's Pink Sheets (The World Bank, 2018a). The prediction is always done for the following two years and from 1999 onwards when the price boom started, the prediction is always below the actual oil price.[11] The same is true for other price forecasts.

[9]Spare capacity is defined by EIA as the volume of production that could start within 30 days and be sustained for at least 90 days (EIA, 2018). The indicator measures the possible responsiveness of oil producers to adjust their oil production level.

[10]As cited in Piotrowski (2015).

[11]The forecast here is only shown until 2007. The World Bank did change their methodology after 2007 and published henceforth values in constant 2000, 2005 or 2010 US$. A further graph, showing forecasts until 2015 in current US$ is provided in the appendix (see figure B.1 in appendix B). In figure B.1 however forecasts between 2001 and 2004 are not reported by the World Bank in current US$ which is the reason why the figure is not included here.

Figure 3.6: Oil price and World Bank forecasts



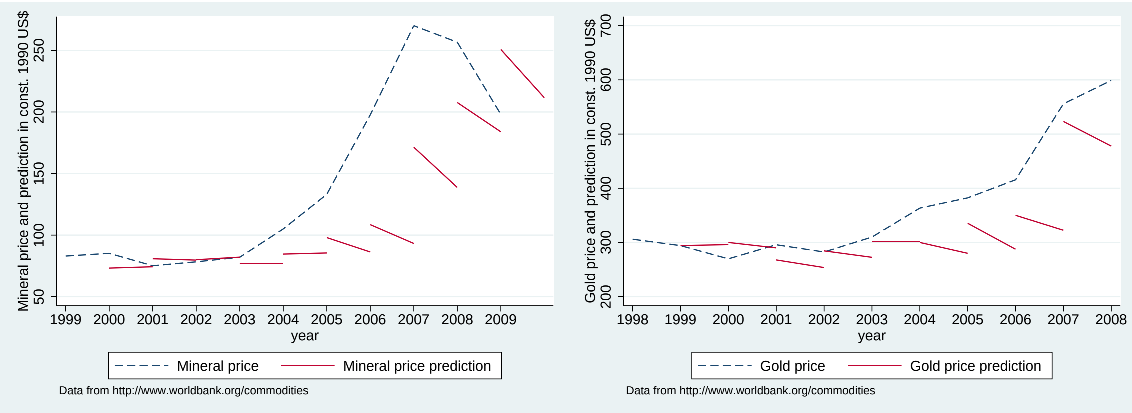
In conclusion, during the 2000s commodity price boom the oil price increased by over 400%, none of the oil exporting countries influenced the price through supply adjustments and it was arguably an unexpected event. Therefore, the oil price boom was plausibly exogenous.

The situation for mineral and precious mineral exporters is similar. The main reason for the price increase was the strong economic growth in China, weak US$ and speculations pushing up the price not just for oil but also for minerals and precious minerals (Helbling, 2012). The mineral and precious mineral exporters in the sample are all minor producers relative to world production. Table B 1 in appendix B shows the market share of each country for its main commodity. The exception is Chile as the world's biggest copper producer contributing 36% of world copper output. With the exception of Chile, it is unlikely that one of the mineral or precious mineral producers have enough market power to influence the price boom. Figure 3.7a compares the actual mineral price index with forecasts from the World Bank and Figure 3.7b does the same for gold.[12] In both cases, the prediction seem to be rather inaccurate.

[12]The main commodity of the three precious mineral exporters in the sample is gold.

Figure 3.7: Mineral and Gold price and WB forecasts

(a) Mineral (b) Gold



3.3 Methodology

The 2000s commodity price boom represents a natural experiment and the resulting exogenous variation is explored in this chapter to identify the causal effect of a positive resource induced income shock on domestic taxation. A common approach to identify a causal effect with natural experiments is the difference-in-difference (DiD) approach (Angrist and Pischke, 2009). DiD estimates a causal effect by contrasting the changes in the pre- and post-treatment period between treatment and control countries. The identifying assumption is that in the absence of the treatment, the outcome variable of the treated and control countries would have followed parallel trends (Abadie, 2005; Angrist and Pischke, 2009; Ashenfelter, 1978; Ashenfelter and Card, 1984). The parallel trend assumption is not always plausible and cannot be tested. However, a minimum requirement for a valid DiD should be that the parallel trend assumption holds in the pre-treatment period, which can be tested by interacting the treatment dummy with the time dummies. The interaction term should be zero for the whole pre-treatment period (Angrist and Krueger, 1999). This test fails for the sample at hand, hence DiD is not feasible with the available data.

An alternative way, to exploit natural experiments is the synthetic control method (SCM) proposed by Abadie et al. (2010) and Abadie and Gardeazabal (2003). SCM assumes that in the absence of treatment the expected outcome would have been the same for treatment and control countries conditional on past outcomes and control variables. This is the so called 'independence conditional on past outcomes' assumption (Firpo and Possebom, 2015). The advantage of SCM is that it does not rely on parallel trends, allows the effect to vary over time and works in situations with small sample size (Abadie et al., 2015), which makes it the preferred methodology for this chapter.

3.3.1 Synthetic Control Method

In what follows, I discuss implementation, inference and identifying assumptions of the synthetic control method (SCM). The original SCM framework was designed for cases where treatment occurs only to one country (Abadie and Gardeazabal, 2003). It is obvious that the 2000s commodity price boom influenced not just one resource exporting country but all of them. For this reason, I follow Cavallo's extended SCM approach, which allows for multiple treated units at different times (Cavallo et al., 2013).

The basic idea of SCM is to construct a synthetic control country as a weighted average of the available control countries. The weights are generated by a data-driven algorithm to ensure that covariates and outcomes of the synthetic control country match with the treated country in the pre-treatment period. The weights are then used to predict the outcome variable for the counterfactual of no treatment in the post-treatment period. The resulting synthetic control country can be compared to the actual outcome and the difference represents the treatment effect (Abadie et al., 2010; Cavallo et al., 2013). A formal discussion follows below.

3.3.2 Implementation of SCM

Suppose a universe with $(J+1) \in \mathbb{N}$ countries during $T \in \mathbb{N}$ time periods. For now, the intervention (price shock) affects only country 1 (treatment country) and the rest of the countries are unaffected. Intervention starts in T_0+1 and continuous uninterrupted till T, where $1 \leq T_0 < T$. Let the scalar $Y_{j,t}^N$ be the potential outcome in the absence of the treatment for country $j \in \{1, \ldots, J+1\}$ in period $t \in \{1, \ldots, T\}$. The scalar $Y_{j,t}^I$ denotes the potential outcome that would be observed if the intervention occurs from T_0+1 to T in country j at time t. With this notation

$$\alpha_{j,t} = Y_{j,t}^I - Y_{j,t}^N \tag{3.1}$$

describes the intervention effect for country j in period t. Let $D_{j,t}$ be the intervention dummy assuming the value 1 if country j faces the intervention in period t and value 0 otherwise. Combining this gives the observed outcome for country j in period t by

$$Y_{j,t} = Y_{j,t}^N + \alpha_{j,t} D_{j,t}.$$

Because only the first country is affected by the intervention from period T_0+1 to T, the intervention dummy is defined as:

$$D_{j,t} = \begin{cases} 1, & \text{if } j = 1 \text{ } and \text{ } t > T_0 \\ 0, & \text{otherwise} \end{cases}$$

The aim is to estimate the intervention effect $(\alpha_{1,T_0+1}, \ldots, \alpha_{1,T})$ for country 1 for each post-intervention period $(T_0 + 1, \ldots, T)$. Since $Y_{1,t}^I$ is observable it is only necessary to estimate $Y_{1,t}^N$, the unobserved outcome for country 1 without treatment.

The synthetic control estimator of $Y_{1,t}^N$ can be defined as

$$\hat{Y}_{1,t}^N = \sum_{j=2}^{J+1} \hat{w}_j Y_{j,t}. \tag{3.2}$$

Suppose a vector of weights $\hat{W} = [\hat{w}_2, \ldots, \hat{w}_{J+1}]'$ with $\hat{w}_j > 0$ for $j = 2, \ldots, J + 1$ and $\sum_{j=2}^{J+1} \hat{w}_j = 1$ exists so that

$$Y_{1,t} = \sum_{j=2}^{J+1} \hat{w}_j Y_{j,t}, \forall t \in \{1, \ldots, T_0\} \text{ } and \text{ } Z_1 = \sum_{j=2}^{J+1} \hat{w}_j Z_j \tag{3.3}$$

holds, then

$$\hat{\alpha}_{1,t} = Y_{1,t} - \sum_{j=2}^{J+1} \hat{w}_j Y_{j,t}, \forall \, t \in \{T_0 + 1, \ldots, T\} \tag{3.4}$$

represents the estimated treatment effect for the treated country. The first part of equation 3.3 states that the weighted average of the pre-treatment outcome of the control countries should perfectly match the pre-treatment outcomes of the treated country. The second part of equation 3.3 indicates that the weighted average of the control countries' covariates perfectly replicate the covariates of the treated country. These two conditions only hold if the outcome and the covariates of the treated country $(Y_{1,t}, Z_1)$ lie within the convex hull of $[(Y_{2,1}, \ldots, Y_{2,T_0}, Z_2'), \ldots, (Y_{J+1,1}, \ldots, Y_{J+1,T_0}, Z_{J+1}')]$ (Abadie et al., 2010). This is not often the case but Abadie et al. (2010) show a way to select $\hat{W}$ so that equation 3.3 holds approximately. They propose to minimize the distance between the vector of covariates and outcome variable of the treatment countries and the weighted matrix with the same outcome variable and covariates of each control country in the pre-treatment period using the Euclidian metric (or a re-weighted version of it) (Firpo and Possebom, 2015).

In practice, let X_1 be the vector of outcome variable and covariates of the treated country in the pre-treatment period and X_0 the corresponding matrix including the same variables as in X_1 for each control country. The distance between treated outcome and covariates and control outcome and covariates is then given by the vector $||X_1 - X_0W||$ and the vector $\hat{W}$ is chosen to minimize the distance

$$||X_1 - X_0W||V = \sqrt{(X_1 - X_0W)'V(X_1 - X_0W)} \tag{3.5}$$

where V is a $(K \times K)$ diagonal positive semidefinite matrix whose trace equals one. Intuitively, W is a weighting vector that measures the relative importance of each country in the donor pool[13] and V measures the relative importance of each covariate and the outcome variable.

It is standard practice to estimate the root mean square prediction error (RMSPE) as a goodness of fit measure to evaluate the discrepancy between treated and synthetic control outcomes, i.e. how good the first part of equation 3.3 holds. RMSPE is defined as

$$RMSPE = \left[\frac{1}{T_0}\sum_{t=1}^{T_0}\left(Y_{1,t} - \sum_{j=2}^{J+1}\hat{w}_j Y_{j,t}\right)^2\right]^{\frac{1}{2}} \tag{3.6}$$

While the choice of the covariates (Z_i) can be justified by including those variables which better explain the outcome (Y_i) the choice of the inclusion of the pre-treatment outcome variable can influence V and the RMSPE. Abadie et al. (2010) propose to include all pre-treatment outcome variables, however, this approach was criticised by Kaul et al. (2018) showing that the inclusion of all pre-treatment outcome variables overshadows all other covariates. Following, Ferman et al. (2016) the preferred specification is the one with the lowest pre-treatment RMSPE. I tested for different combinations of included outcome variables and on average the lowest RMSPE is achieved if the average of the outcome variable is included (see table B 3 in appendix B). In the main specification, I include always the pre-treatment average of the outcome variable to construct the synthetic control country.

So far, the SCM estimator considered in equation 3.4 only deals with the single treatment case but this approach can be extended to allow for multiple treatment countries (Cavallo et al., 2013). With multiple treatment countries, assume that there are $G \in \mathbb{N}$ interventions. For each intervention $g \in \{1, \ldots, G\}$, there are $J^g + 1$ observed countries and denote the country with the intervention as 1^g. In the same manner as in equation 3.4 define the synthetic control estimator of $\alpha_{1^g,t}$ as

$$\hat{\alpha}_{1^g,t} = \frac{\sum_{g=1}^{G}\hat{\alpha}_{1^g,t}}{G} \tag{3.7}$$

[13]Donor pool refers to the set of potential control countries, which are used to construct the synthetic control country (Abadie et al., 2010).

for each $t \in \{1, \ldots, T\}$.

Intuitively, the extension for multiple treatment countries means that first a synthetic control country is created for each treatment country out of the donor pool. Second, results are derived from the difference between treatment and synthetic control country for each treatment country. Finally, the results are pooled together to calculate the average treatment effect for each post-treatment period $(T_0 + 1, \ldots, T)$.

The explained procedure results in a scaling effect because SCM compares the path of the outcome variable. The country-specific effect will depend on the level of the outcome variable, i.e. the same change in total tax per capita is more important in a country with low total tax per capita. To avoid this scale effect, Cavallo et al. (2013) proposes to normalize the estimates before pooling the country-specific results. Normalization is achieved by setting total tax per capita equal to one for each treatment country in the year before the treatment starts (T_0).

3.3.3 Inference

Standard errors in common regression techniques usually measure uncertainty about aggregate data. SCM uses aggregate data, hence, uncertainty about them would be 0. However, other forms of uncertainty occur when using aggregate data. Uncertainty in the SCM is derived from ignorance about the synthetic control country's ability to replicate the treatment country in the absence of the treatment. To establish statistical inference Cavallo et al. (2013) proposes to estimate p-values with a procedure similar to permutation tests. These methods allow for valid inference also in settings with few control countries and pre-treatment periods.[14] The idea is to estimate placebo effects and rank them to analyse whether the effect is relatively large compared to a randomly assigned effect. The placebos are derived from estimating the effect for each untreated country (from the donor pool) treating each as if treatment occurred.

The p-values are estimated for each time period according to the following procedure (Cavallo et al., 2013; Firpo and Possebom, 2015):

1. For each intervention $g \in \{1, \ldots, G\}$, define which country is assumed to be treated and estimate for each of its control countries an individual placebo effect, $\alpha_{j^g,t}$ as described in equation 3.4, where $j^g \in \{2, \ldots, J^g + 1\}$.

2. At each post-treatment period, compute every possible placebo average effect by picking a single individual placebo effect, $\alpha_{j^g,t}$, from each intervention g and then

[14] Nevertheless, confidence increases with $N \to \infty$ and/or $T \to \infty$.

taking the average across the G placebos, $\bar{\hat{\alpha}}_{q,t} = \frac{\sum_{g=1}^{G} \hat{\alpha}_{\tilde{j}^g,t}}{G}$, where q indexes placebo estimations and $\tilde{j}^g \in \{2, \ldots, J^g+1\}$. There are many possible placebo averages given by $Q := \prod_{g=1}^{G} J^g$ and the number quickly grows with G.

3. Rank all placebo average effects and compare in the resulting distribution which rank the actual treatment effect has for each post-treatment period $t \in \{T_0 + 1, \ldots, T\}$.

4. Finally, compute the p-value, $p_t = \frac{\sum_{q=1}^{Q} I[|\alpha_{\bar{q},t}| \geq |\alpha_{\bar{1},t}|]}{Q}$ for each $t \in \{T_0 + 1, \ldots, T\}$ which shows the probability that the actual treatment effect would have been observed by chance (Cavallo et al., 2013; Firpo and Possebom, 2015).

3.3.4 Identifying Assumptions

The main assumption of the SCM is the 'independence conditional on past outcome' assumption meaning that the weighted average of the control countries replicates the treatment country in the pre-treatment period and behave in the post-treatment period the same way as the treatment country would have in the absence of the treatment (Firpo and Possebom, 2015). For this to be true certain assumptions must be made in this setting which will be explained here.

First, it has to be established that the event affects only the treatment countries but not the donor pool or that the event affects all countries the same way with the exception of one mechanism. For policy changes this assumption is easier to defend than in the case of the 2000s commodity price boom because all countries in the world are affected by the price boom in one way or another. While only some countries produce oil or minerals, all countries in the world consume them. Therefore, the identification in this chapter rests on the second part of the assumption, namely that the effect is everywhere the same with one exceptional mechanism.

The exceptional mechanism is that the government in resource exporting countries receive more revenues, which it can use to lower taxes in the non-resource sector. This mechanism, called here 'resource transfer', connects the resource sector with the non-resource sector through the government and does not exist in non-resource producing countries because they do not possess a resource sector. Therefore, the strategy is that by comparing a resource exporting country with a synthetic control country, constructed out of non-resource producing countries, it is possible to capture the 'resource transfer' mechanism.

Let's assume two countries, a resource exporting country and a non-resource producing country. The whole economy in a non-resource producing country consists of a single non-resource sector and the government. Government and economy interact through taxes, regulations, laws, etc. The economy of the resource exporting country can be divided into government, non-resource sector and resource sector. Again, resource and non-resource sectors interact with the government through taxes, laws, regulations, etc. Hence, the only difference is the existence of a resource sector in one of the two countries.

A positive price shock now, as it occurred in the 2000s, has several indications for the two countries. First, the non-resource sector in both countries have to pay a higher price for the resource, which leads to additional revenues for the resource sector. In turn, the resource sector payments to the government in form of taxes, royalties or production sharing agreements increase. This additional government income can now be re-distributed to the non-resource sector by the government in the form of lower taxes or increased spending. Without this 'resource transfer' mechanism the impact in the non-resource sector; higher price, inflation, and less economic growth would be the same in both countries because both non-resource sectors must pay higher prices for the resources. The only difference is the 'resource transfer' mechanism which only occurs in the resource exporting country. The analysis, therefore, compares the non-resource sector of a resource exporting country with a synthetic control non-resource sector. The synthetic control non-resource sector is constructed out of a weighted average of non-resource sectors and government characteristics from a donor pool of non-resource producing countries.

The 'resource transfer' mechanism consists of all the possibilities a government faces when confronted with additional income from a positive price shock. This means they can use it to spend on public goods, save it, steal it, and finally substitute it for non-resource taxes. The latter is the mechanism of interest in this chapter and controls are included for the remaining channels in all specifications.

For the 'independence conditional on past outcome' assumption to hold I have to assume that non-resource sectors in non-resource producing countries are affected in the same way as the non-resource sector in the resource exporting country and the only difference is the 'resource transfer' mechanism through the government. This further implies that spillovers between resource sector and non-resource sector do not exist or are negligible. This is important to ensure that the only mechanism captured by SCM is the 'resource transfer' mechanism. In the case of oil exporting countries this assumption is reasonable. The 'enclave' character of the oil industry in combination with it's high capital intensity fosters only few linkages to the rest of the economy and contributes little to create employment (Karl, 2007). For mineral and precious mineral exporters, the assumption is most likely to be violated because mining can be labour intensive. This has to be considered when analysing the results and could potentially be the reason for the zero results for mineral and precious mineral exporters.

Finally, two further assumptions must hold. The first is that the effect is everywhere the same, which is given for each resource type because the resource price increased everywhere the same. Second, spillovers between countries in the outcome variable do not exist. Countries usually are in competition and tax policy can be a determinant for a company on where to settle. However, this tax competition is more prone between resource poor countries. Nevertheless, if resource-rich countries' tax policies influence non-resource producing countries this would minimize the estimates because the effect is defined as the difference between resource exporters and non-resource producers. If this biases the results the true effect would be greater than what is estimated here.

3.4 Sample, data and descriptive statistics

3.4.1 Treatment countries and donor pool

The treatment group includes countries who are net resource exporter and produce a significant amount of resources before the 2000s commodity price boom. The treatment countries have to be net exporters because selling the commodity domestically would not qualify as an external windfall following the rentier state theory (Beblawi, 1990). Countries are categorised according to their main exported commodity: oil, minerals or precious minerals. Further, they have to produce a significant amount of resources before the event to be sure that they are affected by the price boom. Significant amount is defined by producing economic rents from natural resources exceeding 5% of GDP on average in the pre-treatment period.

Including all net exporting countries producing at least 5% of resource rents on average 10 years prior to the commodity price boom leaves 38 treatment countries. 13 of those countries had to be excluded because of missing *total tax p.c.* data[15] or because no combination of control countries could match the treatment country in the pre-treatment period.[16] Of the 25 remaining treatment countries 19 are oil producers, 3 are precious mineral producers and 3 are other mineral producers (see table 3.1).

[15]Countries with missing tax data: Russia, Iraq, Bahrain, Qatar, United Arab Emirates, Oman, Suriname, Congo, and Liberia.

[16]This was the case for Iran, Republic of the Congo, Angola, and Nigeria

Table 3.1: Treatment countries

Country	**Res. rent**	**Commodity**	**non-res. tax p.c. (US$)**
Algeria	9.56%	Oil	410.34
Azerbaijan	14.78%	Oil	163.82
Brunei	18.57%	Oil	1057.84
Cameroon	5.67%	Oil	85.72
Chile	6.12%	Mineral	1422.57
Ecuador	5.77%	Oil	242.98
Egypt	8.79%	Oil	210.75
Gabon	27.66%	Oil	1228.42
Guinea	5.32%	Mineral	31.66
Guyana	7.19%	Pr. mineral	361.15
Indonesia	5.93%	Oil	171.85
Kazakhstan	7.52%	Oil	461.41
Kuwait	29.55%	Oil	357.60
Libya	22.66%	Oil	713.79
Malaysia	5.05%	Oil	883.76
Mauritania	8.28%	Mineral	120.07
Mongolia	8.79%	Pr. mineral	298.58
Norway	5.20%	Oil	21529.50
Papua New Guinea	20.16%	Pr. mineral	197.82
Saudi Arabia	27.46%	Oil	354.82
Syria	19.60%	Oil	256.77
Trinidad and Tobago	10.29%	Oil	1231.03
Turkmenistan	33.68%	Oil	115.75
Venezuela	15.06%	Oil	622.64
Yemen	23.59%	Oil	75.43

Notes: Resource rent is in percent of GDP, non-resource tax per capita is in constant 2010 US$, values are averages for the pre-treatment period (1989-1998 for oil and precious mineral producer and 1994-2003 for mineral producer).

The pre-treatment period includes, wherever possible, all 10 years prior to the price boom. Because of data issues (gaps) and idiosyncratic shocks (e.g. Arab spring and/or civil war) the pre- and post-treatment period had to be adjusted or missing data has been interpolated for some treatment countries. Table B 4 in appendix B lists all adjustments.

Each treatment country has an individually assigned donor pool. For a country to be eligible to be part of one or more donor pools it has to be from the same region and a non-resource producer.

Restricting each country to the same region ensures that countries have a similar background and are more similar to each other in economic and cultural aspects. This also avoids interpolation bias which occurs when two extreme countries average out to match the treatment country resulting in the possibility that observed effects simply represents differences in the countries' characteristics (Abadie et al., 2015). The region restriction had to be lifted for Gabon and Libya. Otherwise, the pre-treatment fit would not have allowed to include them in the analysis. To ensure that this exception does not drive the results I conducted a robustness check excluding Gabon and Libya from the analysis and the results survive (see section 3.6).

Donor pool countries have to be non-resource producers to comply with the model as explained in section 3.3.4. Because there are only few countries in the world producing no resources the definition is adjusted to be relative to the economic size of a country. Non-resource producers are defined as countries generating resource rents less than 1% of GDP to make sure that the amount is negligible and does not represent an important source of government revenues. Donor pools and weights for each treatment country can be seen in table B 5 in appendix B.

3.4.2 Data

The dependent variable, *total tax p.c.*, measures total non-resource per capita taxes[17] and is derived from the Government Revenue Dataset (GRD), which was created by the International Centre for Tax and Development (ICTD). GRD provides information about government revenues and its components for most countries of the world for the time period 1980 to 2015 as percentage of GDP (Prichard et al., 2014).

The main advantage of the GRD data is that they distinguish between revenues and taxes generated from the resource sector and revenues derived from the remaining economy. Without this distinction, the analysis would be flawed by the fact that resource extracting companies also pay taxes to the government.

The GRD data are stated in percentage of GDP and to obtain the per capita values the variables were multiplied by GDP figures from the World Economic Outlook measured in constant 2010 US$[18] and divided by population data from the World Development Indicators.[19] *Total tax p.c.* ranges within the treatment countries from less than US$ 100 in Cameroon, Guinea and Yemen to over US$ 21,000 in Norway (Table 3.1). Norway is an outlier considering that *total tax p.c.* is 15 times higher than the second highest observed

[17]Excluding social contribution.

[18]The World Economic Outlook does not directly provide GDP in constant US$. I followed the proposed way by the WEO to calculate the GDP in constant US$ series (`https://www.imf.org/external/pubs/ft/weo/faq.htm#q3a`)

[19]WEO also provides population data but WDI are preferred over WEO because they are more precise and cover more countries and years. The exception is Kuwait in 1994 where WEO data are available but WDI population data are missing.

total tax p.c. (Chile, over US$ 1,400). Because of Norway's extreme value a robustness check was carried out excluding Norway from all specifications in section 3.6.

The predictor variable chosen to construct the synthetic control countries are derived from the identifying assumption explained in section 3.3.4. The first variable is the average of the non-resource *total tax p.c.* in the pre-treatment period. The average of the outcome variable rather than a combination of lags was chosen because it resulted in the lowest pre-treatment RMSPE (see appendix B table B 3). The second variable is *non-resource GDP p.c.*, which ensures that the non-resource sectors in the treatment and synthetic control country are of similar size. The third set of variables consists of all alternatives a government faces when confronted with additional resource income. They include government spending measured as *capital formation* and *current government expenditure* as well as *reserves* in case the government saves the money and *corruption* to control for stolen funds. Definition and source of each variable used is provided in the appendix table B 6 and table B 7 shows summary statistics for the whole sample.

Comparing the treatment countries with non-resource producing countries shows that they are on average of a different nature. Table 3.2 shows descriptive statistics comparing treatment countries with non-resource producers. The t-statistic shows that citizens in resource exporting countries pay fewer *total tax per capita* and have a lower *non-resource GDP*. The resource exporters have a higher *capital formation* and are more *corrupt*, while they receive significantly less *ODA* and are more autocratic. There is no significant difference in terms of *government expenditure*, *reserves*, *agriculture* and *inflation*.

Table 3.2: Descriptive statistics

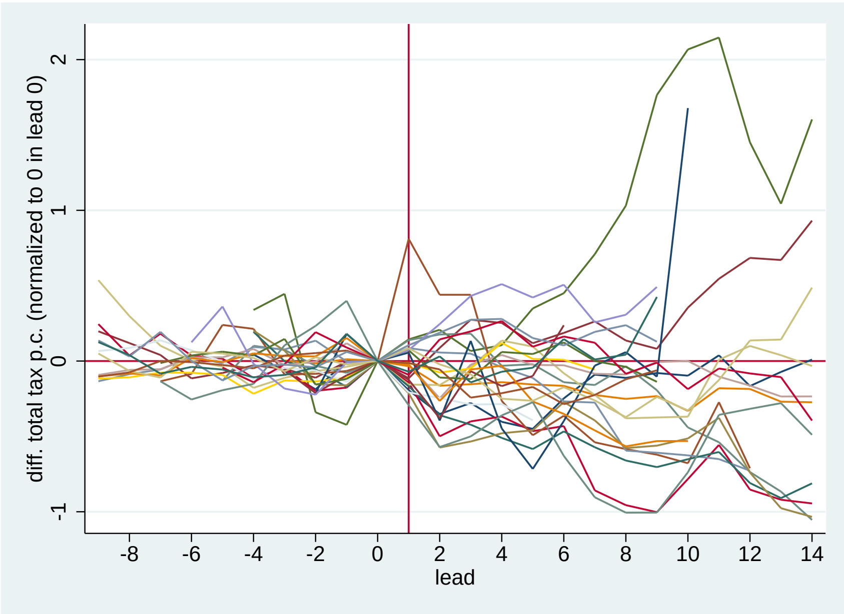
	Non-resource producers	Resource exporters	Diff.	t-stats	p-value
Total tax p.c.	2779.16	907.68	1871.47	5.715	0.000
Non-res. GDP p.c.	8237.46	4083.92	4153.53	5.107	0.000
Gov. Expenditure	16.50	16.36	0.13	0.254	0.800
Capital formation	21.95	24.27	−2.32	−3.576	0.000
Reserves	13.91	14.10	−0.19	−0.166	0.868
Corruption	0.26	−0.36	0.62	4.766	0.000
Agriculture	15.76	16.19	−0.43	−0.419	0.676
ODA	9.66	4.23	5.43	4.724	0.000
Inflation	43.78	78.29	−34.51	−1.490	0.137
Polilty2	4.42	−0.96	5.38	10.605	0.000

Notes: Means calculated for 10 years prior to the 2000s commodity price boom. Government expenditure, capital formation, reserves, agriculture, and ODA is measured in percent of GDP.

3.5 Results

Figure 3.8 shows the results for the synthetic control method. Each line represents one country and shows the difference in non-resource *total tax p.c.* between treatment and synthetic control country over time. The differences are scaled to 0 in the year prior to the treatment (lead 0) and the vertical line at lead 1 indicates the start year of the commodity price boom, 1999 for oil and precious mineral exporters and 2004 for mineral exporters.

Figure 3.8: Synthetic control method, all countries



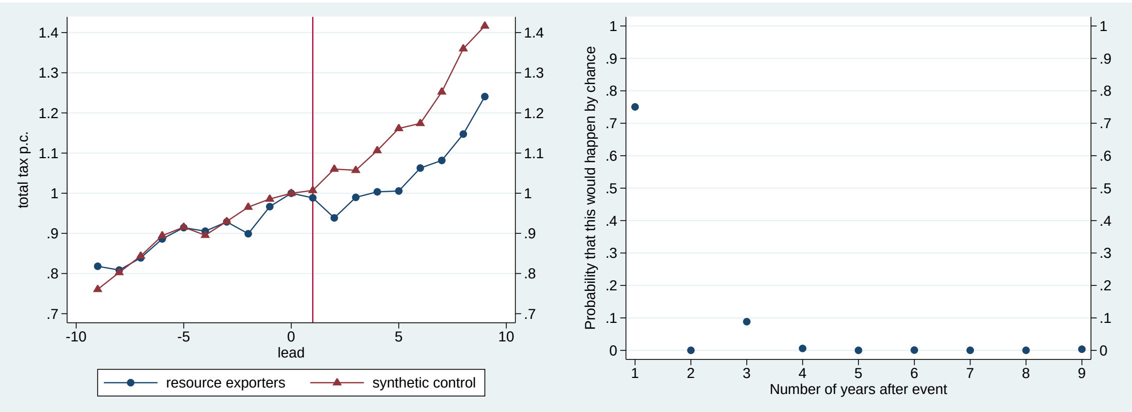
The vast amount of lines in figure 3.8 makes it almost impossible to identify a single country but by laying all countries into one figure it is still possible to derive some information. The first indicative result is that more countries have a negative effect, i.e. *total tax p.c.* decreased because of the commodity price boom. The second indicative result is that the effect is heterogeneous. There are as many countries with seemingly no effect as there are with a negative effect and even a few countries seem to have increased taxes, which would be the opposite of a crowding-out effect. The biggest effect is even positive in Azerbaijan.

The indicative results are that governments extract on average less tax from the non-resource sector when more funds are available from the resource sector due to a positive price shock and that this effect is heterogeneous.

Average treatment effect

The first indicative result derived from figure 3.8, the existence of a negative average treatment effect, is confirmed in figure 3.9 (left panel). Figure 3.9 shows average *total tax p.c.* for the 25 resource exporters and the corresponding synthetic control. The resource exporters and its synthetic counterfactual overlap well in the pre-treatment period (lead -10 to 0) and start to diverge in the post-treatment period. Again lead 1 indicates the first post-treatment year, 1999 for oil and precious mineral exporters and 2004 for mineral exporters. For the whole post-treatment period, *total tax p.c.* is higher in the synthetic control country. This synthetic control country represents the *total tax p.c.* for resource exporting countries in the absence of the 2000s commodity price boom. On average *total tax p.c.* is 11% lower in resource exporting countries. The difference is significant at conventional level for all years after the event start, except for year 1 (Figure 3.9, right panel).

Figure 3.9: Synthetic control estimates, resource exporting countries



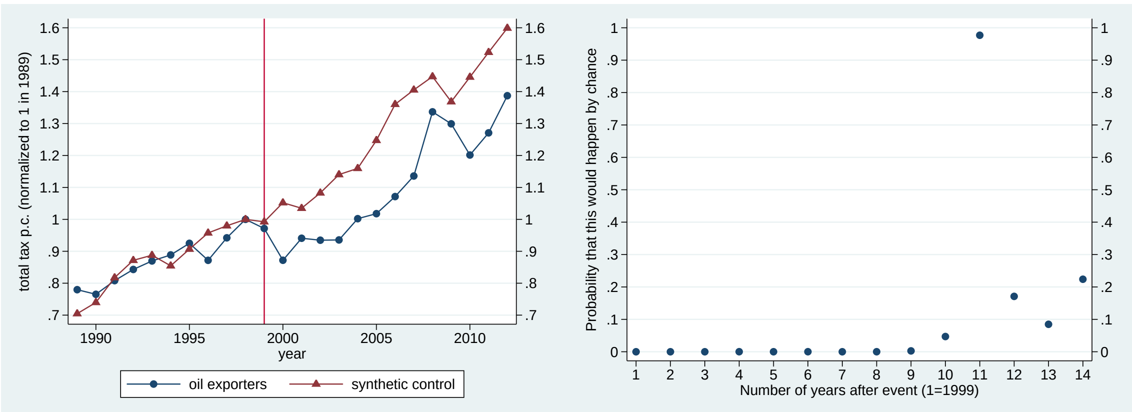
The first indicative result from figure 3.8, negative average treatment effect, is therefore confirmed in the data and in line with the existing literature finding a crowding-out effect (Bornhorst et al., 2009; Crivelli and Gupta, 2014; Thomas and Treviño, 2013). The second indicative result, that the effect is heterogeneous, will be discussed and analysed further below.

Resource type

To analyse possible heterogeneity, I start by separating the three resource types: oil, minerals, and precious minerals. The literature associates different outcomes to different resources (Andersen and Aslaksen, 2013; Isham, 2005; Ross, 2015). One reason oil could influence *total tax p.c.* in a different way than minerals or precious minerals is that the latter two have more forward and backward linkages with the remaining economy. Minerals and precious minerals are labour-intensive industries and require more low-skilled labour, while oil is a capital-intensive industry with the need of advanced technology and few but skilled workers (Karl, 2007). Another reason could be that economic rents are higher in the oil sector and that on average governments are better capable to extract a higher percentage share from an oil well than from a mineral mine. For a mining project governments commonly retain 40-60% of revenues while this share is around 65-85% for an oil project (IMF, 2012a). The higher share of revenues and rents can then be used to substitute resource revenues for non-resource taxes.

Figure 3.10 shows the results for the 19 oil exporting countries in the sample. *Total tax p.c.* is lower for the whole treatment period for this sub-sample compared to their synthetic counterpart. Tax revenues seem to fall straight after the price boom started, but the downward trend is reversed after two years and *total tax p.c.* starts to recover. In the year 2000 *total tax p.c.* is 13% lower than it was in 1998 and 17% lower than in the synthetic control country in the same year.[20] It takes overall six years for the oil exporting countries to get back to their initial 1998 level of *total tax p.c.* and by this time, they still lack 13% behind the synthetic control country. The p-values indicate that the effect is significant with the exception 11-12 years after the event started, which corresponds to the years 2009-2010 and the start of the Great Recession.

Figure 3.10: Synthetic control estimates, oil exporting countries



The results for mineral and precious mineral exporting countries are different. There seems to be no difference between mineral exporting countries and the synthetic control country in the pre- and post-treatment period (Figure 3.11). Precious mineral exporting countries, on the other side, are faced with a *total tax p.c.* increasing effect at the beginning

[20]Predicted values for the synthetic control and actual values for each sub-sample and year are shown in table B 8 in appendix B and table 3.4 discussed below shows the difference in percentage terms.

of the commodity price boom until 2005 (Figure 3.12). However, for both sub-samples the p-values indicate a high probability that anything observed occurred by chance. There seems to be no significant effect for mineral or precious mineral producers.

Figure 3.11: Synthetic control estimates, mineral exporting countries

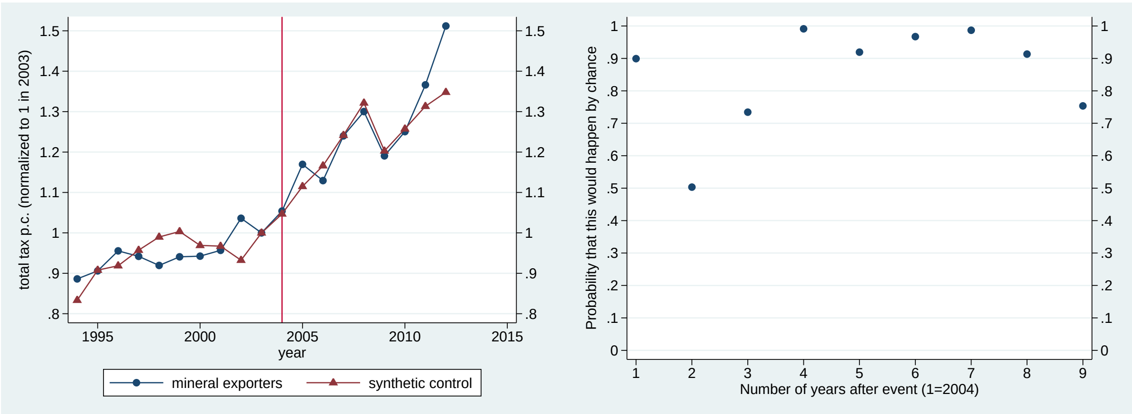
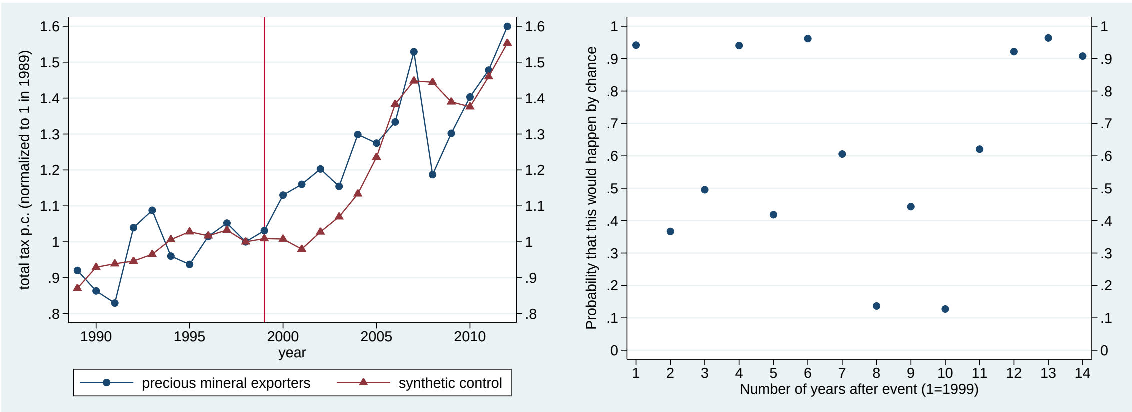


Figure 3.12: Synthetic control estimates, precious mineral exporting countries



Summarizing the results for different resources shows that the commodity price boom decreased *total tax p.c.* in oil exporting countries but not in other resource exporting countries. The non-effect for mineral and precious mineral exporters could be driven by the small sample size of only three countries in each sub-sample. A deeper look at each individual country, however, confirms that there is no effect (see figure B.2 and figure B.3 in appendix B). From this point on forward, I focus on oil exporting countries.

Continuing with the effect on oil exporters, I next split the sample according to institutions, ownership structure of the oil sector, oil tax to oil non-tax ratio, and resource dependency of the state budget. See table 3.3 for an overview which oil exporting country belongs to which category. The classification is according to 1998 values, the year before the oil boom started.

Table 3.3: Oil exporting treatment countries

Country	non-res. tax p.c.	Polity2	Ownership	Oil dependency	tax to non-tax ratio
Algeria	396	-3	State	High	Non-tax
Azerbaijan	144	-7	State	Medium	Non-tax
Brunei	1007	.	State	High	Tax
Cameroon	106	-4	Private	Medium	Non-tax
Ecuador	288	9	State	.	Non-tax
Egypt	231	-6	State	Medium	Non-tax
Gabon	1718	-4	Private	High	Tax
Indonesia	182	-5	State	Medium	Tax
Kazakhstan	609	-4	Private	.	Tax
Kuwait	583	-7	State	High	Non-tax
Libya	746	-7	State	High	Non-tax
Malaysia	904	3	State	Low	Tax
Norway	23300	10	State	Low	Tax
Saudi Arabia	416	-10	State	High	Non-tax
Syria	261	-9	State	High	Non-tax
Trinidad and Tobago	1730	10	Private	Low	Tax
Turkmenistan	132	-9	State	Low	Tax
Venezuela	1024	8	State	Medium	Tax
Yemen	100	-2	Private	High	Non-tax

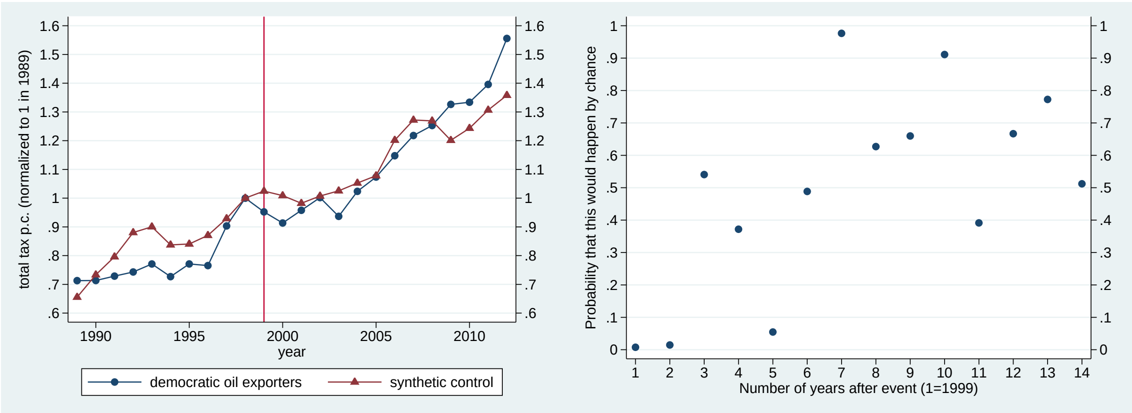
Notes: Values are measured in 1998, the year prior to the event. Non-resource total tax p.c. is measured in constant 2010 US$ from GRD dataset. Polity2 is the polity index from Marshall and Jaggers (2014). Oil dependency measures the percentage share of government revenues derived from the oil sector (low<20%, medium 20-40%, high>40%). Tax to non-ratio measures oil tax revenues divided by oil non-tax revenues (Tax is a ratio>1, non-tax is a ratio<1).

Institutions

Some scholars claim that the adverse effects of natural resources on economic and political outcomes are conditional on the level of institutional quality (Bhattacharyya and Hodler, 2010; Bhattacharyya and Collier, 2014; Mehlum et al., 2006; Robinson et al., 2006). Therefore, it is worthwhile to explore this potential source of heterogeneity. To test for conditionality I use the Polity2 score from Marshall et al. (2013) which measures democracy on a 21 points scale ranging from -10 (autocratic institutions) to +10 (democratic institutions). I split the sample into democratic countries (Polity2: +4 - +10), intermediate countries (Polity2: -3 - +3) and autocratic countries (Polity2: -4 - -10).

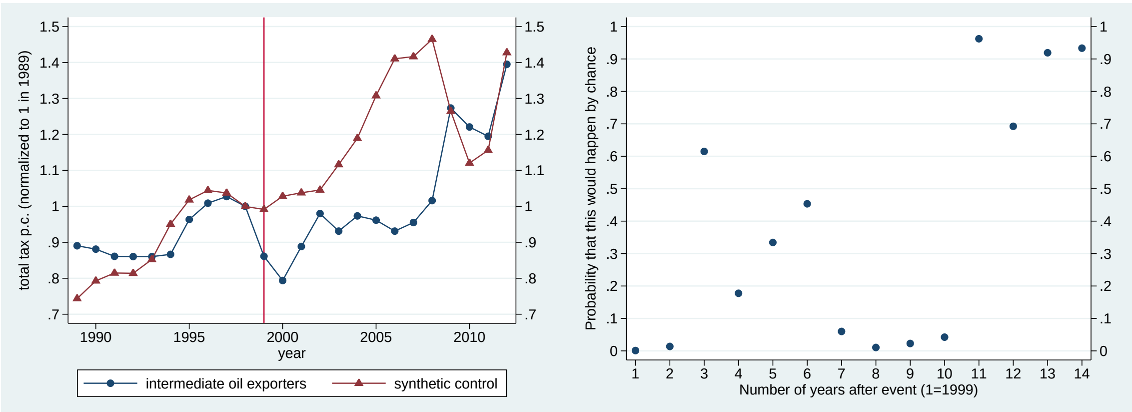
Figure 3.13 shows that the oil price boom did not influence *total tax p.c.* in democratic countries. Democratic oil exporting countries follow the same path as their synthetic counterpart in the pre- and post-treatment period. Differences between democratic oil exporters and synthetic control are likely to happen by chance, most p-values are above conventional levels for the whole treatment period.

Figure 3.13: Synthetic control estimates, democratic oil exporting countries



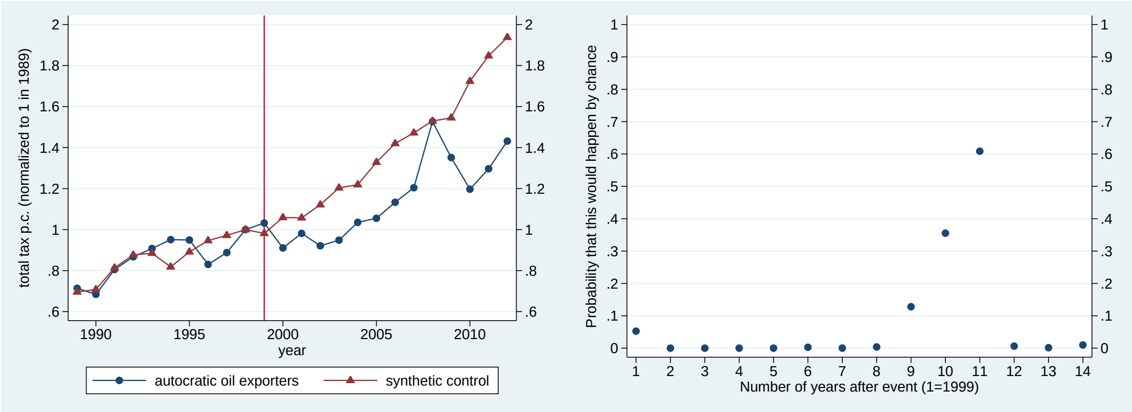
Countries with an intermediate level of institutional quality (Polity2 score between -3 and +3) show mixed results. In figure 3.14, the synthetic control estimates for intermediate countries seem to indicate a *total tax p.c.* decreasing effect and in the years 1-2 and 7-10 the p-values also indicate that this effect is significant. However, for the remaining years the effect is insignificant.

Figure 3.14: Synthetic control estimates, intermediate oil exporting countries



The case for autocratic countries is clearer. Figure 3.15 shows the result and the *total tax p.c.* decreasing effect is significant at conventional levels in all years except for year 9-11 after the event (Great Recession). On average autocratic oil exporting countries collect 16% less *total tax p.c.* than their synthetic counterparts.

Figure 3.15: Synthetic control estimates, autocratic oil exporting countries



The heterogeneous results for countries with different levels of institutional quality could be explained by Garcia's argument that democratic institutions are more expensive (Garcia and von Haldenwang, 2015). Participation, redistribution and more public goods require more funds and therefore the 2000s oil price boom perhaps was not enough to decrease non-resource *total tax p.c.* in democracies. Further, the results support the argument of a conditional resource curse[21] and under this condition confirms the 'tax effect' argument from Mahdavy (1970) and Ross (2015).

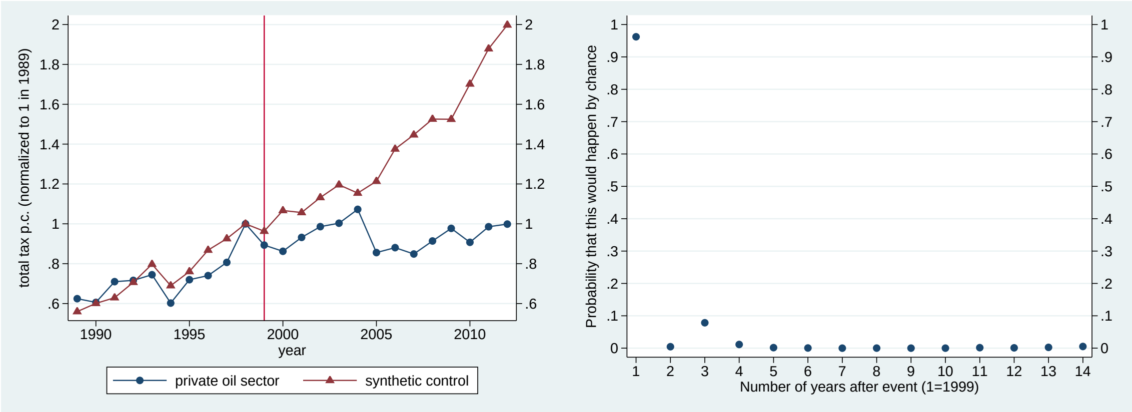
Ownership structure

The ownership structure of the resource sector could also influence taxation of the remaining economy. A private resource sector needs a sophisticated tax administration to extract a fair share. This resource division within the tax administration could have positive spillovers on the rest of the tax administration. The positive spillovers could lead to a more efficient tax administration and to more tax income (Knebelmann, 2017). A nationalized resource sector, on the other hand, is often organized under the direct authority of the leader or in a form that the leader has access to its funds. The easy access to resource revenues could lead the government to neglect income from the remaining economy and reduce taxation.

Figure 3.16 shows the results for countries with a private organized oil sector. Overall a *total tax p.c.* decreasing effect can be observed. However, the effect starts small and becomes stronger after 6-7 years. From 1999 till 2004 the difference is on average 12% and from 2005 till 2012 the oil exporting countries collect on average 40% less *total tax p.c.* compared to their synthetic counterparts.

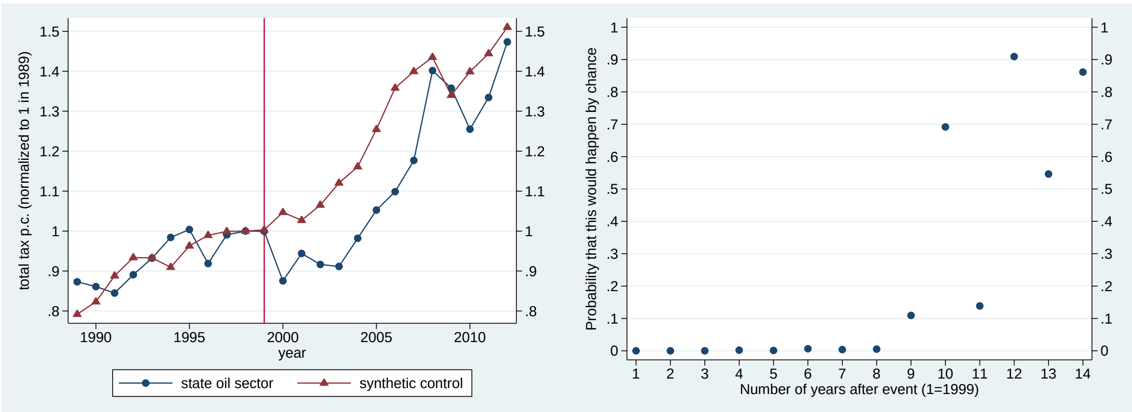
[21]see Liou and Musgrave (2014) for an overview of conditionalist resouce curse research.

Figure 3.16: Synthetic control estimates, private oil sector



The results for countries with nationalised oil sector show a smaller and partly less significant effect (see figure 3.17). After 9 years the effect is not significant anymore. In the remaining years countries with nationalised oil sector collected on average 10% less *total tax p.c.* than their synthetic counterparts.

Figure 3.17: Synthetic control estimates, nationalised oil sector



The results for private- and state-owned oil sectors are indicative that governments intending to extract more revenues from a private oil company faces more challenges and longer negotiation time to increase their share of the resource revenues, which then can be used to substitute for non-resource taxes. Countries with nationalised oil sector benefit immediately but to a lesser extent.

Fiscal instruments

Another form of government preferences that may influence the relationship between oil revenues and *total tax p.c.* could be the instruments chosen to extract revenues from the resource sector. To test for this possible source of heterogeneity I construct a tax to non-tax ratio for each oil exporter in the year before the event. A ratio smaller one indicates that the government extracts more revenues with non-tax instruments while governments with a ratio greater than one use more tax instruments.

The effect in non-tax countries (tax to non-tax ratio < 1) is small and mostly insignificant (Figure 3.18). While tax countries (tax to non-tax ratio > 1) have a *total tax p.c.* reducing effect, significant at conventional level for all years (Figure 3.19). On average tax countries collect 21% less tax than the synthetic control.

Figure 3.18: Synthetic control estimate, tax to non-tax ratio<1

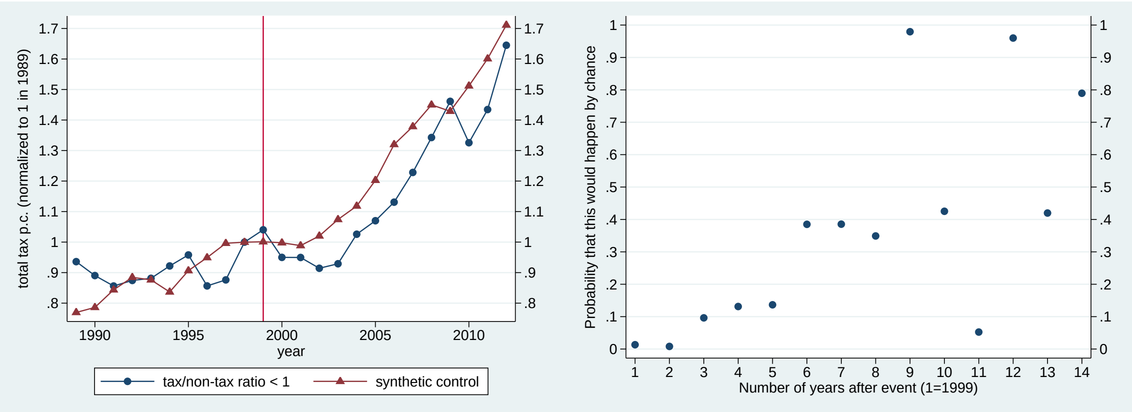
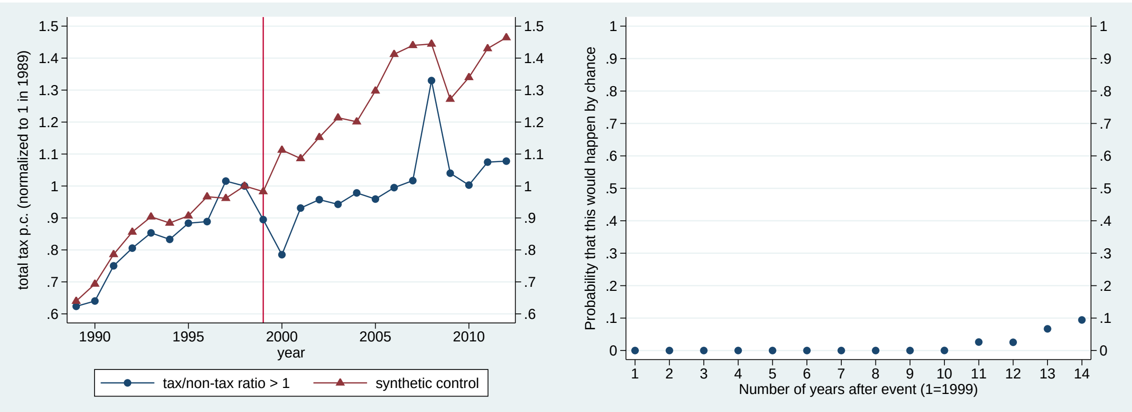


Figure 3.19: Synthetic control estimate, tax to non-tax ratio>1



The heterogeneity between tax and non-tax countries could be driven by the fact that tax countries collect on average more taxes (US$ 913)[22] compared to non-tax countries (US$ 327). The higher tax income gives tax countries more room to reduce taxes while non-tax countries' possibilities are already exhausted, eventually because they never build them.

[22]Excluding Norway, with Norway average non-resource tax per capita would be US$ 3400.

Resource dependency

A last type of heterogeneity is the level of resource dependency of the state budget. Resource dependency is also an inverse proxy for tax effort, i.e. more reliance on resource revenues implies less effort in the non-resource sector. The sample is divided into three categories according to the percentage share of resource revenues of total government revenues in the year prior to the event. Countries are categorised as low resource dependent if less than 20% of government revenues are collected from the resource sector, resource revenues for medium-dependent countries range from 20-40% of total government revenues, and high-dependent countries collect more than 40% of total revenues from the resource sector.

Figure 3.20 and figure 3.21 show results for low and medium dependent countries. For most years the estimates are insignificant. Note that for the first time oil exporting countries have a higher *total tax per capita* in the case of medium-dependent countries even if significant in only a few years.

Figure 3.20: Synthetic control estimate, low oil dependence (less than 20%)

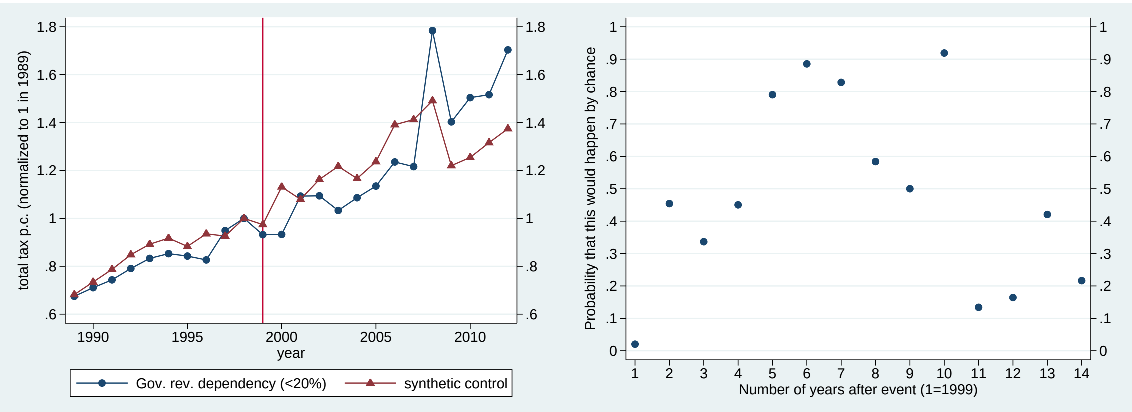


Figure 3.21: Synthetic control estimate, medium oil dependency (20-40%)

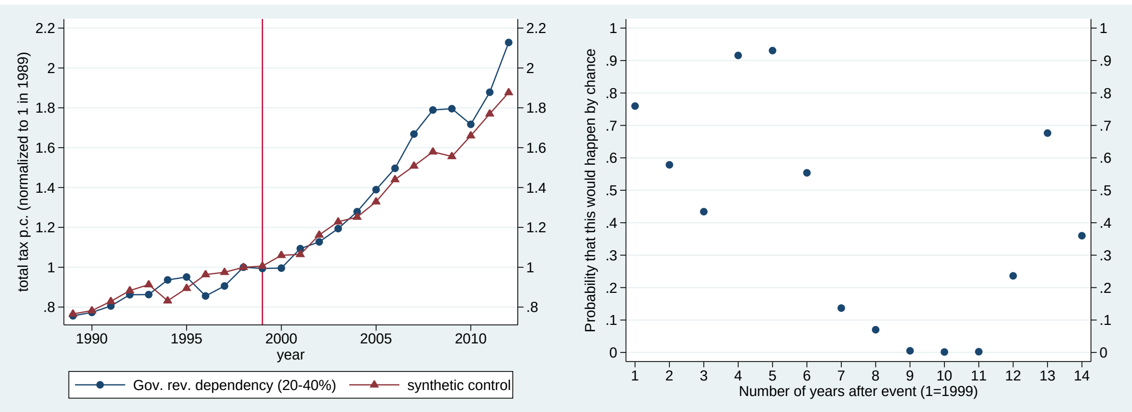
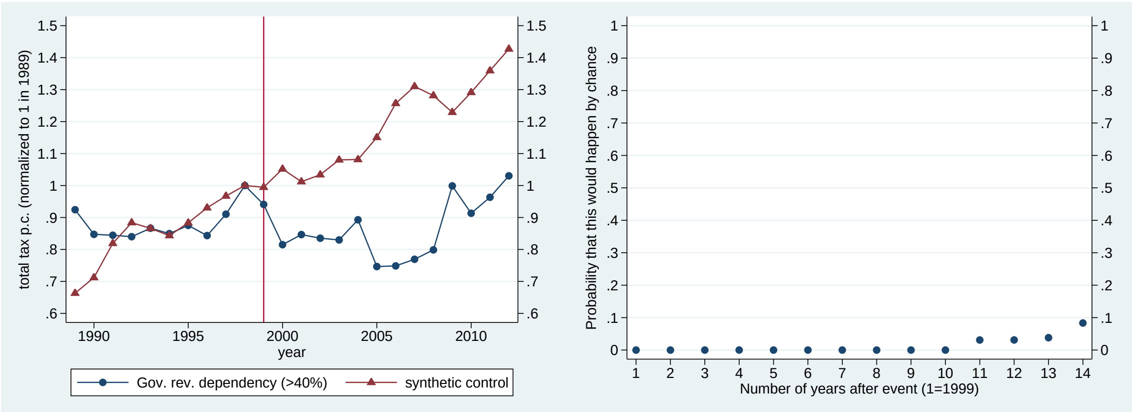


Figure 3.22 shows the result for high-dependent oil exporting countries. Countries with a state budget deriving more than 40% of its funds from the resource sector show a negative effect, i.e. *total tax p.c.* is on average 26% lower in oil exporting countries due to the 2000s oil price boom.

Figure 3.22: Synthetic control estimate, high oil dependency (more than 40%)



The results of the heterogeneity analysis seem to indicate that autocratic countries with a focus on tax revenues or a high share of resource revenues in the state budget are confronted with a crowding-out effect. *Total tax p.c.* is lower in those oil exporting countries because of a positive resource income shock.

The size of the crowding-out effect

Finally, I analyse the size of the crowding-out effect in monetary terms. Table 3.4 shows the percentage and absolute difference between treatment and synthetic control countries for each significant sub-sample.[23] The synthetic control country is chosen as base in each year and the percentage difference shows how many percent the treatment countries' *total tax p.c.* is higher or lower than *total tax p.c.* of the synthetic control. Differences shown in US$ are the corresponding values to the percentage differences of *total tax p.c.* of the treated minus *total tax p.c.* of the synthetic control country.

Column (1) and (2), shows the results for all oil exporting countries and corresponds to the results shown in figure 3.10. On average, individuals and companies in oil exporting countries paid 14% less tax each year or US$ 316 per capita. For example, Saudi Arabia with an average population of 24.4 million loses on average US$ 7.7 bn each year. This is only US$ 1.55 bn short of what the Saudi's government expects to generate from the 5% VAT introduced in 2018.

[23]The significant sub-samples are all, autocratic, private, state, tax to non-tax ratio > 1 and highly resource dependent oil exporting countries.

The sub-sample of autocratic countries (column (3) and (4)) shows a smaller absolute effect but bigger percentage difference. The synthetic control countries collect on average US$ 114 (16%) more in *total tax p.c.* than the actual autocratic oil exporting countries. For example, Cameroon, and Syria both with similar population size (17.8 and 18.7 million, respectively) lose US$ 2.0 bn and US$ 2.1 bn on average each year. Comparing oil exporting countries with private or state organized oil sector shows that the overall effect is greater for countries with private oil sector, US$ 372 against US$ 257 respectively.

The biggest effect can be seen for countries with a tax to non-tax ratio greater than one. Those are countries focusing more on tax instruments to extract money from the resource sector than on non-tax instruments. Overall, individuals and companies in those countries pay on average US$ 938 less in *total tax p.c.* due to the oil price boom.

Concluding, the average yearly increase in oil price of 14% from 1999 to 2012 reduced *total tax per capita* on average between US$ 110 and US$ 940 per capita depending on the sub-sample.

Table 3.4: Absolute and percentage differences between oil exporting countries and synthetic control countries

	All oil countries		**Autocratic oil countries**		**Private oil sector**		**State oil sector**		**Tax to non-tax ratio>1**		**High oil dependent**		**Oil price**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Year	diff. in %	diff. in US$	diff. in %	diff. in US$	diff. in %	diff. in US$	diff. in %	diff. in US$	diff. in %	diff. in US$	diff. in %	diff. in US$	in US$	% change
1999	-2.10%	-37.22	5.17%	23.64	-7.23%	-59.38	-0.34%	-7.31	-8.92%	-297.94	-5.40%	-35.06	18.56	
2000	-17.14%	-321.47	-14.03%	-69.25	-19.18%	-174.50	-16.39%	-362.97	-29.43%	-1113.37	-22.51%	-154.72	28.50	53.57%
2001	-9.08%	-167.52	-7.18%	-35.40	-11.81%	-106.38	-8.08%	-175.46	-14.28%	-527.28	-16.35%	-108.16	23.70	-16.85%
2002	-13.68%	-264.03	-17.85%	-93.29	-12.91%	-124.61	-13.97%	-314.68	-16.93%	-663.29	-19.20%	-129.71	23.72	0.07%
2003	-17.95%	-364.94	-21.19%	-118.89	-16.12%	-164.33	-18.65%	-441.96	-22.32%	-921.12	-23.18%	-163.65	26.54	11.92%
2004	-13.58%	-280.85	-15.07%	-85.59	-7.06%	-69.50	-15.44%	-379.12	-18.54%	-757.22	-17.43%	-123.17	34.30	29.23%
2005	-18.40%	-409.18	-20.57%	-127.35	-29.49%	-305.14	-16.10%	-427.23	-26.09%	-1151.49	-35.10%	-263.81	47.26	37.78%
2006	-21.24%	-515.09	-20.18%	-133.55	-35.98%	-422.00	-19.10%	-548.81	-29.55%	-1418.90	-40.44%	-332.10	55.37	17.16%
2007	-19.19%	-480.78	-18.19%	-124.78	-41.34%	-509.82	-15.92%	-471.17	-29.38%	-1438.45	-41.27%	-353.25	60.12	8.58%
2008	-7.63%	-196.97	-0.15%	-1.06	-40.09%	-521.45	-2.33%	-70.59	-7.92%	-389.02	-37.66%	-315.33	77.79	29.38%
2009	-5.06%	-123.41	-12.53%	-90.26	-35.91%	-466.81	1.32%	37.55	-18.23%	-788.32	-18.73%	-150.43	49.50	-36.36%
2010	-16.88%	-435.18	-30.56%	-245.52	-46.69%	-677.49	-10.29%	-304.53	-25.14%	-1145.25	-29.27%	-246.98	62.78	26.82%
2011	-16.57%	-449.92	-29.82%	-256.79	-47.54%	-761.47	-7.61%	-232.56	-24.85%	-1208.29	-29.13%	-258.75	85.17	35.67%
2012	-13.24%	-377.51	-26.13%	-235.95	-50.01%	-851.95	-2.43%	-77.67	-26.39%	-1314.11	-27.80%	-259.22	83.75	-1.66%
Sum		-4424.06		-1594.02		-5214.83		-3776.50		-13134.06		-2894.34		
Av.	**-13.70%**	**-316.00**	**-16.31%**	**-113.86**	**-28.67%**	**-372.49**	**-10.38%**	**-269.75**	**-21.28%**	**-938.15**	**-25.96%**	**-206.74**		**13.95%**

Notes: The table shows the difference in *total tax per capita* between oil exporting countries and synthetic control country. The synthetic control country serves as base value and percentage differences are calculated accordingly. The Oil price is in constant 2000 US$ from Ross and Mahdavi (2013).

3.6 Robustness checks

I conduct a battery of robustness checks dealing with Saudi Arabia, Norway, Gabon, Libya and additional predictor variables.

I start by excluding Saudi Arabia from the specifications. As discussed in section 3.2, Saudi Arabia is a swing producer and may have enough market power to influence the oil price. If Saudi Arabia changed oil production in the considered time period influencing the 2000s oil price boom this would lead to endogeneity. Results for the synthetic control estimates excluding Saudi Arabia are shown in figure B.4 in appendix B. Overall the effect becomes slightly smaller but the patterns and significance stays the same.

A further robustness check is conducted by excluding Libya and Gabon. As mentioned in section 3.4 the construction of the synthetic control countries was only possible for Gabon and Libya by ignoring the region restriction. Therefore, the donor pool consists for those two countries out of all non-resource producer in the world. To ensure that Gabon and Libya are not driving the results I test the main specifications excluding Gabon and Libya. Results for the synthetic control estimates excluding Libya and Gabon are shown in figure B.6 in appendix B and effects observed in the main specifications survive.

Next, I include further predictor variables to construct the synthetic control. So far the analysis only included the variables derived from the identifying assumption: *total tax p.c., non-resource GDP, public expenditure, capital formation, reserves* and *corruption*. These variables cover all the areas of what the government can do with the additional funds derived from the price boom and ensures that the non-resource economy is of the same size. However, other variables could determine how much tax the government can extract from the non-resource sector such as the sectoral composition, foreign aid, or inflation. For this reason, I include *(value added) agriculture* and *ODA*, both measured as percentage of non-resource GDP and *inflation* successively and combined. Figure B.8 in the appendix shows the results, which remain robust.

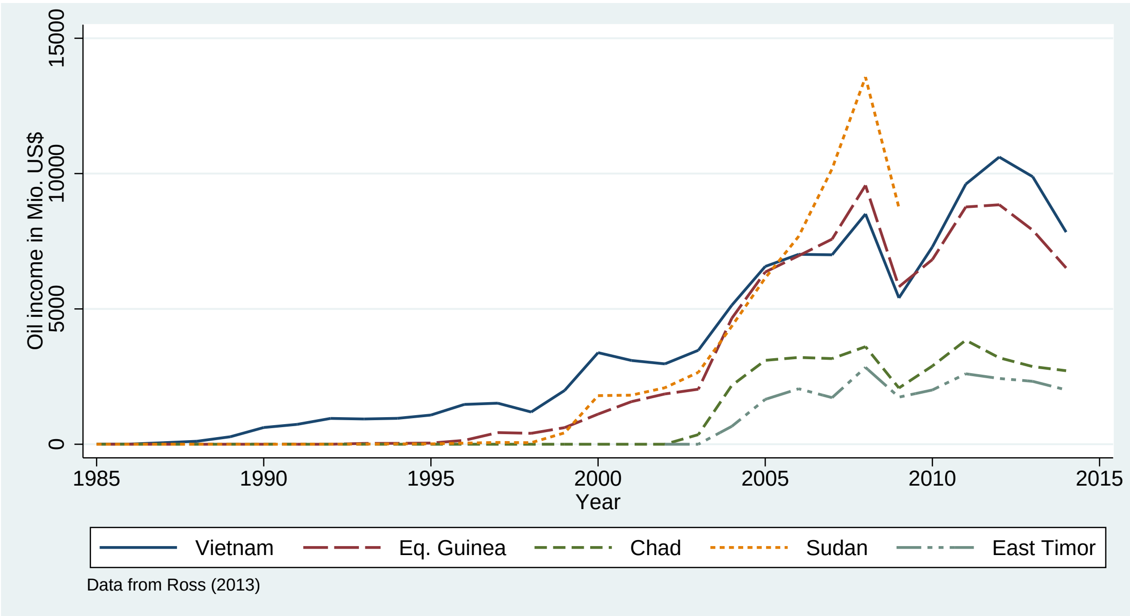
Finally, I run a last robustness check excluding Norway from the sample. The fact that Norway's *total tax p.c.* is 15 times higher than the second highest *total tax p.c.* in the sample unfolds the question whether Norway is driving the results. Figure B.9 in the appendix presents robust results.

3.7 New producers

In this section, I will discuss five case studies of non-resource producing countries who discovered oil and started extraction between 1980 and 2015. Contrary to the main analysis, which focused on established resource exporters, here the focus is on new producers and provides relevant information for future oil producers.

The five new producers and their treatment start years are: Vietnam (1989), Equatorial Guinea (1993), Sudan (1999), Chad (2003) and East Timor (2004). Figure 3.23 shows oil income generated in each of the five countries. Most countries produced oil already before the treatment, but oil rents never exceeded 1% of GDP and played an insignificant role in the economy. Treatment is therefore defined from the year in which oil rents start to exceed 1% of GDP.

Figure 3.23: Oil income, new producers

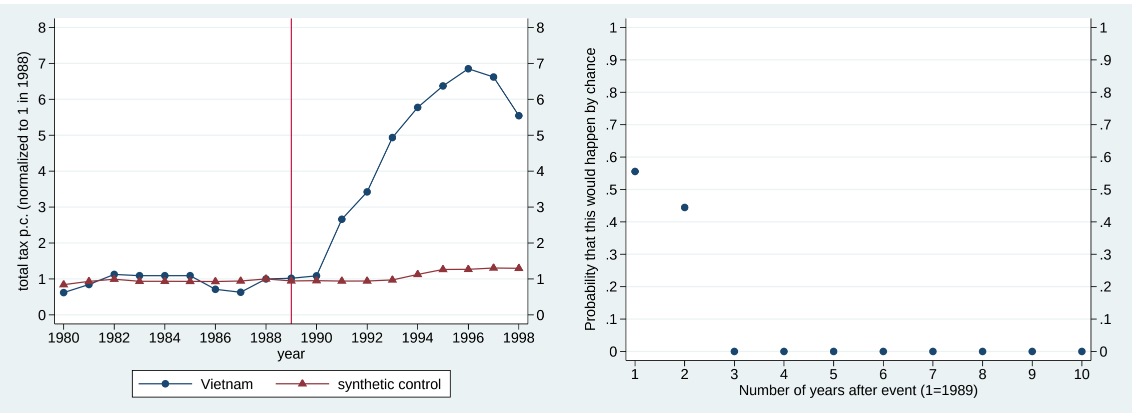


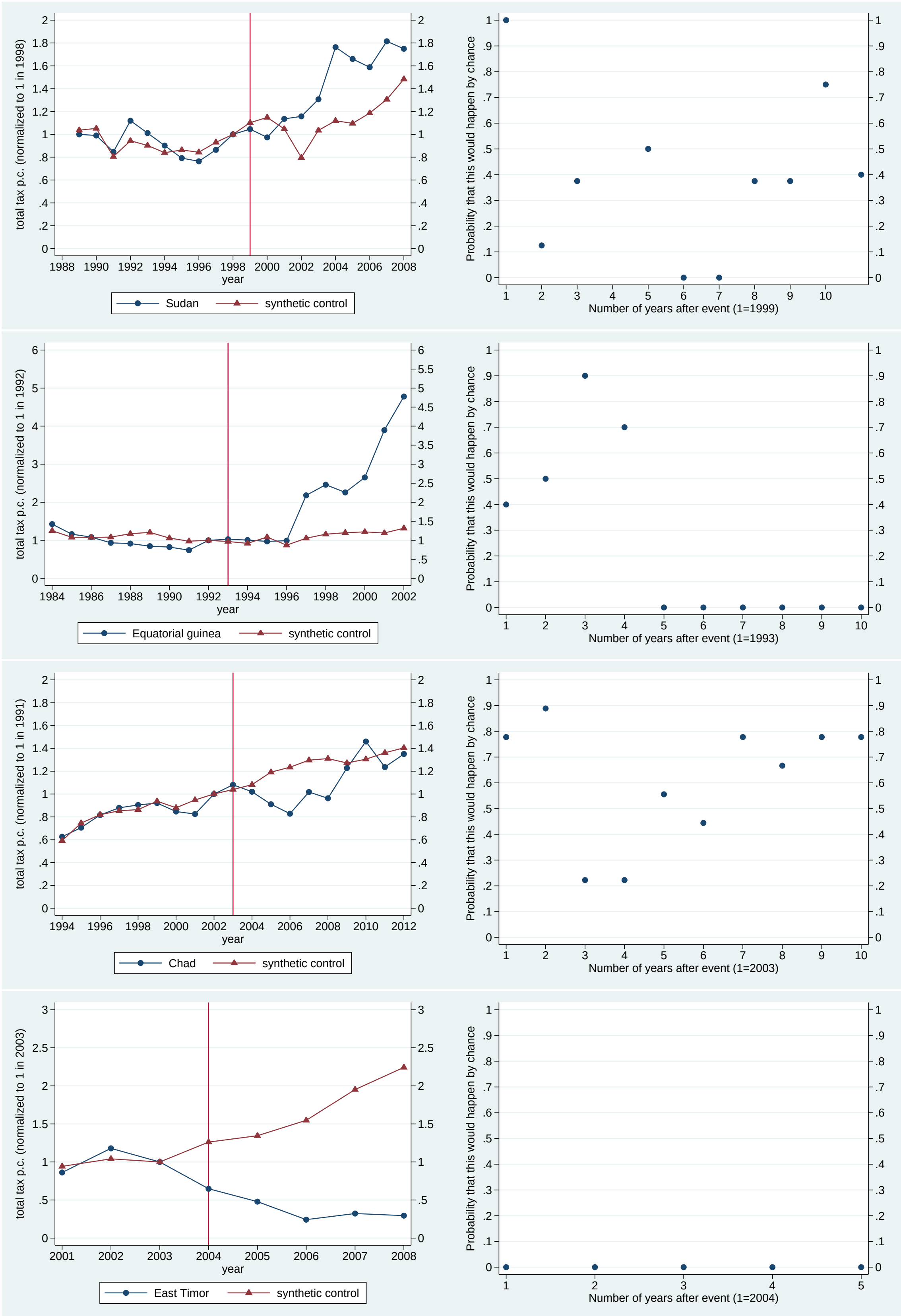
A few notes on identification and methodology is appropriate for this new setting. First, it should be noted that the timing of oil production start is not exogenous. This is because a country's fiscal regime influences the decision of oil companies to start extraction, delay it or not to produce at all. Therefore, the results can only be seen as a correlation. Second, the countries started to produce at different times, which makes data availability an issue. For example, Vietnam started oil extraction in 1989 and is lacking data on *corruption, reserves* and *government expenditure*. To make the most out of the limited data I included all possible control variables to construct the synthetic control. They include the main control variables: *non-resource GDP, government expenditure, capital* *formation, reserves* and *corruption* as well as the additional predictor *agriculture, ODA* and *inflation*. Variables and weights are shown in table B 9 in the appendix. Third, p-values should not be taken at face value with only one treatment country. This is because the iteration procedure used to calculate p-values compares the effect of the treatment country with all possible placebo effects. The number of placebo effects depends on the size of the donor pool, which is significantly smaller in the case of a single treated country.

The analysis follows the same pattern as outlined in section 3.3 following Abadie et al. (2010) approach for a single treated country. First, different specifications are tested with different combinations of the lagged outcome variables to construct the synthetic control. Pre-treatment RMSPEs for each country and specification are shown in table B 10 in appendix B. Second, the donor pool is chosen in the same manner as above, including only non-resource producers from the same region. Third, a synthetic control country is constructed and the difference between actual and counterfactual is analysed. Post-treatment period is restricted to 10 years, except for Equatorial Guinea for which pre-treatment is only three years and post-treatment period was downsized to five years.

The results for each new producer are shown in figure 3.24 and the difference between treatment and synthetic control country in percent and US$ are shown in table 3.5. Vietnam, Sudan and Equatorial Guinea all show a *total tax p.c.* increase after oil extraction took off compared to the synthetic control, while Chad and East Timor experienced a negative effect.

Figure 3.24: Synthetic control estimate, new producers





total tax p.c. (normalized to 1 in 1998)
year
Sudan
synthetic control
Probability that this would happen by chance
Number of years after event (1=1999)
total tax p.c. (normalized to 1 in 1992)
year
Equatorial guinea
synthetic control
Probability that this would happen by chance
Number of years after event (1=1993)
total tax p.c. (normalized to 1 in 1991)
year
Chad
synthetic control
Probability that this would happen by chance
Number of years after event (1=2003)
total tax p.c. (normalized to 1 in 2003)
year
East Timor
synthetic control
Probability that this would happen by chance
Number of years after event (1=2004)

On average *total tax p.c.* is 287% higher in Vietnam during the ten years after oil extraction started. This seems like a considerable effect in percentage terms but considering Vietnam's low level of *total tax p.c.* (US$ 16) in the pre-treatment period this 287% increase represent only US$ 53 on average.

Sudan's initial *total tax p.c.* was US$ 71 in 1998 and since oil extraction took off in 1999 *total tax p.c.* increased to over US$ 124. On average Sudan's actual *total tax p.c.* is 26% or US$ 20 per capita higher compared to the synthetic control.

Equatorial Guinea started with *total tax p.c.* of about US$ 59 in 1993. Since oil extraction took off it is on average by 93% or US$ 66 higher compared to the synthetic control.

Compared to the three new producers above, the effect is negative and a lot smaller in Chad. On average *total tax p.c.* is 11% smaller in Chad compared to the synthetic control, which represents a mere difference of about US$ 5.

Finally, the effect in East Timor is also negative with a lower average *total tax p.c.* of 74%. However, considering the data limitation for East Timor this result should be interpreted with caution.

Table 3.5: Absolute and percentage differences, New producers

	Vietnam		Sudan		Eq. Guinea		Chad		East Timor	
	difference		difference		difference		difference		difference	
T	in %	in US$	in %	in US$	in %	in US$	in %	in US$	in %	in US$
1	7.8%	1.17	-5.1%	-4.00	6.1%	3.52	4.0%	1.51	-48.6%	-57.35
2	14.1%	2.13	-15.2%	-12.44	9.4%	5.13	-5.7%	-2.23	-64.4%	-81.06
3	182.9%	27.30	8.4%	6.24	-10.5%	-6.73	-23.6%	-10.22	-84.3%	-122.20
4	263.3%	39.37	45.3%	25.68	13.4%	6.92	-32.9%	-14.80	-83.5%	-152.46
5	407.9%	62.89	26.3%	19.35	106.7%	66.67	-21.5%	-10.15	-86.8%	-182.33
6	413.4%	73.78	57.5%	45.82	112.0%	76.96	-26.5%	-12.64		
7	404.1%	81.06	51.5%	40.14	88.3%	62.71	-3.5%	-1.63		
8	440.4%	88.59	33.8%	28.53	117.1%	84.66	11.9%	5.63		
9	407.6%	84.36	39.0%	36.20	226.3%	159.86	-9.2%	-4.57		
10	328.0%	67.42	17.9%	18.90	262.5%	204.80	-3.8%	-1.95		
Sum		528.07		204.42		664.51		-51.04		-595.39
Av.	**287.0%**	**52.81**	**25.9%**	**20.44**	**93.1%**	**66.45**	**-11.1%**	**-5.10**	**-73.5%**	**-119.08**

Notes: The table shows the difference in *total tax per capita* between actual and synthetic control country. The synthetic control countries serve as base value and percentage differences are calculated accordingly. Treatment starts in T=1: Vietnam (1989). Sudan (1999), Equatorial Guinea (1993), Chad (1992), East Timor (2004)

3.8 Conclusion

This chapter uses a novel methodology to shed light on the question whether natural resources crowd out non-resource tax revenues. The synthetic control method (SCM) confirms the existence of a crowding-out effect and further provides evidence about country characteristics that determine this effect. The average treatment effect shows that the 2000s commodity price boom decreased *total tax p.c.* in resource exporting countries by around 11% compared to a scenario without a price boom. This is roughly a US$ 300 lower tax burden per capita.

Apart from the negative average treatment effect, the SCM also shows that the effect differs according to resource type, institutional quality, government preferences in terms of tax instruments, and resource dependency. The crowding-out effect could only be found in oil exporting countries but not in mineral and precious mineral exporting countries. Furthermore, the crowding-out effect was only observed in high oil dependent countries with autocratic institutions and a preference of extracting funds from the oil sector through tax instruments.

The crowding-out effect should be a concern for policy makers for several reasons. Lower taxes increase the dependency on resource revenues which is a volatile income stream impeding budget planning, non-fiscal objectives become more difficult to achieve, and positive externalities from taxes such as transparency and better governance are averted.

However, the analysis also shows that the crowding-out effect is not a necessary pathway for new oil producers. Five case studies for Vietnam, Sudan, East Timor, Equatorial Guinea and Chad show that only two out of the five countries suffer from lower taxes while the remaining countries averted the crowding-out effect and could even increase taxes after they started to produce oil.

One caveat regarding the analysis should be mentioned here. SCM can only accompany one treatment or commodity boom, which raises an issue regarding the assumption that the treatment is the same in each treatment country. Some countries extract more than one resource, for example Azerbaijan extracts apart from oil also iron ore, copper and gold. Therefore, Azerbaijan faced two income shocks from 1999 onwards (oil and gold) and another two from 2004 onwards (iron ore and copper). Countries are identified by the main commodity they produce, and this resource should be the main contributor to any observed effect. However, it is difficult to assign the whole effect to one particular resource.

Future research could disentangle the tax data even further and analyse the effect on different tax types, e.g. income, VAT, property, direct, indirect, individual or company tax. This is of particular interest because it can shed light into the behaviour of governments in resource rich countries. The burden of different taxes is carried by different parts of the population. Lower property tax, for example, benefits the elite while sales tax or VAT is burdened by the entire population and proportionally affects more the poor.

Chapter 4

Wasted windfalls: Inefficiencies in health care spending in oil rich countries

4.1 Introduction

Oil rich countries often underperform in economic and social development.[1] For example, Gabon, an oil rich upper middle-income country reached merely 64.5 years in terms of life expectancy in 2013. This is 7.5 years below the average life expectancy in upper-middle income countries in the same year. The discrepancy of Gabon is not an exceptional case for oil rich countries. The mediocre performance is also true in Angola (11 years), Chad (7 years), Trinidad and Tobago (7 years) and Saudi Arabia (4 years). This chapter explores one possible reason, namely that funds spend on health care are disproportionally wasted in countries with high oil revenues.

The literature about natural resources usually focuses on the effect of oil on economic growth. For a decade or two the common wisdom was that natural resources impede economic growth (Isham, 2005; Sachs and Warner, 2001). Those findings have been challenged lately (Brunnschweiler and Bulte, 2008; Brunnschweiler, 2008; Cotet and Tsui, 2013b). A smaller, but still essential literature is connecting natural resources with social development and analyses the effect of natural resources on non-monetary well-being indicators, such as education or health outcomes (e.g. Arezki and Gylfason (2013); Blanco and Grier (2012); Carmignani (2013); Cotet and Tsui (2013b); Edwards (2016); Gylfason (2001)).

This chapter contributes to the literature connecting oil with social development by

[1] For an overview of this literature see Frankel (2010); van der Ploeg (2011); Ross (1999, 2015)

estimating the effect of oil rents on inefficiency in the health care sector. Using stochastic frontier analysis (SFA), I construct health production functions for 119 countries for the period 2000-2015 and test whether oil rents are a determinant of inefficiency in the health care sector. SFA estimates a frontier representing the maximum potential outcome a country could have achieved in terms of health output (life expectancy at birth) and compares it with the actual health output, the difference is defined as inefficiency. I find that oil rich countries have on average a lower level of efficiency than oil poor countries and that oil is a significant determinant of this inefficiency partially explaining the underperformance of oil rich countries while controlling for income. For example, Gabon has a technical efficiency estimate of 0.82 and by eradicating inefficiency Gabon could increase life expectancy by 11 years, outperforming the average upper-middle income country by about 3.5 years.

The empirical literature finds mostly a negative effect of natural resources on health outcomes. Edwards (2016) analyses the impact of mining on health and education outcomes in up to 157 countries by instrumenting the size of the mining sector with the geological variation in a country's resource endowment and controlling for income, geography and institutions. He finds a negative effect of the mining sector on life expectancy and infant mortality. His results show that doubling the mining share of an economy increases infant mortality on average by 20% and reduces life expectancy by about 5%. Carmignani and Avom (2010) find a statistically significant negative effect of resource intensity on social development in a sample of 87 countries for the period 1975-2005. Social development is defined as an aggregate measure of life expectancy, immunization rate and average year of schooling. Resource intensity is defined as 'primary commodity exports as percentage of total merchandise exports'. They use the instrumental variable approach and dynamic panel estimators to confirm their hypothesis that primary commodities are negatively correlated with social development. They further provide evidence that the negative effect is due to inequality and macroeconomic volatility. Bulte et al. (2005) find an indirect connection between point-source resources and development indicators. The connection in their model is through institutional quality and they show that point-source resources negatively affect institutional quality which in turn reduces social development indicators such as the Human Development Index, undernourished population share, water access, and life expectancy. Daniele (2011) analyses the relation between resource dependence/abundance and social development (Human development index and child mortality). He finds a negative correlation between resource dependence and social development but finds a positive correlation for his resource abundance measure. The findings are robust particularly in countries with low levels of institutional quality.

There is also evidence that points in the opposite direction. Cotet and Tsui (2013b) find a positive effect of oil on health. Exploiting the timing of oil discoveries and cross-country variation in the size of initial oil endowments they find that oil increases life expectancy and decreases infant mortality in the long run. They also find that the effect is stronger in non-democratic countries.

I depart from the existing literature in several ways. First, I use stochastic frontier analysis (SFA) and to the best of my knowledge this is the first study including oil rents as an inefficiency determinant in SFA. The empirical techniques used in the literature all assume that countries produce efficiently completely ignoring inefficiency. That inefficiency is present in the health care sector is well established (Greene, 2005a; Grigoli and Kapsoli, 2013; Kapsoli and Teodoru, 2017; Ogloblin, 2011). Further, SFA uses inputs -public/private health care expenditure and education- to estimate the production function, apart from education the empirical literature does not control for government preferences in the form of health care expenditure. Second, I exploit exogenous variation in oil rents due to fluctuations in the international oil price to establish causality. Third, I conduct a heterogeneity analysis and test whether the effect is different across institutional quality, sex and age. The latter two dimensions represent new results.

The identification strategy is similar to Smith (2016) and relies on the stochastic, often unpredictable nature of price changes. I compare oil rents in boom, bust and valley years. Boom years are defined as years in which the international oil price increases by at least 10% compared to the previous year and in bust years the oil price decreases by at least 10%. Valley years are years with less than +/- 10% price fluctuation and serve as comparison unit. The plausible exogenous variation of the international oil price can be exploited to analyse unexpected changes in oil income in a country. A decrease in oil income should force the government to save which in turn should increase inefficiency. Hence, a causal relation should show up as greater inefficiency in bust years compared to valley years. The effect in boom years is more ambiguous. An increase in the international oil price should increase the state budget and increase funds available for the health care sector. More investment should improve life expectancy but the effect on inefficiency could go either way, depending on investment quality. Inefficiency could decrease if the additional funds are invested efficiently but inefficiency could also increase if the additional funds are spent in a wasteful or corrupt manner. Identification strategy and methodology are discussed in section 4.2 and 4.3.

The results indicate that oil is a significant determinant of inefficiency and explains aside from other factors why life expectancy is lower in oil rich countries compared to oil poor countries. For example, the average technical efficiency estimate of oil rich high-income countries is 0.94 compared to 0.97 in oil poor countries in the same income group. The potential gains in life expectancy from eradicating inefficiency in oil rich high-income countries would be 5 years compared to only 2 years in oil poor high-income countries. The boom-bust-valley year analysis shows that the effect is causal for the full sample running from oil rents to inefficiency. The effect is also heterogeneous and stronger in democratic countries compared to intermediate and autocratic countries and causality could only be established in the democratic sub-sample, but not in the intermediate and autocratic sub-sample. Further, the results are heterogeneous across sex and age. Women's health is more affected by oil than men's and children suffer more than adults.

The results are robust to the exclusion of potential oil price setters, time lags and different definitions of price shocks. The robustness checks are discussed in section 4.6.

Transparency and inequality are identified as potential channels through which oil rents affect inefficiency in the health care sector. Oil rents incentivize the government to be less transparent, so it is easier to use them for their own purposes, such as patronage spending or stealing (Ross, 2011; Williams, 2011). Lower transparency increases the possibilities for officials to enrich themselves and spend the money with their own aims in mind contributing to inefficiency. Inequality persists in oil rich countries because oil is a point-source resource from which the elite benefits disproportionally more relative to the rest of the population (Karl, 2007). Inequality impedes poor people from accessing health care facilities and promotes the misallocation of funds contributing to inefficiency (Ogloblin, 2011). My analysis confirms that lower transparency and higher inequality lead to higher inefficiency in the health care sector in democratic countries. The two mechanisms are tested and discussed in section 4.7.

The chapter contributes to the literature about the resource curse, social development and health care spending efficiency. Health represents human capital itself and is also an input to produce other forms of human capital (Bleakley, 2010). Human capital contributes to economic growth and an inefficient health care sector triggered by oil could reduce human capital accumulation. Therefore, the analysis shows a way how natural capital in the form of oil reduces human capital and in turn could slow down economic growth. Further, the chapter contributes to the literature concerned with the determinants of social development. The SFA analyses how a non-monetary well-being indicator −life expectancy− is affected by oil. Finally, the chapter contributes to the literature concerned with efficiency in the health care sector. Health care expenditure contributes between 9-10% to world GDP representing a significant part in most economies (Ortiz-Ospina and Roser, 2018). Therefore, the scarce resources should be used in the most efficient way possible, because waste in this sector does not only affect economic indicators but everyone's life directly.

The chapter proceeds as follows: Section 4.2 outlines the identification strategy used to test for a causal relationship between oil and inefficiency in the health care sector. Section 4.3 explains the stochastic frontier approach and section 4.4 describes data and descriptive statistics. Section 4.5 and 4.6 presents results and robustness checks. Section 4.7 discusses possible mechanisms and section 4.8 concludes.

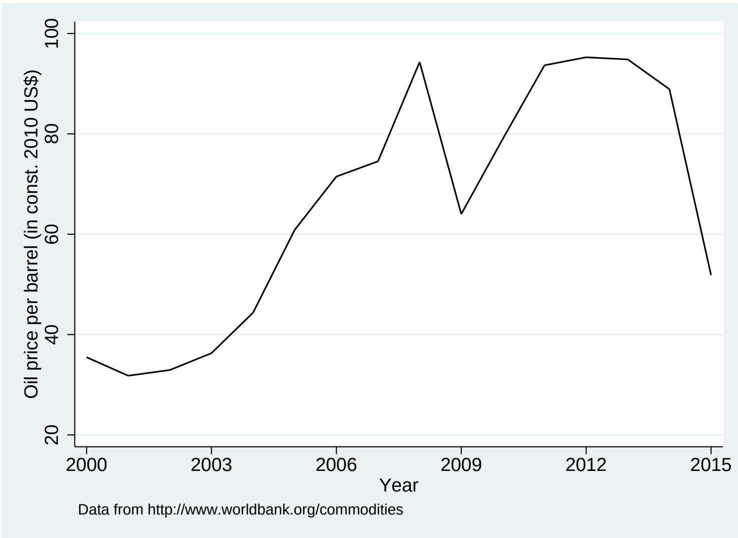
4.2 Identification Strategy

Identifying causality in an analysis concerned with natural resources is a major challenge. It can be argued that any dependent variable could cause a change in oil production or exploration efforts and is therefore vulnerable to reverse causality. For example, an inefficient health care sector could be the reason to extract more resources to generate more funds which in turn could be invested into the health care sector to improve life expectancy through higher investments or efficiency improving investments.

To establish a causal relation running from oil rents to health care inefficiency it would be necessary to exploit exogenous variation in oil income. Several strategies have been proposed in the literature ranging from the timing of giant resource discoveries (Arezki et al., 2017; Bhattacharyya et al., 2017; Cotet and Tsui, 2013a) over instrumenting past reserves (Edwards, 2016) or price fluctuations due to natural disasters (Ramsay, 2011) to price shocks (Smith, 2016). This chapter follows a strategy similar to Smith (2016) exploiting price shocks during the 2000-2015 period. This period offers a wide range of oil price changes which are plausibly exogenous. To define the price shocks as exogenous it is necessary to establish that the shocks are orthogonal to country's characteristics, i.e. the oil producers did not influence the oil price shocks and did not anticipate it (Liou and Musgrave, 2014).

From the beginning of the 2000s until 2008 the international oil price increased by 165% (see figure 4.1). The reasons for this boom are still discussed in the literature. The main arguments include an increase in demand for oil driven by economic growth in China (Hamilton, 2009), low interest rates set by the Federal Reserve resulting in depreciation of the US$ (Carter et al., 2011; Frankel, 2008), and speculative investment (Masters, 2008). In 2009 the oil price plummeted by 32% due to the Great Recession but consistent high demand from China and low interest rates set by the Federal Reserves helped the oil price to recover quickly. After the recovery the oil price stayed at an elevated level till 2013 and between 2013 and 2015 a decrease of the oil price by 45% occurred which is associated with a decline in world economic growth and to a lesser extent to the shale oil revolution in the US (Prest, 2018).

Figure 4.1: Oil price 2000-2015



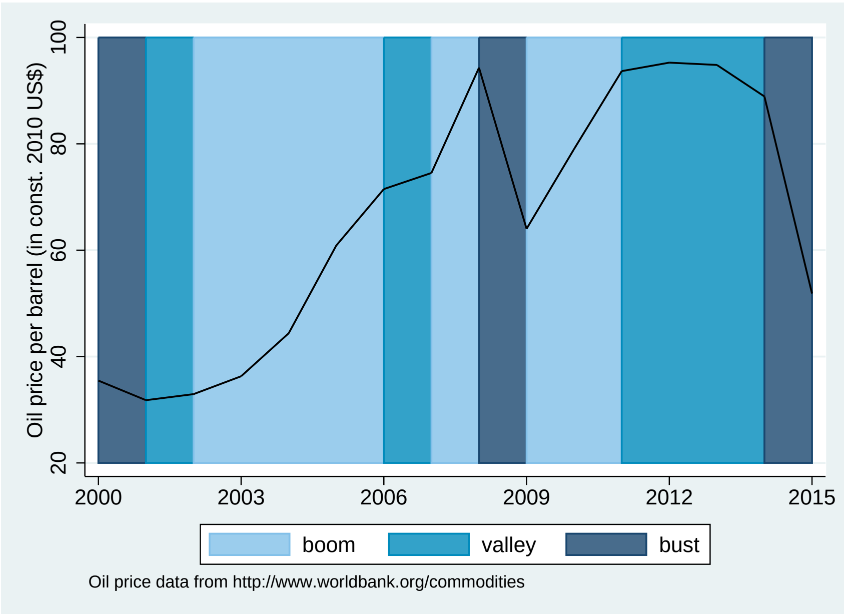
Oil producing countries can influence the international oil price only through the supply side. Except for the shale oil revolution in the US, the reasons mentioned in the literature explaining the oil price fluctuation happened on the demand side. This makes the price fluctuations for this period plausible exogenous for oil producers.

The only country traditionally associated with enough market power to influence the international oil price is Saudi Arabia (Fattouh and Mahadeva, 2013). Saudi Arabia played for a long time the role of a swing producer to stabilize oil prices. However, in recent years through the shale oil revolution the new big player in the oil market is the USA (Morse, 2018). Saudi Arabia makes its decisions within OPEC and the USA can influence the oil price through shale oil production and its own interest rate. Therefore, both countries could have influenced the oil price between 2000 and 2015. To ensure that Saudi Arabia, the USA and OPEC do not drive the results by influencing the oil price I run robustness checks excluding those countries individually and combined and the results do not alter (robustness checks are shown section 4.6).

The remaining oil producing countries in the sample do not have large enough market shares to influence the oil price and cannot anticipate the shocks[2] making the price fluctuations between 2000 and 2015 plausibly exogenous for them.

To exploit the price fluctuations, I define boom and bust years as years in which the oil price increased or decreased by more than 10% respectively compared to the previous year. The remaining years with fluctuation less than 10% are defined as valley years and serve as comparison group. Figure 4.2 shows the oil price from 2000 to 2015 and indicates the boom, bust and valley years for the sample period.

Figure 4.2: Boom, bust and valley years



The strategy of this chapter is to exploit price fluctuations of the international oil price as exogenous shocks in oil income. Overall, the oil rents coefficients in boom, bust and valley years are expected to be positive and significant, i.e. inefficiency is greater in oil producing countries. Further, a significant difference in the size of the effect in boom and bust years compared to the effect in valley years would imply that changes in oil rents influence inefficiency. If the difference between boom, bust and valley years is according to expectation, then it can be concluded that causality runs from oil rents to inefficiency and not the other way around. The expected changes in boom and bust years will be discussed below.

The effect in boom years is expected to be ambiguous, i.e. inefficiency could increase or decrease due to an increase in oil income. This is because in boom years oil income should

[2]See chapter 3 of this thesis for a discussion about oil price anticipation.

increase the state budget and the extra funds can be invested in the health care sector. This should increase the performance in terms of life expectancy by shifting the production function outwards. However, the effect on inefficiency −distance between actual outcome and production function− depends on the quality of the investment. Hiring an additional doctor or a nurse should decrease inefficiency if the doctor or nurse is needed in the hospital. If the doctor or nurse is not needed and the motivation for hiring was to reduce unemployment then the additional doctor or nurse will not improve the performance of a hospital and could increase inefficiency. Similarly, building a new hospital should increase access to health care, increasing life expectancy and decrease inefficiency. However, if the hospital is built in a special location to favour a certain group and gain political support then the impact on efficiency is not clear and depends on the location's initial hospital endowment. It could be that this location already has enough hospitals and it would have been more efficient to build it somewhere else.

The effect in bust years should be unambiguous, showing an inefficiency increase compared to the effect in valley years and is used in this chapter as the base to establish causality. The unexpected decrease in the international oil price should reduce funds available for investments and should lead to austerity. Austerity comes with an increase in inefficiency, especially in the health care sector. First, unfinished projects which only contributed so far to costs −but benefits have not been harvested yet− are usually the first to be cancelled. Second, necessary updates −like investments in new medical machinery− will be delayed making it necessary to use already out-dated and therefore inefficient machinery for longer. Third, saving in health care personal usually affects first support workers, nurses and junior doctors in that order. Especially nurses and support workers serve complimentary for senior doctors to perform efficiently. Therefore, a decrease in the oil price (bust year) should increase inefficiency.

The exception could be that in bust years unprofitable investments are shut down first which could overall increase efficiency. However, this is unlikely because if an inefficient project started it is likely that the motivation behind it was not purely driven by a social cost-benefit argument but rather by the incentive of personal gains such as in 'white elephant' projects[3] to gain political support (Robinson and Torvik, 2005). Shutting down these projects first would be the same as admitting by the politician that the project was unproductive in the first place and would harm the politician's reputation. To avoid the bad reputation the politician is incentivised to shut down efficient projects before shutting

[3] White elephants are investments with negative social surplus and can be used by politicians to gain political support in the form of patronage (Robinson and Torvik, 2005).

down his/her 'own inefficient projects'.

It could also be argued that spending cuts generate more value per dollar with improvements in terms of efficiency. However, the effect on inefficiency depends on the comparison group and timing. First, even if the value per dollar increases the counterfactual could still be an even greater increase in value per dollar. Second, the potential benefits of spending cuts in term of health outcome or inefficiency usually take time to develop. In the short-run, it is even more likely that inefficiency increases because personal needs time to adjust to the new situation.

Summarizing the identification strategy: fluctuation in the international oil price should increase/decrease oil rents. The effect of oil rents on inefficiency in valley years is used as the baseline effect showing the basic level of inefficiency due to oil. Changes in this baseline effect, i.e. different coefficients in boom and bust years, can be attributed to an increase/decrease in oil price and therefore interpreted as a causal relationship running from oil rents to inefficiency in the health care sector. Because the effect on inefficiency is ambiguous in boom years, the analysis focuses on the difference of the effect between bust and valley years. A confirmation for causality running from oil rents to inefficiency would show up as significant greater inefficiency in bust years compared to valley years.

4.3 Methodology

In this section, I explain the conceptual framework of efficiency analysis followed by a detailed explanation of the stochastic frontier methodology used to estimate the impact of oil on inefficiency in the health care sector. I start by explaining basic concepts relevant to efficiency analysis.

Production is simply defined as the process transferring inputs into outputs. In this context, inefficiency can be defined in two ways, first as output-oriented and second as input-oriented inefficiency. A production process is efficient if the highest possible output is achieved with given inputs (output-oriented), or that a given output cannot be achieved with fewer inputs (input-oriented) (Kumbhakar et al., 2015). The focus in this chapter is on output-oriented inefficiency for two reasons. First, the budget allocated to the health care sector is usually fixed for a certain period, hence the health care sector produces outputs with given inputs. Second, the output −life expectancy− is supposedly to be maximised and not set to a given level.

Inefficiency in this chapter always refers to technical inefficiency. Contrary to allocative inefficiency, technical inefficiency is only concerned with the fact that given inputs are fully utilized given current technology. Allocative inefficiency would also be concerned with the possible combinations of inputs used to produce the output. However, to estimate allocative inefficiency it would be necessary to use a cost minimization or profit maximization approach, both would need information about the quantity and price of each input (Kumbhakar et al., 2015). Such detailed data is not available and therefore only technical inefficiency is considered.

The methodologies used to estimate technical efficiency can be categorized into parametric and non-parametric approaches. Both have advantages and disadvantages. Parametric approaches for example require several assumptions on the distribution of the error term and the functional form of the model. However, one advantage of parametric approaches is that they assume a stochastic relation between inputs and outputs which allows to separate inefficiency from measurement errors and noise in the data. The most often used parametric method is the stochastic frontier model (Kapsoli and Teodoru, 2017).

Non-parametric methods, on the other side, do not require assumptions about the shape and form of the inefficiency term because they are based on mathematical programming. However, this advantage of non-parametric methods creates also disadvantages because they do not account for randomness in the data. Each observation is assumed to provide information which ignores measurement errors and noise in the data and makes the approach sensitive to outliers (Grigoli and Kapsoli, 2013). Further, it is difficult to estimate unbiased coefficients for the determinants of inefficiency.

To estimate the impact of oil on inefficiency in the health care sector I use a dataset covering 119 countries. The countries are potentially heterogeneous in several ways and the data could include measurement errors and perhaps outliers. Those reasons are already enough to opt for a parametric approach in the form of stochastic frontier analysis, however, considering that the main aim of this chapter is to determine whether oil is a determinant of inefficiency and the non-parametric approaches do not provide a convincing strategy to measure unbiased estimators it becomes necessary to use stochastic frontier analysis in this setting.

The Stochastic Frontier Model

The idea of stochastic frontier analysis (SFA) was initially developed in the seminal papers from Aigner et al. (1977) and Meeusen and van den Broeck (1977). The basic idea consists of estimating an OLS and split the error term into a noise term and an inefficiency term, such that the model to be estimated is of the following form:

$$y_i = \alpha + x_i'\beta + \epsilon_i, \quad i = 1, \ldots, N \tag{4.1}$$

$$\epsilon_i = v_i - u_i \tag{4.2}$$

$$v_i \sim \mathcal{N}(0, \sigma_v^2) \tag{4.3}$$

$$u_i \sim \mathcal{F}(\mu_i, \sigma_u^2) \tag{4.4}$$

where y_i represents the logarithm of the output and x_i is a vector of inputs in country i. β is the vector of technology parameters showing the impact of an input on the output. The composed error term, ϵ_i, consists of a random component, v_i, representing measurement and specification errors, and a one-sided disturbance component, u_i, representing inefficiency. The distribution of the random component, v_i, is assumed to follow a normal distribution with zero mean and variance σ_v^2. The distribution of the one-sided disturbance component, u_i, must be assumed to make the model estimable. The most common assumptions about the distribution of u_i is the half-normal ($u_i \sim \mathcal{N}^+(0, \sigma_u^2)$), exponential ($u_i \sim \mathcal{E}(\sigma_u)$), gamma ($u_i \sim \mathcal{G}(\Theta, P)$) and truncated-normal ($u_i \sim \mathcal{N}^+(\mu_i, \sigma_u^2)$).

Since Aigner et al. (1977) and Meeusen and van den Broeck (1977) many new models were developed with more desirable characteristics (e.g. Greene (2005b); Schmidt and Sickles (1984); Stevenson (1980); Battese and Coelli (1988); Cornwell et al. (1990); Pitt and Lee (1981); Battese and Coelli (1992, 1995); Kumbhakar (1990); Belotti et al. (2013)). One of the main improvements was the introduction of panel data in SFA. Cross-sectional data allow to estimate the performance of each country at one point in time, while panel data allow to estimate the pattern of inefficiency over time. This is important because there is no reason to believe that inefficiency in the health care sector is constant over time. Further, panel data allow to separate country specific effects that are not related to inefficiency (Battese and Coelli, 1995).

The model chosen in this chapter is from Battese and Coelli (1995). It allows us to use panel data estimating time variant inefficiency and it also includes the possibility to estimate inefficiency determinants, which is of special interest for this chapter because the main question is whether oil rents influence inefficiency in the health care sector. The model is of the following form:

$$y_{it} = \alpha + x'_{it}\beta + \epsilon_{it}, \quad i = 1, \ldots, N, \; t = 1, \ldots, T_i \tag{4.5}$$

$$\epsilon_{it} = v_{it} - u_{it} \tag{4.6}$$

$$v_{it} \sim \mathcal{N}(0, \sigma_v^2) \tag{4.7}$$

$$u_{it} \sim \mathcal{F}(\mu_{it}, \sigma_u^2) \tag{4.8}$$

where everything is defined in the same way as in equation 4.1 - 4.4 except for the subscript t indicating that the observations are now for country i in year t. Including the time dimension and comparing the same country over time allows to estimate time variant inefficiency. Further, Battese and Coelli (1995) show that equations 4.5 - 4.8 allow to define the mean of the inefficiency distribution, μ_{it}, as a function of explanatory variables. This allows to estimate the production function and the inefficiency determinants simultaneously.

Battese and Coelli (1995) define u_{it} as:

$$u_{it} = z'_{it}\delta + w_{it} \tag{4.9}$$

where z'_{it} is a vector of inefficiency determinants and δ are the parameters to be estimated. Thus, δ shows how a variable of the z-vector influences the inefficiency term. w_{it} is a random variable defining the truncation of the normal distribution with zero mean and variance, σ^2. w_{it} is set such that the point of truncation is $-z'_{it}\delta$. Therefore, u_{it} has the following distribution: $\mathcal{N}^+(z'_{it}, \sigma_u^2)$, i.e. a non-negative truncated normal distribution with mean $z'_{it}\delta$ and variance σ_u^2.

Equations 4.5 - 4.9 can be estimated with maximum likelihood (Battese and Coelli, 1995) and technical efficiency in country i in year t is defined by equation 4.10:

$$TE_{it} = exp(-u_{it}) = exp(-z_{it}\delta - w_{it}) \tag{4.10}$$

One shortcoming of the Battese and Coelli (1995) model is that the intercept α is the same across countries leading to a potential misspecification bias in the presence of time-invariant unobservable factors, which are unrelated to the production process but affect the output. The time-invariant effect of these factors may be falsely included in the inefficiency term leading to biased results (Greene, 2004). Greene (2005b) developed the 'true fixed effects' model to deal with the potential problem of time-invariant unobservable heterogeneity. The main difference to Battese and Coelli (1995) is that the intercept α in equation 4.5 becomes α_i, a unit specific intercept. The two models represent two extremes, while Battese and Coelli (1995) include all time-invariant unobserved country differences in the inefficiency term, Greene (2005b) excludes all of them from the inefficiency term. How much of the unobserved country differences should be part of the inefficiency term is debatable and the truth would most likely lie between the two extremes (Greene, 2005c). Hence, the best approach would be to estimate both models and see them as upper and lower bound estimates of the true values. However, my attempt to estimate Greene (2005b) 'true fixed effects' model failed as the regression did not converge. Therefore, I admit the shortcoming of Battese and Coelli (1995) that all time-invariant unobserved heterogeneity is included in the inefficiency term and try to mitigate this issue by including income dummies in the production function to group countries which are more similar than others together which should reduce the problem to a certain extend.

Production function of health (y and x variables)

The outcome variable (y_{it}) is the natural logarithm of *life expectancy at birth* indicating the number of years a newborn infant would live if prevailing patterns of mortality at the time of birth were to stay the same (The World Bank, 2018b).

The following variables are included in the production function as inputs (x):

Publ. exp. Public health care expenditure per capita in international purchasing power parity (PPP) dollars.

Priv. exp. Private health care expenditure per capita in international purchasing power parity (PPP) dollars.

Schooling Mean years of education of the population over 25.

All input variables are converted to their natural logarithm. *Public* and *private expenditure* are the monetary resources a country allocates to the health care sector to pay for doctors, nurses, medicines and medical equipment. The impact on the output should therefore be self-explanatory. Higher spending −public or private− should be positively correlated with *life expectancy*. The monetary values are measured in international purchasing power parity dollars to make them comparable across countries. Note, *public* and *private health expenditure* refer to mandatory and voluntary contributions to the health care sector respectively (OECD/WHO, 2014). Hence, the variables do not measure the performance of private or public health care facilities such as private or public hospitals.[4]

There is also consensus in the literature that educational attainment is an input in the production function of health (Evans et al., 2000; Greene, 2005b; Ogloblin, 2011). *Schooling* is positively correlated with *life expectancy* and is likely to be a causal factor in the production of health. Better educated people tend to have healthier life-styles with more exercise, better diet, use of preventive care and a better understanding of medical treatments. Following Evans et al. (2000) and Greene (2005b), a square term of *schooling* is also included in the production function to account for the diminishing effect of education.

A critical point with SFA is that a form of homogeneity in the production function is assumed. The homogeneity assumption is that countries produce with the same technology (Kumbhakar et al., 2015). This creates an issue in an analysis pooling potentially heterogenous countries together. It is likely that low-income countries use different or out-dated technology compared to high-income countries. To control for this issue, income dummies for low-, lower middle-, upper middle- and high-income countries are included in the production function in all regressions.[5] Countries are categorised according to World Bank income categories. The inclusion of the income dummies allows to estimate a production function for each income group and compares therefore only countries with similar income level. The same level of income should reduce the heterogeneity of technology used in the health care sector between countries.

Finally, to control for technological change over time, time dummies are included for each year in the production function in all specifications (Greene, 2004).

Determinants of inefficiency (z-variables)

The inefficiency determinants or z-variables included in equation 4.9 are the *log of GDP per capita* and *oil rents*.

The literature shows that *GDP per capita* is a significant determinant of *life expectancy* (Edwards, 2016), however, it cannot be included in the production function because it does not represent a health input (Greene, 2005a). On its own *GDP per capita* does not make people healthier (Ogloblin, 2011). The impact of *GDP per capita* on *life expectancy* goes through channels, such as higher spending on health, which is already controlled for in the form of *private* and *public expenditure* or higher educational attainment, which is also controlled for in the *schooling* variable. Apart from *health expenditure* and *schooling*,

[4]See section 4.4 for a detailed definition of the expenditure variables.

[5]To avoid multicollinearity the low-income dummy was dropped and represents the base category.

GDP per capita also influences the access to goods and services that enhance health and therefore *life expectancy*, such as nutrition or proxies for general working conditions in the country that can have an effect on health outcomes (Ogloblin, 2011). The fact that the impact of oil on income is still debated in the literature also contributed to the decision to include *GDP per capita* as a z-variable. Assuming that both sides of the resource curse literature are partly correct and oil increases income in some countries and decreases it in others, then any effect of *oil rents* on inefficiency could be cancelled out resulting in insignificant results. As long as there is no agreement about the relation between oil and income I control for it in all specifications. Therefore, the estimates represent the impact of *oil rents* on inefficiency aside from any effect *oil rents* have on income.

Finally, the variable of interest in this chapter is *oil rents* and measures oil revenues minus the costs of oil extraction as percentage of GDP and is derived from the World Development Indicators.

4.4 Sample, data and descriptive statistics

The data are primarily retrieved from the World Health Organization (WHO) and World Bank databases. Analysis was restricted to 119 countries for which all data are available for the whole period 2000 to 2015. Hence, I am using a balanced dataset. A list of all countries in the sample is provided in appendix C table C 1. Table **??** shows descriptive statistics of the variables used in the stochastic frontier analysis and for an overview of definitions and sources see table C 2 in appendix C.

Life expectancy at birth is from the World Development Indicators and measures the years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same (The World Bank, 2018b). *Life expectancy* varies widely in the sample from 39 years in Sierra Leone to 83 years in Italy with a mean of 68 years.

Public and *private health expenditure* data are from WHO and the basic differentiation between the two follows the rule whether payments or contributions are compulsory or not (OECD/WHO, 2014). Therefore, *public* and *private health expenditure* does not measure who provides the health service (e.g. a private or a public hospital), rather they measure how the money is raised (in a mandatory or voluntary scheme). *Public health expenditure* includes transfers from government domestic revenues, social insurance contribution, compulsory prepayment other than social contribution (variable FS1, FS3 and FS4 in the SHA2011 framework). *Private health expenditure* includes voluntary prepayments and other domestic revenues (FS5 and FS6 in the SHA2011 framework).[6] Transfers from government domestic revenues (FS1) are the funds from the state budget allocated to the health care sector and includes income from the oil sector.

Public health expenditure per capita varies widely between countries. The smallest public contribution to health expenditure occurs in the Democratic Republic of the Congo with a small $0.58 per capita in 2000, while Luxembourg provides a staggering $5290 in *public health expenditure per capita* in 2009.[7] Private contributions are highest in the United States with $4350 in 2015, which is almost three times as high as the second highest private contribution made to the health care sector of $1630 per capita in Singapore in the same year.

Table 4.1: Descriptive statistics

	N	**Mean**	**St.d.**	**Min**	**Max**
Life expectancy	1904	67.66	9.24	38.70	83.09
Public health exp. p.c.	1904	518.10	848.03	0.58	5,290.82
Private health exp. p.c.	1904	291.52	429.52	3.35	4,355.71
Schooling in years	1904	7.29	3.10	1.10	13.30
Income group	1904	2.55	1.03	1	4
Democracy	1808	1.63	0.79	1	3
GDP per capita	1904	14,903.33	20,479.60	503.83	129,349.92
Oil rent (% of GDP)	1904	5.32	11.15	0.00	60.78

The average years of education of the population over 25 is around 7 years. Income groups are defined according to World Bank income groups. The maximum value of *oil rents* occurs in Kuwait in 2011.

Mehlum et al. (2006) argue that the resource curse is conditional on institutional quality and that any adverse effect should be greater or more pronounced in non-democratic countries. To exploit this potential source of heterogeneity I categorized countries according to the Polity2 index which measures the level of democracy on a 21 point scale ranging from -10 to +10 with -10 indicating a fully autocratic country and +10 a fully democratic country (Marshall and Jaggers, 2014). The countries in the sample are defined as democratic (Polity2: +4 to +10), intermediate (Polity2: -3 to +3) and autocratic (Polity2: -4 to -10) countries.[8]

Comparing the average values of *life expectancy*, *public* and *private health expenditure* between income groups shows significant differences (see table 4.2). The mean of each

[6]FS2 and FS7 are not included because they have foreign origins, e.g. bilateral or multilateral aid and poor data coverage.

[7]Monetary values are measured in purchasing power parity (constant 2010 international dollars).

[8]Table C 1 in appendix C lists all countries and the corresponding institutional category.

variable is significantly different from the mean of the other income groups and underlines the necessity to control for income in the production function. As discussed in section 4.3, lower income should also lead to cheaper or out-dated technology, which is usually less efficient. Hospitals with limited funds are more likely to acquire the out-dated cheap version of medical equipment than a hospital with more funds.

Table 4.2: Differences in life expectancy, public and private health expenditure by income group

Panel A: Life expectancy				
	Low income	Lower middle inc.	Upper middle inc.	High income
Low income	0			
	–			
Lower middle inc.	9.5	0		
	(0.000)	–		
Upper middle inc.	14.5	4.9	0	
	(0.000)	(0.000)	–	
High income	21.3	11.7	6.8	0
	(0.000)	(0.000)	(0.000)	–

Panel B: Public health expenditure				
	Low income	Lower middle inc.	Upper middle inc.	High income
Low income	0			
	–			
Lower middle inc.	79.86	0		
	(0.000)	–		
Upper middle inc.	331.14	251.27	0	
	(0.000)	(0.000)	–	
High income	1745.40	1665.53	1414.26	0
	(0.000)	(0.000)	(0.000)	–

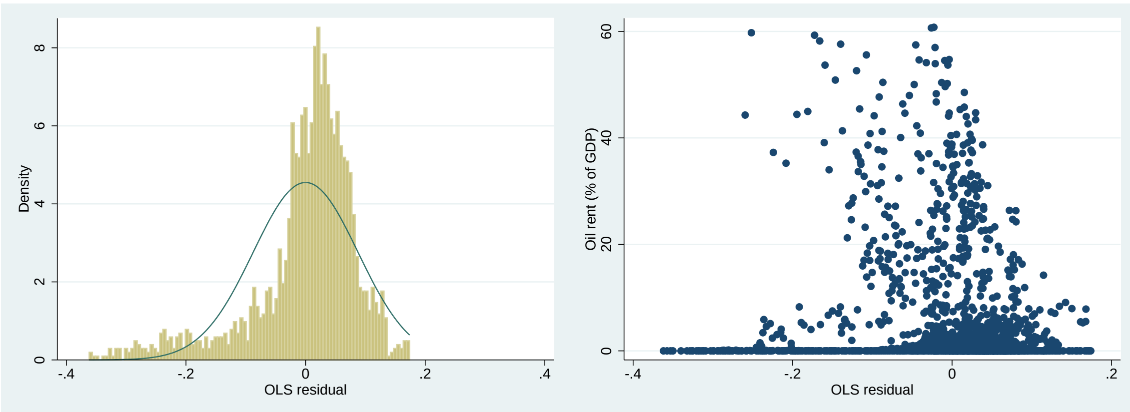
Panel C: Private health expenditure				
	Low income	Lower middle inc.	Upper middle inc.	High income
Low income	0			
	–			
Lower middle inc.	81.96	0		
	(0.000)	–		
Upper middle inc.	247.23	165.28	0	
	(0.000)	(0.000)	–	
High income	743.46	661.50	496.23	0
	(0.000)	(0.000)	(0.000)	–

Notes: The table shows the mean difference of *life expectancy*, *public* and *private health expenditure per capita* between income groups. P-values from Wald tests, testing for significant differences between the means, are shown in parenthesis.

Before discussing the results, I perform a test for the existence of inefficiency in the sample. By estimating the production function shown in equation 4.5 as a simple OLS without inefficiency term to test if the distribution of the residuals is skewed. Left skewness of the residual distribution indicates that inefficiency is present in the sample (Schmidt and Sickles, 1984). The left panel of figure 4.3 shows the distribution of the residuals compared to a normal distribution. The left skewness is visible in the figure and confirmed by a skewness test for normality following D'Agostino et al. (1990) (skewness: -1.443; p-value: 0.000).

The skewness so far only shows that inefficiency is present in the sample but says nothing about any determinants. A scatterplot of the residuals and *oil rents*, right panel of figure 4.3 indicates that the skewness of the residual distribution is at least partly related to the level of *oil rents* in an economy.

Figure 4.3: Residual distribution



4.5 Results

Oil rents and inefficiency in the health care sector

Before testing for the causal relationship between *oil rents* and inefficiency in the health care sector, I estimate the stochastic frontier with the plain *oil rents* variable to see if the production function coefficients are according to expectation.[9]

Column (1) in table 4.3 shows the baseline specification with all 119 countries and coefficients for the production function and mean inefficiency terms. The coefficients of the frontier function are in line with the literature.

[9]The *production function* part of the tables shows the coefficients for the x-variables and their impact on *life expectancy*. The *mean inefficiency* part shows the coefficients for the z-variables which measures the impact on inefficiency.

Table 4.3: SFA: Inefficiency in the health care sector

	(1)	(2)	(3) Democracy	(4) Intermediate	(5) Autocracy
Prod. function					
Constant	3.8***	3.8095***	3.8504***	3.7678***	3.6995***
	(0.0373)	(0.0378)	(0.037)	(0.0708)	(0.1177)
Public exp.	0.014***	0.014***	0.0238***	0.0201	−0.0042
	(0.0013)	(0.0013)	(0.002)	(0.0226)	(0.0058)
Private exp.	0.0157***	0.0162***	0.0048*	0.012	0.0048
	(0.002)	(0.002)	(0.0028)	(0.0361)	(0.0045)
Schooling	0.3103***	0.2989***	0.2583***	0.3236**	0.5996***
	(0.0372)	(0.0382)	(0.0434)	(0.1419)	(0.1232)
Schooling^2	−0.0681***	−0.0656***	−0.0558***	−0.0668*	−0.1494***
	(0.0088)	(0.009)	(0.0103)	(0.0369)	(0.031)
LM income	0.0212***	0.0223***	0.0264***	0.0193	0.0083
	(0.0062)	(0.0063)	(0.0077)	(0.0439)	(0.022)
UM income	0.0133	0.015*	0.0388***	−0.0163	0.0186
	(0.0079)	(0.0078)	(0.0098)	(0.084)	(0.0229)
High income	0.0302***	0.0314***	0.0409***	0.0226	0.0532**
	(0.0095)	(0.0092)	(0.0127)	(0.0724)	(0.0266)
Mean inefficiency					
Constant	1.5717***	1.6087***	2.5087***	1.2496***	1.9382***
	(0.1326)	(0.1575)	(0.5276)	(0.1746)	(0.1269)
Oil rents	0.0083***		0.0295***	0.0073***	0.0021*
	(0.0011)		(0.0098)	(0.0008)	(0.0012)
Low oil dep.		0.016			
		(0.0189)			
Medium oil dep.		0.1526***			
		(0.0339)			
High oil dep.		0.3291***			
		(0.0489)			
GDP p.c.	−0.2141***	−0.2192***	−0.3577***	−0.1613***	−0.2334***
	(0.0222)	(0.0254)	(0.0845)	(0.0291)	(0.0156)
Distribution					
σ^2	0.034***	0.0345***	0.0618***	0.0136*	0.0237***
	(0.0046)	(0.0046)	(0.0173)	(0.0079)	(0.0013)
λ	0.9952***	0.9953***	0.9996***	0.9811***	0.9997***
	(0.001)	(0.0009)	(0.0002)	(0.1044)	(0.0001)
LL	2591.366	2589.115	1525.359	535.1794	522.2409

Notes: Production functions include time dummies. Public, private health care expenditure, schooling, schooling^2 and GDP per capita are converted to their natural logarithm. Low, medium and high oil dependent are dummies for countries producing between 1-10%, 11-20% and more than 20% of *oil rents* as percentage of GDP, respectively. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Private and *public health expenditure* are positively correlated with *life expectancy.* A one percentage point increase in *public health expenditure* increases *life expectancy* by 0.014 percentage points. At the sample mean, a one percentage point increase in *public health expenditure* is equivalent to US$ 5 per capita and would increase *life expectancy* by 0.0095 years or around 3.5 days. *Private health expenditure* also has a positive correlation with *life expectancy.* The coefficient is slightly bigger compared to *public health expenditure.*

Educational attainment, *schooling*, shows a bigger effect than *health care expenditure.* The *schooling* coefficient of 0.3103 and -0.0681 of the square term indicate that an additional year of schooling at the sample mean of 7 years increases *life expectancy* by around 0.34% or 0.23 years (83 days). The maximum effect of *schooling* on *life expectancy* occurs at 10 years with 0.35% after which the effect slowly diminishes.

To interpret the income dummies, remember that low-income countries are the base category and therefore the positive significant coefficient of 0.0212 for lower middle-income countries indicates that *life expectancy* is 2.1% or 1.1 years higher in lower middle-income countries. Considering that the mean difference in *life expectancy* between low-income and lower middle-income countries is around 9.5 years it seems that 8.4 years are explained by differences in *private* and *public health care expenditure, schooling* and the z-variables (*oil rents* and *GDP per capita*). The upper middle-income dummy is insignificant on the other hand, which means that any difference in *life expectancy* is captured by the controlled variables. The high-income dummy shows a positive significant coefficient of 0.0302 indicating that *life expectancy* is around 3% or 1.7 years higher in high-income countries compared to low-income countries. Hence, 19.6 years of the difference in *life expectancy* between low- and high-income countries is explained by the control variables included in the specification.[10]

Now, I am turning to the determinants of inefficiency. In the Battese and Coelli (1995) model a positive coefficient of a z-variable indicates an inefficiency increasing effect while a negative coefficient is inefficiency decreasing.[11] The z-variables, *oil rents* and *GDP per capita* are both significant but point in opposite directions. The *oil rents* coefficient is positive indicating that more *oil rents* in an economy is positively correlated with ineffi-

[10]Mean difference in *life expectancy* between low-income and high-income countries is 21.3 years, see table 4.2.

[11]Note, to interpret the magnitude of a z-coefficient it is necessary to calculate the marginal effects which require the calculation of an adjustment term. The adjustment term or marginal effects are not part of the output in Frontier4.1, the software developed by Coelli (1996) and used in this chapter. Therefore, I am restricted here to interpret signs and compare coefficient size relative to each other. However, the adjustment term in this setting is always positive, because the z-variables are only included in the mean of u_{it} but not in the variance of u_{it} or v_{it} (Wang, 2002). Hence, the sign of the z-coefficients unambiguously indicates the direction of the effect.

ciency and explains partly why oil rich countries underperform in terms of *life expectancy*. The opposite is true for *GDP per capita* which seems to decrease inefficiency.

In column (2) of table 4.3, I test whether the correlation of *oil rents* and inefficiency is non-linear by introducing dummy variables for low, medium, and high oil dependent countries into the regression instead of *oil rents*.[12] The coefficient for low oil dependent countries is insignificant indicating that a low level of oil dependency does not necessarily affect inefficiency. Medium and high oil dependent countries on the other hand have highly significant coefficients, both positive indicating that more oil dependency leads to higher inefficiency with the coefficient for high oil dependent countries double the size of the coefficient for medium oil dependent countries. Hence, higher oil dependency increases inefficiency whereas at low levels there seems to be no effect. This is in line with other findings of the resource curse literature that oil can be beneficial in a more developed and diversified economy but can be harmful in a less developed and more concentrated economy (Ross, 2017).

Next, I split the sample according to institutional quality to exploit potential heterogeneity. Mehlum et al. (2006) argue that the resource curse is conditional on institutional quality and that any adverse effect should be greater in autocratic countries. The countries are defined as democratic, intermediate and autocratic countries according to Marshall and Jaggers (2014) Polity2 index as explained in section 3.4.

Columns (3)-(5) show the results for the democratic, intermediate and autocratic subsample respectively. Surprisingly, the results are inverse of what Mehlum et al. (2006) predicted. The inefficiency increasing effect of *oil rents* is around 4 and 14 times bigger in democracies as it is in intermediate and autocratic countries respectively. This result is perhaps surprising but not entirely new. Cotet and Tsui (2013b) also find that oil rich autocracies are better performing with respect to *life expectancy* than their democratic counterparts.

The results reported in table 4.3, so far confirm the hypothesis that there is a correlation between *oil rents* and inefficiency in the health care sector.

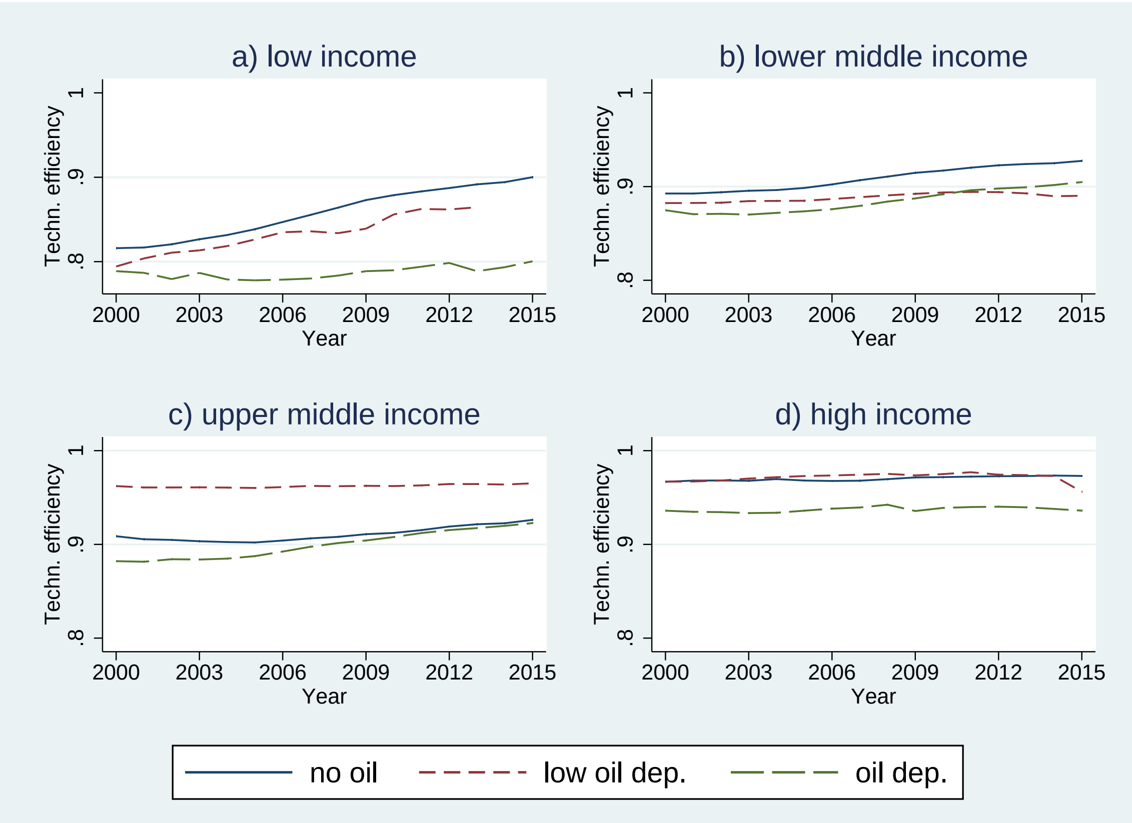
[12] Low oil dependent countries are defined as countries with *oil rents* between 1 and 10% of GDP, medium oil dependent countries produce *oil rents* between 11 and 20% of GDP and high oil dependent countries produce more than 20% of GDP in *oil rents*. The omitted category are countries with less than 1% *oil rents* in GDP.

Technical efficiency over time

Next, I analyse how efficiency developed over time. Note that the efficiency estimates in this section do not show the impact of *oil rents* alone. They also incorporate the effects of *GDP per capita* and the constant term. It is a way of showing by how much a country could improve *life expectancy* if it could eradicate inefficiency completely. To bring the oil dimension back into the analysis all the results are shown according to oil dependency.[13] The average efficiency estimates for each individual country are shown in table C 3 in appendix C.

Figure 4.4 shows average efficiency estimates by income group and oil dependency. The efficiency estimate can be interpreted as percentage term showing the actual performance of a country in terms of *life expectancy* as percentage of the maximum possible *life expectancy*.

Figure 4.4: Technical efficiency by income groups



Notes:'No oil' countries are defined as countries producing less than 1% of GDP in *oil rents* (blue line), 'low oil dependent' countries are countries with 1-10% *oil rents* of GDP (red line) and 'oil dependent' countries include all countries with *oil rents* more than 10% of GDP (green line).

[13]The oil dependency categories are: 'no oil' countries, defined as countries producing less than 1% of GDP in *oil rents*; 'low oil dependent' are countries with 1-10% *oil rents* of GDP; and 'oil dependent' countries include all countries with *oil rents* more than 10% of GDP.

In the low and lower middle-income group, 'no oil' countries have the highest efficiency score and 'low oil dependent' countries generally perform better than 'oil dependent' countries (Graph a) and b)). The sub-sample of upper middle-income countries shows that 'low oil' dependency can be beneficial with higher efficiency scores compared to 'no oil' and 'oil dependent' countries (Graph c)). In high-income countries 'no oil' and 'low oil dependent' countries are almost identical (Graph d)). The worst performing countries in the upper middle-income and high-income group are 'oil dependent' countries (Graph c) and d)).

The results previously derived from table 4.3 −*oil rents* increase inefficiency− seem to be driven by low- and high-income countries. To illustrate this, table 4.4 lists the mean efficiency score and *life expectancy* for each income group and compares them according to oil dependency. Potential gains in table 4.4 shows the number of years *life expectancy* would increase if inefficiency could be eradicated completely.

Table 4.4: Average efficiency, life expectancy and potential gains by income groups and oil dependency

		no oil	**low oil dep.**	**oil dep.**
Low income	efficiency	0.86	0.83	0.79
	life expectancy	56.22	54.50	49.45
	potential gain	9.32	10.96	13.38
LM income	efficiency	0.91	0.89	0.88
	life expectancy	66.60	64.59	62.72
	potential gain	6.68	8.11	8.20
UM income	efficiency	0.91	0.96	0.90
	life expectancy	69.20	73.04	67.88
	potential gain	6.77	2.86	7.57
High income	efficiency	0.97	0.97	0.94
	life expectancy	77.91	78.10	74.38
	potential gain	2.40	2.32	4.98

Notes: 'No oil' countries are defined as countries producing less than 1% of GDP in *oil rents*, 'low oil dependent' countries are countries with 1-10% *oil rents* of GDP and 'oil dependent' countries include all countries with *oil rents* more than 10% of GDP. Income groups are defined according to World Bank income groups.

Comparing 'no oil' countries with 'low oil dependent' countries there seems to be only minor differences in efficiency, *life expectancy* and potential gains in most income groups. The exception is the sub-sample of upper middle-income countries where 'low oil dependent' countries outperform 'no oil' countries and 'oil dependent' countries. Efficiency is as high as 96% in 'low oil dependent' upper middle-income countries, whereas it is only

91% and 90% in ‘no oil’ and ‘oil dependent’ countries, respectively.

‘Oil dependent’ countries underperform significantly in the sub-sample of low- and high-income countries. The potential gains of eradicating inefficiency in *life expectancy* amounts to 13 years in ‘oil dependent’ low-income countries which is two and five years more than in ‘no oil’ and ‘low oil dependent’ countries respectively. The gap is smaller in high-income countries, nevertheless, ‘oil dependent’ countries could still gain five years in terms of *life expectancy* compared to two years in ‘no oil’ and ‘low oil dependent’ countries.

Oil rents and inefficiency in boom and bust years

So far, the analysis used simply *oil rents* to establish the relationship between oil and inefficiency in the health care sector. This measure is easily marked as endogenous because an underperforming government could increase oil extraction and use the funds to close the gap and produce more efficiently in the health care sector. This would make inefficiency the reason for higher *oil rents* and not *oil rents* the reason for inefficiency.

Therefore, in this section I test for a causal relationship between *oil rents* and inefficiency in the health care sector by exploiting price fluctuations of the international oil price as exogenous income shocks. The *oil rents* variable is divided into boom, bust and valley years, whereas boom and bust years are defined as years in which the international oil price fluctuated by more than 10% compared to the previous year. The remaining years with fluctuation less than 10% are considered as valley years and serve as comparison group. The basic idea is that a significantly greater coefficient of the *oil rents* variable in bust years compared to the coefficient in valley years is an indication of causality from *oil rents* to inefficiency. See section 4.2 for a detailed discussion.

Table 4.5 shows the results with the *oil rents* variable divided into boom, bust and valley years. Overall, the coefficients for the production function are similar to those in table 4.3. Column (1) shows the result for the full sample, all three coefficients of the *oil rents* variable are positive and significant indicating that *oil rents* increase inefficiency in the health care sector in boom, bust and valley years. Comparing the *oil rents* coefficient in boom and valley years shows a smaller coefficient in boom years by around 9%. The difference between the two coefficients, however, is insignificant.[14]

[14] Any statement claiming a ‘significant’ difference between two coefficients have been tested with a Wald-test $\left(\sqrt{\frac{(A-B)^2}{var(A)+var(B)-2cov(A,B)}}\right)$.

Table 4.5: SFA: Inefficiency in boom, bust and valley years

Variable	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Production function				
Constant	3.8004***	3.8506***	3.8184***	3.5827***
	(0.0365)	(0.0363)	(0.0589)	(0.1066)
Public exp.	0.014***	0.0238***	0.0132	−0.0039
	(0.0013)	(0.0018)	(0.0089)	(0.0039)
Private exp.	0.0157***	0.0048	0.0106**	0.0067**
	(0.0021)	(0.003)	(0.0051)	(0.0033)
Schooling	0.31***	0.258***	0.3227***	0.6859***
	(0.0365)	(0.042)	(0.0491)	(0.1252)
Schooling^2	−0.0681***	−0.0557***	−0.0693***	−0.1653***
	(0.0087)	(0.01)	(0.0106)	(0.0338)
LM income	0.0213***	0.0264***	0.0151	0.0133
	(0.0062)	(0.0076)	(0.01)	(0.1067)
UM income	0.0134*	0.0388***	−0.0101	0.0037
	(0.0078)	(0.0093)	(0.0062)	(0.1216)
High income	0.0305***	0.0409***	0.0444***	0.0414
	(0.0095)	(0.0118)	(0.0042)	(0.1436)
Mean inefficiency				
Constant	1.5706***	2.5077***	1.5341***	1.8264***
	(0.1557)	(0.517)	(0.0552)	(0.3155)
Oil rents boom	0.0078***	0.0278***	0.0075***	0.0033***
	(0.001)	(0.0094)	(0.0008)	(0.0012)
Oil rents bust	0.0111***	0.0426***	0.0087***	0.0025
	(0.0017)	(0.0113)	(0.0013)	(0.002)
Oil rents valley	0.0085***	0.0285***	0.0083***	0.0027***
	(0.0014)	(0.0101)	(0.0013)	(0.0003)
GDP per capita	−0.2138***	−0.3574***	−0.1963***	−0.2204***
	(0.0249)	(0.0827)	(0.0056)	(0.0452)
Distribution				
σ^2	0.0339***	0.0617***	0.0152***	0.0216***
	(0.0049)	(0.0168)	(0.0009)	(0.0075)
λ	0.9952***	0.9996***	0.9991***	0.9998***
	(0.001)	(0.0002)	(0.0016)	(0.0013)
LL	2592.348	1525.586	560.5318	518.0747

Notes:Production functions include time dummies. Public, private health care expenditure, schooling, schooling^2 and GDP per capita are converted to their natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Comparing the coefficient in bust and valley years yields the expected result. The coefficient in bust years is significantly larger by around 30% compared to the coefficient in valley years indicating that inefficiency increases when the international oil price decreases. This result shows that the causal relationship between *oil rents* and inefficiency moves from *oil rents* to inefficiency. An exogenous decrease in oil income due to a negative price shock increases inefficiency in the health care sector.

Columns (2)-(4) in table 4.5 show the results for the democratic, intermediate and autocratic sub-samples. In democracies the direction of the effect and the causal relationship is the same as in the full sample with a significant difference between bust and valley years. The inefficiency increasing effect becomes larger by about 50% in bust years when the international oil price decreases.

The coefficients in the intermediate sub-sample have the same pattern as the democratic sub-sample with smaller coefficient in boom years and larger coefficient in bust years compared to valley years. However, the Wald test reveals that the differences between the coefficients are not significantly different from zero, i.e. causality cannot be established in the intermediate sub-sample. Furthermore, the causal relation does not hold in autocratic countries. The result indicates that autocratic countries are wasteful with their funds in boom years but not in bust years. Hence, causality running from *oil rents* to inefficiency present in the full sample is purely driven by the democratic sub-sample. The results for the intermediate and autocratic sub-samples do not show signs of a causal relationship between *oil rents* and inefficiency.

Oil rents and inefficiency in the health care sector by sex

Next, I analyse whether the *oil rents* driven inefficiency effect in the health care sector is heterogenous across sexes. Ross (2008) argues that oil leads to lower female labour participation and lower female representation in parliament. The sex discrepancy could also occur in the health care sector. Lower labour market participation of women reduces their income and could decrease private health investments and fewer women in parliament could lead to lower public health care spending for women.

Panel A of table 4.6 shows the results using *life expectancy, male* as dependent variable. The overall causal relationship is the same as before with *life expectancy, both sexes* (shown in Table 4.5). In the democratic sub-sample, the *oil rents* coefficient is significantly greater in bust years compared to valley years, showing a causal relation. Again, this is not the case for the intermediate sub-sample. While the coefficients point in the same direction, the differences are not significant. The sub-sample of autocratic countries does not show any significant effect of *oil rents* on inefficiency in boom, bust or valley years, i.e. inefficiency in the health care sector is not affected by *oil rents* for men in autocratic countries.

Table 4.6: SFA: Inefficiency by sex

	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Panel A: Life expectancy, male				
Constant	1.2358***	1.4179***	1.3575***	0.931***
	(0.0992)	(0.1154)	(0.085)	(0.1942)
Oil rents boom	0.0058***	0.0192***	0.0068***	0.0007
	(0.0007)	(0.0032)	(0.0007)	(0.0017)
Oil renst bust	0.0081***	0.0291***	0.0095***	0.0032
	(0.0016)	(0.0065)	(0.002)	(0.0025)
Oil renst valley	0.0061***	0.0175***	0.0083***	−0.0012
	(0.001)	(0.004)	(0.0014)	(0.0026)
GDP per capita	−0.159***	−0.1896***	−0.1683***	−0.1018***
	(0.0153)	(0.0166)	(0.0121)	(0.0214)
Panel B: Life expectancy, female				
Constant	1.9417***	3.3678***	1.1668***	2.0609***
	(0.2244)	(0.4252)	(0.1014)	(0.1284)
Oil rents boom	0.01***	0.0243***	0.0051***	0.0039***
	(0.0014)	(0.006)	(0.0009)	(0.0012)
Oil rents bust	0.0141***	0.0346*	0.0087***	0.0054**
	(0.0025)	(0.0183)	(0.002)	(0.0023)
Oil rents valley	0.0112***	0.0223***	0.0066***	0.0033**
	(0.0017)	(0.0052)	(0.0014)	(0.0015)
GDP per capita	−0.2723***	−0.4746***	−0.1458***	−0.252***
	(0.0363)	(0.0692)	(0.0145)	(0.0156)

Notes: Production functions (not shown) include public, private health care expenditure, schooling, schooling^2 (converted all to their natural logarithm), income dummies and time dummies. GDP per capita is converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Panel B shows the results for *life expectancy, female* and while all the *oil rents* coefficients are positive and significant, the differences between boom, bust and valley years are not significant. There is no evidence for causality for female health production, only a strong correlation.

Nevertheless, comparing the coefficients between men and women shows that the inefficiency increasing effect of *oil rents* is generally greater for women. For example, in the full sample the boom, bust and valley coefficients are 72, 74, and 83% greater for *life expectancy, female* respectively compared to *life expectancy, male.* The same is true in the sub-samples of democratic and autocratic countries with greater coefficients in Panel B. For intermediate countries the opposite is the case. *Oil rents* coefficients are greater for men's health outcome compared to women's. For democratic and autocratic countries the results are in line with Ross (2008) argument and point towards a potential consequence of lower labour market participation and representation in parliament of women due to oil.

Oil rents and inefficiency in the health care sector by sub-population

Certain sub-groups of the population are more vulnerable than others, especially children and older people need more medical care than adults. To explore this potential source of heterogeneity in the effect of *oil rents* on inefficiency I test whether mortality rates of certain sub-groups of the population are affected in a different way by *oil rents*.

The dependent variable in this setting is *mortality rate* instead of *life expectancy*. The reason for this change is that *life expectancy* is generally defined as the numbers of years a person would live if prevailing patterns of mortality were to stay the same (The World Bank, 2018a). Because of this definition a government investment aiming to improve health and therefore *life expectancy* of older people affects the 'prevailing pattern of mortality' for everyone younger than the older people. *Life expectancy* at birth would be affected in the same way as *life expectancy* for a 10-, 20-, 30- or 40-year-old person. Therefore, using *life expectancy* for different age groups would not be comparable. *Mortality rate* on the other side is specific for each age group or sub-sample of the population and a change in the *mortality rate* between 60 and 70 years does not affect the *mortality rate* between 10 and 20 year old people.

Mortality rates measure the number of the population in a sub-group dying before reaching a certain age and the available categories are neonatal, infant, child, adult (both sexes), adult (male), adult (female), and maternal mortality rate. Neonatal, infant and child mortality rates measure the number of dying newborns before reaching the age of 28 days, 1 year and 5 years, respectively. Adult mortality corresponds to the probability of dying between the age 15 and 60 years and maternal mortality measures the number of women dying because of pregnancy related reasons up to 48 days after pregnancy termination. Except for maternal mortality the data are measured as the number of deaths per 1000 people of the specific sub-population, maternal mortality measures the number of deaths per 100,000 live births.

All the mortality rates are rescaled by dividing the minimum number of deaths in year i by the actual number of deaths in year i and was multiplied by 100. The new scale is equal 100 for the best performing country, i.e. lowest mortality rate in year i and the measure decreases with higher mortality rate. Hence, the direction of the variable is the same as for *life expectancy* (higher values equal better outcomes) and a production function can be used again to estimate inefficiency.

Table 4.7: SFA: Inefficiency by age-groups

Mortality rate	(1) Neonatal	(2) Infant	(3) Child	(4) Adult
Mean inefficiency				
Constant	0.4002***	4.1171***	4.8574***	-0.1775
	(0.0927)	(0.2404)	(0.4631)	(0.538)
Oil rents boom	0.0086***	0.0152***	0.0161***	0.01**
	(0.001)	(0.0011)	(0.001)	(0.0043)
Oil rents bust	0.0145***	0.0221***	0.0235***	0.0129
	(0.0024)	(0.0019)	(0.0024)	(0.0077)
Oil rents valley	0.0101***	0.0173***	0.0185***	0.0072*
	(0.0014)	(0.0016)	(0.0014)	(0.0041)
GDP per capita	−0.0355***	−0.3864***	−0.39***	-0.0952**
	(0.0094)	(0.0246)	(0.0285)	(0.0396)

Mortality rate	(5) Adult, male	(6) Adult, female	(7) Maternal
Mean inefficiency			
Constant	−0.8783	−0.5664	0.0293*
	(0.6697)	(1.8459)	(0.0162)
Oil rents boom	−0.0005	0.0502**	0.0042***
	(0.0031)	(0.0221)	(0.0003)
Oil rents bust	−0.0016	0.0682	0.0054*
	(0.007)	(0.0515)	(0.0028)
Oil rents valley	−0.0049	0.047**	0.0032
	(0.0052)	(0.0193)	(0.0023)
GDP per capita	0.0383	−0.5753**	−0.0242***
	(0.0399)	(0.2506)	(0.0051)

Notes: Neonatal are newborn babies between 0 and 28 days. Infants are children between 0 and 1 years. Children are between 0 and 5 years old. Adults are between 15 and 60 years old. Maternal mortality measures pregnancy-related deaths. Production functions (not shown) include public, private health care expenditure, schooling, schooling^2 (all converted to their natural logarithm), income dummies and time dummies. GDP per capita is converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 4.7 shows the results for the full sample and table C 4 in appendix C shows estimates for the democratic, intermediate and autocratic sub-samples. Neonatal, infant and child mortality rates do all look similar with highly significant *oil rents* coefficients, significantly greater coefficient in bust years and insignificantly smaller coefficients in boom years compared to valley years, showing a causal relation. The pattern is the same in democratic, intermediate and autocratic countries (see table C 4 in appendix C).

The results for the different groups of adult mortality rates show a weaker effect and sometimes even no effect for the full sample. For example, all coefficients for male adults are insignificant and for females and both sexes only the *oil rents* coefficients in valley and boom years are significant at the 5 or 10% level. A look at the institutional sub-samples shows that the weak effects for the full sample is driven by insignificant coefficients in autocracies and sometimes democracies. Inefficiency in the adult health care sector is only influenced in intermediate countries and to a smaller extent in democratic countries due to *oil rents*.

The significant results for adults in intermediate countries could be driven by the fact that the polity score categorizes countries 'interregnum' and in transition as 0 on the Polity2 index. A period of interregnum are years with total collapse of political authority and include internal wars and periods of anarchy (Marshall and Jaggers, 2014). Periods of civil unrest are accompanied by higher mortality rates and because the conflict parties consist of adults, the adult mortality rate should be affected. A huge literature exists analysing the relation between natural resources and civil war (e.g. Arezki et al. (2015); Bell and Wolford (2015); Cotet and Tsui (2013a); Lei and Michaels (2014); Ross (2015); De Soysa and Neumayer (2007); Wegenast (2013). However, scholars concerned with the question have not delivered a clear answer yet (e.g. Lei and Michaels (2014) find a positive effect while Cotet and Tsui (2013a) find no effect with similar data and slightly different strategies). However, if natural resources led to periods of interregnum and civil unrest with higher mortality rates, this could explain the significant results for intermediate countries. To test if this is the driving factor I re-run the specifications, excluding countries with interregnum years from the sample. The results are the same as before, hence this possibility does not drive the results.

In summary, the analysis concerned with different age-groups reveals that the inefficiency increasing effect of *oil rents* is strong for the most vulnerable part of the population (newborns, infants, and children) while the effect for adults is weaker and only significant in intermediate countries.

4.6 Robustness checks

In this section, I conduct robustness checks concerned with potential oil price setters, time lags of the effect and different definition of price shocks.

Excluding Saudi Arabia and the US

I start by testing whether the causal relationship found in the data is driven by the inclusion of OPEC, Saudi Arabia and the United States. As discussed in section 4.2, Saudi Arabia was the traditional swing producer collaborating with OPEC and the United States have the potential to be the new swing producer today due to the shale oil revolution. The US can also influence the oil price through monetary policy. These countries or group of countries −in the case of OPEC− could have influenced the international oil price rendering the oil rents boom, bust and valley variable as endogenous which would reduce the identification strategy as invalid.

Table C 5 in the appendix shows the main specifications excluding one country at a time and combined. Significance and signs of the oil rents boom, bust, and valley coefficients do not change and changes in the magnitude of any coefficient are minor. Hence, I conclude that the results concerned with causality are robust and not driven by the inclusion of potential oil price setters.

Time lags of the effect

The next robustness check is concerned with potential time lags of the effect of *oil rents* on inefficiency. Grigoli and Kapsoli (2013) argue that health expenditure needs time to affect *life expectancy* and inefficiency. The same could be argued for *oil rents* and an additional concern for the identification strategy is that a country could smooth out consumption through borrowing in bust years.

However, this does not seem to be the case here. Table C 6 in the appendix shows the results with lagged values of *life expectancy* by 1, 2, 3, 4, and 5 years to test if the effect of *oil rents* on inefficiency this year is different in 1, 2, 3, 4 or 5 years. The *oil rents* coefficients in boom, bust and valley years slightly decrease with increasing lags, hence the effect can be seen as immediate and diminishing over time but does not take a certain lagged number of years to develop.

Different definitions of boom, bust and valley years

A further robustness check is concerned with the definition of boom and bust years. So far, the definition was a more than 10% change in the international oil price. The chosen 10% benchmark is arbitrary and for this reason I re-run the main specification with different benchmarks.

Table C 7 in the appendix shows the results using 5, 10, 15 and 20% price fluctuation as benchmark. The results are almost identical in all specifications; hence my main results are robust to different definitions of price shocks.

4.7 Two potential mechanisms

In this section, I discuss two mechanisms through which *oil rents* potentially influence inefficiency in the health care sector. The first mechanism is that oil increases inequality, which in turn increases inefficiency and the second mechanism is that oil reduces transparency, which in turn increases inefficiency.

The spoils of oil are often unevenly distributed in the population benefiting the elite proportionally more than the rest. This is because oil is a capital intensive industry with only few linkages to the rest of the economy, therefore creating little employment (Karl, 2007). The result is that oil rich countries are plagued with high inequality (Mallaye et al., 2015). In turn, high inequality influences inefficiency in the health care sector (Herrera and Pang, 2005; Ogloblin, 2011; Ravallion, 2003). Inequality can create a barrier for the poor to access health care services and generally reflects unhealthy working conditions. Further, unequal societies tend to misallocate resources more in favour of the population that can afford them and away from the part of the population who actually needs them (Ogloblin, 2011).

The enclave characteristic and high profitability of oil makes it also lucrative for governments to be less transparent allowing them to use the spoils of oil for their own purposes (Karl, 2007). Williams (2011) confirms this argument empirically finding that point-source resources, such as oil, decrease transparency. Less transparency should increase inefficiency due to missing ways of holding the government accountable for their decisions.

Both −inequality and transparency− should lead to more inefficiency in the health care sector, because an unequal income distribution is seen as obstacle for many to access health care services and lower transparency could lead to the wrong kind of public health investments. Therefore, I test here the two following hypotheses:

Hypothesis 1 (H_1) : *oil rents decrease transparency, which in turn increases inefficiency*

Hypothesis 2 (H_2) : *oil rents increase inequality, which in turn increases inefficiency*

To test the hypotheses I follow Carmignani and Avom (2010) and include a variable measuring inequality and transparency in addition to the *oil rents* variable in the model.

If the hypotheses are correct then the *oil rents* coefficients should lose in magnitude and significance after including inequality or transparency. This is because any effect of *oil rents* on inefficiency should be accounted for by the estimated coefficient of inequality or transparency. Further, the inequality and transparency coefficient should be significant.

I am using Gini from the World Income Inequality database provided by UNU-WIDER (2017) to capture inequality and to measure transparency I use the Release of Information Index compiled by Williams (2009). The inclusion of the two variables creates some data issues due to lower data coverage in terms of countries and years. To include the maximum amount of countries the time dimension of the panel was shortened to 2000-2010. Even with this adjustment some countries were lost completely. In the case of inequality the number of countries drops from 119 to 96. Because of this, I first estimate the model with the smaller sample to see whether the results still hold and then I include the transparency and inequality variables to see whether they affect the *oil rents* coefficients.

Table 4.8 shows the results testing H_1 (oil rents decrease transparency, which in turn increases inefficiency). The odd columns re-estimate the specifications without transparency for the new smaller sample. The results are overall in line with the main results.

Column (2) of table 4.8 shows the results for the full sample including *transparency*. The *transparency* coefficient is insignificant and has no influence on the *oil rents* coefficients. Hence, H_1 cannot be confirmed. However, the situation changes for the democratic sub-sample in column (4) where *transparency* is significant, and the *oil rents* coefficient lose in magnitude and significance as it would be expected if H_1 is true. The situation changes again for the intermediate and autocratic sub-samples (columns (6) and (8)). Whereas the sub-sample of intermediate countries is not affected by *transparency* (insignificant *transparency* coefficient and no changes in *oil rents* coefficients), the autocratic sub-sample surprisingly shows a significant and this time positive *transparency* coefficient. The *transparency* coefficient indicates that more transparency increases inefficiency in autocratic countries.

Concluding the *transparency* results: the inefficiency increasing effect due to *oil rents* is partly driven by lower *transparency* in democratic countries, but *transparency* does not seem to be the driving force in intermediate or autocratic countries.

Table 4.8: Transparency mechanism

	(1) All countries	(2) All countries	(3) Democratic	(4) Democratic
Mean inefficiency				
Constant	1.6283***	1.6308***	1.6835***	1.7651***
	(0.1684)	(0.1729)	(0.1227)	(0.1251)
Oil rents boom	0.0079***	0.0082***	0.0138***	0.0085**
	(0.0012)	(0.0013)	(0.0036)	(0.0043)
Oil rents bust	0.011***	0.0113***	0.0206***	0.0108
	(0.002)	(0.0022)	(0.007)	(0.0083)
Oil rents valley	0.0092***	0.0094***	0.0161**	0.0094
	(0.0018)	(0.0019)	(0.007)	(0.0072)
Transparency		0.0007		−0.0155***
		(0.0012)		(0.0022)
GDP per capita	−0.2193***	−0.2238***	−0.2159***	−0.1279***
	(0.0267)	(0.0293)	(0.0159)	(0.0215)

	(5) Intermediate	(6) Intermediate	(7) Autocracy	(8) Autocracy
Mean inefficiency				
Constant	1.3163***	1.5386***	3.3746***	1.4454***
	(0.1233)	(0.0964)	(0.1683)	(0.0978)
Oil rents boom	0.0061***	0.0073***	0.0037***	0.0029***
	(0.0009)	(0.0006)	(0.0008)	(0.0005)
Oil rents bust	0.0089***	0.0106***	0.0048***	0.0048***
	(0.002)	(0.0022)	(0.0015)	(0.0015)
Oil rents valley	0.0067 * **	0.0082***	0.0059***	0.0044***
	(0.0018)	(0.0018)	(0.0014)	(0.001)
Transparency		0.0039		0.0091***
		(0.0025)		(0.0018)
GDP per capita	−0.166***	−0.2161***	−0.434***	−0.2073***
	(0.016)	(0.016)	(0.0235)	(0.0048)

Notes: Production functions (not shown) include public, private health care expenditure, schooling, schooling^2 (all converted to their natural logarithm), income dummies and time dummies. GDP per capita is converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table 4.9 shows the results testing H_2 (oil rents increase inequality, which in turn increases inefficiency). *Inequality* data are rare and Papyrakis (2016) even shows that resource rich countries tend to under-report or not report *inequality* at all. The sample is reduced to 96 countries and the list of excluded countries consists mainly of resource rich countries.[15] Replicating the main specifications for the smaller *inequality* sample

[15] The countries with missing inequality data are: Azerbaijan, Bahamas, Bahrain, Benin, Brunei, Central African Republic, Chad, Rep. of Congo, Democratic Republic of Congo, Gabon, Guyana, Jamaica, Kenya, Kuwait, Liberia, Myanmar, Oman, Samoa, Saudi Arabia, Togo, Trinidad and Tobago, United Arab

resulted in insignificant results for intermediate and autocratic countries. Therefore, it is not possible to test the *inequality* mechanism for intermediate and autocratic countries and only the results for the full sample and democratic samples are discussed.

Table 4.9 shows the results for the full sample and the democratic sub-sample. In column (1) and (3) the main specifications are re-estimated for the smaller samples without *inequality*. Both show similar effects of *oil rents* in boom, bust and valley years as before. Column (2) and (4) include *inequality* and the coefficients are positive and significant in both samples, i.e. more *inequality* increases inefficiency. The *oil rents* coefficients for the full sample lose in magnitude, but not in significance. The *oil rents* coefficients for the democratic sub-sample again lose in magnitude and this time they also lose significance. Not being able to test H_2 for intermediate and autocratic countries leaves the conclusion that *inequality* drives the *oil rents* effect on inefficiency to some degree in democratic countries.

Table 4.9: Inequality mechanism

	(1) All countries	(2) All countries	(3) Democratic	(4) Democratic
Mean inefficiency				
Constant	2.762***	0.9804***	2.4606***	0.6021***
	(0.5777)	(0.0772)	(0.1261)	(0.0932)
Oil rents boom	0.0114***	0.0068***	0.0163***	0.0042
	(0.0036)	(0.0011)	(0.0054)	(0.005)
Oil rents bust	0.0157***	0.0097***	0.0273***	0.0153*
	(0.005)	(0.0025)	(0.0105)	(0.0085)
Oil rents valley	0.0136***	0.0085***	0.0212***	0.0042
	(0.004)	(0.0023)	(0.0079)	(0.0069)
Inequality		2.8942***		3.1154***
		(0.1752)		(0.1799)
GDP per capita	−0.4007***	−0.2904***	−0.349***	−0.2499***
	(0.0943)	(0.0123)	(0.019)	(0.0147)

Notes: Production functions (not shown) include public, private health care expenditure, schooling, schooling^2 (all converted to their natural logarithm), income dummies and time dummies. GDP per capita is converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Emirates, and Uzbekistan.

4.8 Conclusion

This chapter uses stochastic frontier analysis (SFA) to estimate inefficiency in the health care sector and focuses in particular on the question whether unexpected changes in oil rents have an impact on inefficiency. The SFA estimates show that oil dependent countries could increase life expectancy between 5 and 13 years by eradicating inefficiency in health care spending. Further, the results confirm that oil rent is a significant determinant of inefficiency in the health care sector, i.e. higher oil dependency leads to more inefficiency. Exploiting exogenous fluctuations in the international oil price also shows that the effect can be considered as causal for democratic countries.

The inefficiency increasing effect is heterogenous in several dimensions. First, the effect is stronger in democratic countries compared to intermediate and autocratic countries. Second, women's health is affected by higher inefficiency compared to men's and finally, vulnerable parts of the population, such as infants and children, are affected by higher inefficiency compared to adults.

Two mechanisms that could drive the effect have been postulated and tested. The identified mechanisms are transparency and inequality. The results show that both mechanisms are responsible for the effect in democracies, but not in intermediate and autocratic countries. Hence, policy implications for democratic oil rich countries would be to invest the oil dividends into poverty reducing policies to battle inequality and reform institutions to increase transparency.

Two caveats accompany the analysis and could not have been resolved yet. The first is that the applied SFA model from Battese and Coelli (1995) includes all time-invariant unobserved country heterogeneity in the inefficiency term and therefore represent upper bound estimates. Other models, such as Greene (2005b) 'true fixed effects' model would be capable to exclude time-invariant unobserved heterogeneity from the inefficiency term. However, it is debatable how much of the unobserved heterogeneity should be included or excluded in the inefficiency term and −as was noted by Greene himself− the true estimates should be somewhere in between. The results in this chapter are derived completely from Battese and Coelli (1995) model, because the Greene (2005b) model did not converge. Therefore, the results should be seen as upper bound estimates of the real effect.

The second caveat is concerned with the quantification of the z-variables. The analysis would benefit from the calculation of the marginal effects of *oil rents* and *GDP per capita*. Wang (2002) shows that the marginal effects in this setting would be the slope coefficient of the z-variables multiplied by an adjustment function. Using the Frontier4.1 software from Coelli (1996) I was unable to calculate the adjustment function and therefore cannot make a statement by how much inefficiency increases if *oil rents* increases by one percent. However, because *oil rents* and *GDP per capita* are included only in the mean of u_{it} the direction of the effect (inefficiency increasing or decreasing) is still valid because the adjustment function would be positive Wang (2002).

Future research could focus on allocative inefficiency. The analysis here is restricted to technical inefficiency due to missing data measuring input quantity and prices in the health care sector. However, with time comes data and an analysis taking the allocation of inputs into account would be of interest because resource curse theories predict that oil rents increase the misallocation of resources which could be detected with allocative inefficiency. Further, the analysis is not limited to the health care sector and stochastic frontier analysis could analyse whether oil influences inefficiency in other areas as well, such as education or infrastructure.

Chapter 5

Conclusion

This thesis has provided an empirical analysis of the political economy of natural resources. The thesis consists of three chapters, each of them providing new insights on how natural resources influence political survival, taxation and efficiency in the health care sector. Here, I summarize the findings of each chapter, discuss their shortcomings and offer an outlook for future research.

The first empirical chapter (chapter 2) asked the question whether natural resources influence the time a leader stays in office. The question was addressed by applying 'single risk' and 'competing risk models' to a large dataset of 1255 leaders from 158 countries.

The 'single risk model' measures the impact of giant resource discoveries on the hazard of leaving office and the results indicate that giant mineral discoveries reduce the overall risk of leaving office in non-election years. The same is true for giant oil discoveries, but only in countries with a low level of institutional quality. The results of the 'competing risk model' refines the results derived from the 'single risk model' and show that the risk reducing effect in non-election years induced by giant mineral discoveries is solely driven by a reduced risk of resignation. The risk reducing effect of oil discoveries in countries with low level of institutional quality is due to a reduction in risk of resignation and military coups.

The risk reducing effect of giant mineral and oil discoveries appear to be induced by actual income rather than by income expectation. The time evolution of the effect of a mineral discovery shows that risk is significantly reduced during construction and extraction stages of a mine. The effect of oil discoveries needs almost a decade to develop and coincides with the extraction stage when income is generated. Identified mechanisms through which resource discoveries reduce the risk for the incumbent are lower taxation of the non-resource economy and increased military expenditures.

The findings are mostly in line with the existing literature and include some new results. With respect to our results for oil, Omgba (2008) finds the same risk reducing effect for African leaders, Wright et al. (2013) and Andersen and Aslaksen (2013) for regime survival and Cuaresma et al. (2011) for autocratic leaders. Our result of a risk reducing effect for mineral discoveries contradicts to some degree the zero effect in Omgba (2008) and the risk increasing effect in Andersen and Aslaksen (2013). The different findings could be explained by the mineral variable used in our analysis. Mineral rents −used in Omgba (2008) and Andersen and Aslaksen (2013)− capture also small mines, while we only include giant mineral discoveries. The effect could be non-linear, risk increasing for small mineral deposits, which can be easier captured by the opposition, while bigger mines benefit the incumbent. The significant findings of the 'competing risk model' represent new results.

While the timing of resource discoveries represents a cleaner identification strategy than resource production related variables, the discovery variable comes with a trade-off. Giant resource discoveries are rare events and the two chosen categories of minerals and oil could be too broadly defined. For example, the category of oil includes oil and gas discoveries and the analysis cannot differentiate whether the effect is different between the two resources. While oil and gas have a lot in common, they also have some different characteristics in form of extraction, price or transportation. These differences could influence the effect on political survival. The same is true for mineral discoveries. Hence, the results should be interpreted as the net effect of giant resource discoveries.

Future research could pick up at this point and analyse the heterogeneity of different resource discoveries. Case studies focusing on individual events would enrich our understanding of the effect of giant resource discoveries on political survival. Comparing case studies with different resource types could answer the question whether the broad categories of oil and minerals are justified.

A potential mechanism on how resource discoveries reduce the risk of a leader leaving office −reduced non-resource tax− was already mentioned in the first empirical chapter. Taxes are part of the fiscal contract between citizens and the government and any change to it can have severe effects on development. Hence, this mechanism deserves an analysis on its own.

The second empirical chapter (chapter 3) analyses whether resource revenues crowd out domestic taxation. The question was addressed by applying synthetic control method to a dataset of 25 resource exporting countries and by exploiting the 2000s commodity price boom as exogenous positive income shock.

The results confirm the existence of a crowding-out effect, more resource revenues decreased domestic tax income during the 2000s commodity price boom. An advantage of the synthetic control method is the possibility to test for an effect in small samples. The results for different sub-samples show that the crowding-out effect is not a necessity for resource rich countries and only shows up significantly in countries with certain characteristics. The sub-sample analysis shows that the crowding-out effect depends on resource type, institutional quality, the amount of resources in the state budget, and government preferences in terms of ownership structure and applied fiscal instruments. For example, the crowding-out effect is present in oil exporting countries, but not in mineral or precious mineral exporting countries. Within the sub-sample of oil exporting countries, a low level of institutional quality and high oil dependency affects the significance of the crowding-out effect positively. Further, a higher reliance on tax instruments compared to non-tax instruments supports the existence of a crowding-out effect and while the effect is present for both ownership structures −state and private− a nuanced difference in the timing and magnitude between the two could be observed, with a delayed but overall greater effect in countries with private oil ownership.

The confirmation of the crowding-out effect is in line with the existing literature (Bornhorst et al., 2009; Crivelli and Gupta, 2014; Thomas and Treviño, 2013; Ossowski and Gonzales, 2012). The heterogeneity analysis represents new results and is the main contribution of the chapter to the literature. The results improve our understanding of the necessary conditions in a country for a crowding-out effect to be present and provide possible policy implications. For example, new producers could avoid the crowding-out effect by improving institutional quality, investing into tax administration and diversify their revenue sources.

One caveat of the analysis rests in the availability of tax data in combination with restrictive data requirements for the synthetic control method. The overall sample consists of only 25 resource exporting countries, including six mineral producers. Compared to other studies[1] who managed to include over 30 oil rich countries this could be a concern. Future research will hopefully benefit from the continuous effort of the International Centre of Tax and Development in collecting reliable and comparable tax data.

Another concern regarding the analysis in chapter 3 relates to the assumption that the treatment is the same in all treatment countries. Synthetic control method is only capable

[1] For example Bornhorst et al. (2009); Crivelli and Gupta (2014); Knebelmann (2017)

to assign one price boom to each treatment country. Some countries extract more than one resource. Therefore, they could be affected by several price booms. Countries are identified by the main commodity they extract contributing most to government income and should be the main contributor to any observed effect. However, there is no certainty that the main resource is the sole contributor to the captured effect.

A natural follow-up analysis of chapter 3 would be an investigation of potential heterogenous effects across different tax types. Currently, the analysis is solely concerned with the impact of resource revenues on total tax income. The effect could be different for VAT, property tax, individual income tax or company's profit tax and the insights of such an analysis would highlight government preferences. The burden of different taxes is carried by different parts of the population. Whether the government of a resource rich country supports the elite or the poor can be seen in the way resource revenues affect regressive or progressive taxes.

The third empirical chapter (chapter 4) asked the question whether oil rents are a determinant of inefficiency in the health care sector. The question was addressed by applying stochastic frontier analysis to a sample covering 119 countries and the period 2000 to 2015.

The applied stochastic frontier model from Battese and Coelli (1995) estimates health production functions and inefficiency determinants simultaneously and by exploiting unexpected price fluctuations of the international oil price it was possible to test for causality.

The results of the chapter show that the efficiency score of oil rich countries is on average lower compared to oil poor countries. The efficiency estimates show that oil rich countries could increase life expectancy by eradicating inefficiency in the health care sector between 5 and 13 years. Further, the analysis confirms that oil rents are a significant determinant for inefficiency in the health care sector, i.e. higher oil dependency leads to higher inefficiency. In terms of causality, the price fluctuation analysis shows that the results can be considered as causal for democratic countries.

The analysis further reveals that the effect of oil rents on inefficiency in the health care sector depends on institutions and is heterogenous for different parts of the population. The inefficiency increasing effect of oil rents is greater and more significant in democratic countries compared to intermediate and autocratic countries. Comparing the results for different parts of the population shows that oil rents influence inefficiency more for women's health than men's and that the most vulnerable part of the population (infants and children) is affected by higher inefficiency due to oil than adults.

Inequality and transparency are identified as mechanisms through which oil rents influence inefficiency in the health care sector. This part of the analysis shows that parts of the oil rents inefficiency increasing effect is explained by higher inequality and lower transparency in oil rich countries. This result only holds for democratic countries and policy implications for oil rich democratic countries could include investment of the oil dividend into transparency increasing reforms and re-distributional policies to reduce inequality.

In the current form, the analysis in chapter 4 has one shortcoming that I couldn't resolve. The results derived from the Battese and Coelli (1995) stochastic frontier model should be interpreted as upper bound estimates of the true effect. The reason for this is that the Battese and Coelli (1995) model incorporates all time-invariant unobserved country characteristics into the inefficiency term, which can lead to misspecification bias in the presence of time-invariant unobservable factors that influence the outcome, but are not part of the production process. A more precise analysis would also present lower bound estimates of the true effect by applying a model that excludes output related time-invariant unobserved country characteristics from the inefficiency term (e.g. the 'true fixed effects' model from Greene (2005b)). However, the 'true fixed effects' model did not converge and therefore I am restricted to present only upper bound estimates.

Future research could go in two directions. First, with regards to the health care sector an analysis estimating allocative inefficiency could provide more insights into the question how oil influences inefficiency in the health care sector than the technical inefficiency estimated in chapter 4. Second, the stochastic frontier analysis is not restricted to the health care sector and could also be applied to other areas, such as education or infrastructure, to evaluate the impact of oil on inefficiency once respective data is collected and made available.

In summary, this thesis contributes to our understanding of the political economy of natural resources by analysing the impact of natural resources on political power, taxes and inefficiency in the health care sector. It is important to understand how natural resources influence policies and politicians' behaviour to create and apply efficient instruments to counteract any adverse effect natural resources potentially have on economic, political and social development.

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Appendix A

Appendix to chapter 2

A.1 Tables

Table A 1: List of countries in the sample

Albania, Algeria, Angola, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahrain, Bangladesh, Belarus, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Central African Republic, Chad, Chile, China, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Ethiopia, Finland, France, Gabon, Gambia, Georgia, Ghana, Greece, Guatemala, Guinea, Guinea Bissau, Haiti, Honduras, Hungary, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Ivory Coast, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea South, Kuwait, Kyrgyzstan, Laos, Latvia, Lebanon, Lesotho, Liberia, Lithuania, Luxembourg, Macedonia, Madagascar, Malawi, Malaysia, Mali, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Swaziland, Sweden, Syria, Taiwan, Tajikistan, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, United Arab Emirates, United Kingdom, USA, Uganda, Ukraine, Uruguay, Uzbekistan, Venezuela, Vietnam, Yugoslavia, Zambia, Zimbabwe.

Table A 2: Countries and number of giant oil discoveries

Russia (139), Iran (64), Saudi Arabia (55), China (36), USA (33), Australia (32), Brazil (32), Iraq (28), Nigeria (27), Norway (27), Libya (26), United Kingdom (22), Canada (20), Indonesia (16), Egypt (14), Mexico (14), Kuwait (13), Venezuela (13), Angola (11), Malaysia (8), Colombia (7), United Arab Emirates (7), India (5), Myanmar (5), Oman (5), Pakistan (5), Algeria (4), Argentina (4), Bolivia (4), Congo, Rep. (4), Kazakhstan (4), Thailand (4), Netherlands (3), Peru (3), Tunisia (3), Turkmenistan (3), Vietnam (3), Yemen (3), Azerbaijan (2), Ecuador (2), France (2), Ghana (2), Italy (2), Mozambique (2), Qatar (2), Sudan (2), Trinidad and Tobago (2), Afghanistan (1), Bangladesh (1), Denmark (1), Ethiopia (1), Gabon (1), Germany (1), Hungary (1), Israel (1), Ivory Coast (1), Morocco (1), New Zealand (1), Philippines (1), Romania (1), Sierra Leone (1), Spain (1), Syria (1)

Table A 3: Countries and number of giant mineral discoveries

Australia (48), Canada (46), USA (43), Chile (37), Russia (37), South Africa (33), Brazil (18), Peru (18), China (16), Indonesia (14), Argentina (11), Philippines (10), Mexico (9), Colombia (7), Tanzania (7), Turkey (6), Congo, Dem. Rep. (5), Finland (5), Ghana (5), Greece (5), Ecuador (4), Mongolia (4), Botswana (3), Guatemala (3), Iran (3), Mali (3), Panama (3), Poland (3), Romania (3), Venezuela (3), Burkina Faso (2), Congo, Rep. (2), Guinea (2), Iraq (2), Ivory Coast (2), Madagascar (2), Mauritania (2), Mozambique (2), Niger (2), Saudi Arabia (2), Afghanistan (1), Angola (1), Bolivia (1), Bulgaria (1), Burundi (1), Cameroon (1), Egypt(1), Hungary (1), India (1), Japan (1), Myanmar (1), Namibia (1), New Zealand (1), Norway (1), Pakistan (1), Portugal (1), Sierra Leone (1), Sudan (1), Sweden (1), Zambia (1), Zimbabwe (1)

Table A 4: List of further variables

List of variables used in tables 2.2 and 2.3, for others see section 2.2.1:

(log of) GDP p.c.:	Natural logarithm of real GDP at constant national prices, obtained from national accounts data for each country divided by population (Source: Penn World Table)
Economic growth:	Yearly percentage change of GDP p.c. (Source: Penn World Table)
Trade (% of GDP):	Sum of exports and imports of goods and services measured as a share of gross domestic product (Source: World Development Indicators)
Wildcat:	Number of explorative boreholes drilled in a country in a year, serves as a proxy for exploration effort (Source: Cotet and Tsui (2013a))
Crude oil price:	Real crude oil price measured in 1990 US Dollar (Source: Cotet and Tsui (2013a))
Metal index:	Price index for bauxite, copper, lead, zinc, nickel, iron ore, tin. Base year 2010. (Source: World Bank)
Precious metal index:	Price index for gold, silver and platinum. Base year 2010 (Source: World Bank)
Land area:	Measures the size of a country in square kilometres (Source: Cotet and Tsui (2013a))
Human capital:	Human capital is measured using the average years of schooling for the population aged 15 and older and the rates of return for completing different sets of years of education (Source: Penn World Table)

Table A 5: Resource poor countries in 1950 according to Smith (2015)

Asia and Pacific				
Afghanistan	Bangladesh	Cambodia	China	India
Indonesia	Japan	Laos	Malaysia	Mongolia
Nepal	New Zealand	Pakistan	Philippines	Korea, Rep.
Singapore	Sri Lanka	Taiwan	Thailand	Vietnam
Latin America and the Caribbean				
Costa Rica	Dominican Rep.	Ecuador	El Salvador	Guatemala
Honduras	Jamaica	Nicaragua	Panama	Paraguay
Uruguay				
Middle East and North Africa				
Algeria	Egypt	Israel	Jordan	Lebanon
Libya	Morocco	Oman	Syria	Tunisia
Turkey	Yemen			
Europe				
Albania	Belgium	Bulgaria	Czech Rep.	Denmark
Finland	France	Germany	Greece	Hungary
Ireland	Italy	Netherlands	Norway	Poland
Portugal	Spain	Sweden	UK	
Sub-Saharan Africa				
Benin	Botswana	Burkina Faso	Burundi	Cameroon
Centr. African Rep.	Chad	Congo, Rep.	Ivory Coast	Gabon
Gambia	Ghana	Guinea	Kenya	Lesotho
Liberia	Madagascar	Malawi	Mali	Mauritania
Mauritius	Mozambique	Namibia	Niger	Nigeria
Rwanda	Senegal	Somalia	Sudan	Swaziland
Tanzania	Togo	Uganda	Zambia	Zimbabwe

Table A 6: First Resource Discovery, Institutions and Political Survival: Single Risk Model in election years

	(1)	(2)	(3)	(4)
Institution:	x-polity	x-polity	xconst	xconst
F. oil discovery	-0.839	-44.394^{***}	-0.923	-35.048^{***}
	(0.627)	(4.015)	(0.625)	(2.830)
F. mineral discovery	-1.239^{**}	-2.093	-1.296^{**}	-2.948
	(0.588)	(2.204)	(0.576)	(2.277)
Insitution	0.205^{***}	0.194^{***}	0.380^{***}	0.354^{***}
	(0.032)	(0.033)	(0.067)	(0.068)
F. oil # Institution		3.187^{***}		5.037^{***}
		(0.308)		(0.426)
F. mineral # Inst.		0.091		0.340
		(0.197)		(0.402)
Observations	596	596	596	596
# of leaders	371	371	371	371
# of countries	83	83	83	83
LL	-301	-298	-304	-300

Notes: The table shows the impact of first (F.) resource discoveries in initially resource poor countries on the hazard of leaving office for leaders in election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 7: Resource Discovery and the Risk of Other:
Competing Risk Model in non-election years

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	−0.389	−0.998	−0.431	−1.070	−0.382	−2.145*
	(0.470)	(0.619)	(0.469)	(0.703)	(0.466)	(1.164)
Mineral disc.	−0.355	0.454	−0.323	−0.300	−0.366	−1.243
	(0.542)	(0.983)	(0.544)	(0.868)	(0.531)	(0.784)
Institution	0.012	0.007	−0.054	−0.076	−0.522**	−0.609**
	(0.039)	(0.043)	(0.088)	(0.097)	(0.218)	(0.242)
Oil # Inst.		0.117		0.227		0.796
		(0.087)		(0.198)		(0.499)
Mineral # Inst.		−0.139		−0.023		0.362
		(0.147)		(0.203)		(0.294)
Observations	5,211	5,211	5,211	5,211	5,212	5,213
# of leaders	1053	1053	1053	1053	1053	1053
# of countries	143	143	143	143	143	143
LL	-1957	-1957	-1957	-1957	-1940	-1906

Notes: The table shows the impact of resource discoveries and institutions on the hazard of leaving office because of other reasons in non-election years. Other reasons include domestic protest, domestic rebels, other government actors, foreign force and assassination by unsupported individuals. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 8: Exploration Effort, Resource Discovery, Institutions and Survival: Single Risk Model in non-election years

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample:	original	cotet & tsui	cotet & tsui	original	cotet & tsui	cotet & tsui	original	cotet & tsui	cotet & tsui
Institution:	x-Polity	x-Polity	x-Polity	x-Polity	x-Polity	x-Polity	xconst	xconst	xconst
Oil discovery	−0.281	−0.401	−0.389	−1.584***	−1.531***	−1.554***	−0.323	−0.431	−0.422
	(0.254)	(0.274)	(0.278)	(0.437)	(0.444)	(0.442)	(0.259)	(0.278)	(0.282)
Mineral disc.	−0.342**	−0.174	−0.156	−0.413	−0.357	−0.474	−0.326*	−0.178	−0.163
	(0.163)	(0.218)	(0.221)	(0.468)	(0.643)	(0.654)	(0.169)	(0.221)	(0.223)
Wildcat			−0.061			−0.185***			−0.051
			(0.051)			(0.067)			(0.053)
Institution	0.059***	0.071**	0.071**	0.040**	0.033	0.031	0.084**	0.102*	0.104*
	(0.017)	(0.029)	(0.029)	(0.017)	(0.027)	(0.027)	(0.036)	(0.057)	(0.057)
Oil # Inst.				0.159***	0.139***	0.147***			
				(0.039)	(0.043)	(0.042)			
Mineral # Inst.				0.005	0.015	0.035			
				(0.045)	(0.068)	(0.069)			
Observations	5,211	1,839	1,839	5,211	1,839	1,839	5,211	1,839	1,839
# of leaders	1053	396	396	1053	396	396	1053	396	396
# of countries	143	57	57	143	57	57	143	57	57
LL	-1598	-590	-589	-1584	-581	-580	-1605	-593	-593

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office for the single risk model in non-election years. Model 1, 4 and 7 uses all leaders from the results section. Model 2, 5 and 8 re-estimate the regression with the data available from Cotet and Tsui (2013a) and Model 3, 6 and 9 includes *Wildcat* variable as measure of exploration effort. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 9: (cont'd from table A 8) Exploration Effort, Resource Discovery, Institutions and Survival: Single Risk Model in non-election years

Sample:	(10) original	(11) cotet & tsui	(12) cotet & tsui	(13) original	(14) cotet & tsui	(15) cotet & tsui	(16) original	(17) cotet & tsui	(18) cotet & tsui
Institution:	xconst	xconst	xconst	xrcomp	xrcomp	xrcomp	xrcomp	xrcomp	xrcomp
Oil discovery	−1.715***	−1.637***	−1.675***	−0.346	−0.446	−0.442	−2.569***	−2.389***	−2.469***
	(0.512)	(0.500)	(0.500)	(0.265)	(0.285)	(0.289)	(0.699)	(0.755)	(0.749)
Mineral disc.	−0.483	−0.379	−0.521	−0.283	−0.154	−0.148	−0.915	−0.996	−1.209
	(0.474)	(0.623)	(0.641)	(0.174)	(0.225)	(0.229)	(0.608)	(0.946)	(0.990)
Wildcat			−0.183***			−0.021			−0.193***
			(0.069)			(0.054)			(0.071)
Institution	0.048	0.032	0.027	−0.029	0.050	0.051	−0.100	−0.099	−0.111
	(0.036)	(0.054)	(0.054)	(0.070)	(0.109)	(0.110)	(0.071)	(0.108)	(0.107)
Oil # Inst.	0.337***	0.298***	0.316***				0.811***	0.714***	0.759***
	(0.094)	(0.099)	(0.098)				(0.211)	(0.241)	(0.235)
Mineral # Inst.	0.026	0.029	0.075				0.207	0.264	0.360
	(0.092)	(0.131)	(0.133)				(0.194)	(0.319)	(0.332)
Observations	5,211	1,839	1,839	5,211	1,839	1,839	5,211	1,839	1,839
# of leaders	1053	396	396	1053	396	396	1053	396	396
# of countries	143	57	57	143	57	57	143	57	57
LL	-1591	-585	-584	-1611	-597	-597	-1593	-585	-584

Notes: Continuation from table A 8. The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office for the single risk model in non-election years. Model 10, 13 and 16 uses all leaders from the results section. Model 11, 14 and 17 re-estimate the regression with the data available from Cotet and Tsui (2013a) and Model 12, 15 and 18 includes *Wildcat* variable as measure of exploration effort. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 10: Resource Discovery, Institutions and Political Survival:
Single Risk Model in non-election years excluding leaders with term limit

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	-0.215	-1.784^{***}	-0.277	-1.962^{***}	-0.326	-3.368^{***}
	(0.280)	(0.462)	(0.290)	(0.560)	(0.302)	(0.856)
Mineral disc.	-0.450^{**}	-0.883^{*}	-0.445^{**}	-1.047^{*}	-0.366^{*}	-1.606^{**}
	(0.197)	(0.512)	(0.203)	(0.557)	(0.211)	(0.744)
Institution	0.094^{***}	0.067^{***}	0.145^{***}	0.096^{**}	0.023	-0.073
	(0.020)	(0.020)	(0.039)	(0.040)	(0.086)	(0.087)
Oil # Inst.		0.187^{***}		0.397^{***}		1.099^{***}
		(0.042)		(0.099)		(0.253)
Mineral # Inst.		0.050		0.132		0.430^{**}
		(0.047)		(0.100)		(0.219)
Observations	3,513	3,513	3,513	3,513	3,513	3,513
# of leaders	684	684	684	684	684	684
# of countries	124	124	124	124	124	124
LL	-1120	-1103	-1130	-1113	-1145	-1119

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in non-election years for leaders without term limits. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 11: Resource Discovery, Institutions and Political Survival:
Single Risk Model in non-election years excluding leaders not facing elections

	(1)	(2)	(3)	(4)
Institution:	x-polity	x-polity	xconst	xconst
Oil discovery	0.016	-1.075^{**}	0.003	-1.117^{**}
	(0.246)	(0.511)	(0.247)	(0.565)
Mineral discovery	-0.492^{***}	-0.758	-0.497^{***}	-0.835
	(0.170)	(0.493)	(0.173)	(0.521)
Institution	0.046^{***}	0.031^{*}	0.079^{**}	0.050
	(0.018)	(0.018)	(0.037)	(0.036)
Oil # Institution		0.117^{***}		0.244^{**}
		(0.044)		(0.101)
Mineral # Institution		0.030		0.073
		(0.046)		(0.098)
Observations	4,687	4,687	4,687	4,687
# of leaders	1016	1016	1016	1016
# of countries	132	132	132	132
LL	-1510	-1502	-1512	-1505

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in non-election years for leaders from countries with elections. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 12: Resource Discovery, Institutions and Political Survival: Single Risk Model in election years with lagged covariates

Institution:	(1) x-polity	(2) x-polity	(3) xconst	(4) xconst
Oil discovery$_{t-1}$	−0.015	−1.723	−0.036	−2.073*
	(0.311)	(1.258)	(0.315)	(1.079)
Mineral discovery$_{t-1}$	−0.365	−1.284	−0.381	−1.246
	(0.312)	(0.915)	(0.314)	(0.946)
Institution$_{t-1}$	0.116***	0.096***	0.211***	0.170***
	(0.025)	(0.026)	(0.053)	(0.054)
Oil # Institution$_{t-1}$		0.154		0.374**
		(0.099)		(0.170)
Mineral # Institution$_{t-1}$		0.084		0.158
		(0.072)		(0.150)
Observations	785	785	785	785
# of leaders	505	505	505	505
# of countries	126	126	126	126
LL	-448	-444	-450	-445

Notes: The table shows the impact of lagged resource discoveries, institutions and their interactions on the hazard of leaving office in election years. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 13: Resource Discovery, Institutions and Political Survival:
Single Risk Model in non-election years treating assassinated leaders as censored

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	-0.312	-1.655^{***}	-0.354	-1.783^{***}	-0.377	-2.624^{***}
	(0.261)	(0.452)	(0.266)	(0.532)	(0.273)	(0.727)
Mineral disc.	-0.378^{**}	-0.500	-0.362^{**}	-0.560	-0.319^{*}	-0.968
	(0.166)	(0.474)	(0.172)	(0.484)	(0.176)	(0.624)
Institution	0.059^{***}	0.040^{**}	0.083^{**}	0.047	-0.031	-0.102
	(0.018)	(0.017)	(0.037)	(0.036)	(0.071)	(0.072)
Oil # Inst.		0.163^{***}		0.345^{***}		0.820^{***}
		(0.041)		(0.098)		(0.220)
Mineral # Inst.		0.011		0.035		0.213
		(0.046)		(0.096)		(0.203)
Observations	5,211	5,211	5,211	5,211	5,211	5,211
# of leaders	1053	1053	1053	1053	1053	1053
# of countries	143	143	143	143	143	143
LL	-1582	-1566	-1588	-1574	-1594	-1576

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in non-election years treating assassinated leaders as censored. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 14: Resource Discovery, Institutions and Political Survival:
Single Risk Model in non-election years excluding resource dependent countries

	(1)	(2)	(3)	(4)	(5)	(6)
Institution:	x-polity	x-polity	xconst	xconst	xrcomp	xrcomp
Oil discovery	-0.281	-1.783^{***}	-0.316	-1.877^{**}	-0.319	-2.581^{***}
	(0.347)	(0.607)	(0.356)	(0.729)	(0.365)	(0.914)
Mineral disc.	-0.585^{**}	-1.239^{**}	-0.587^{**}	-1.543^{**}	-0.591^{**}	-1.975^{**}
	(0.227)	(0.559)	(0.233)	(0.616)	(0.242)	(0.777)
Institution	0.051^{***}	0.029	0.069^{*}	0.028	-0.069	-0.138^{*}
	(0.018)	(0.018)	(0.038)	(0.038)	(0.082)	(0.083)
Oil # Inst.		0.192^{***}		0.392^{***}		0.871^{***}
		(0.052)		(0.126)		(0.261)
Mineral # Inst.		0.094^{*}		0.252^{**}		0.568^{**}
		(0.050)		(0.114)		(0.239)
Observations	3,670	3,670	3,670	3,670	3,670	3,670
# of leaders	745	745	745	745	745	745
# of countries	92	92	92	92	92	92
LL	-1191	-1176	-1195	-1181	-1197	-1181

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in non-election years for countries considered as resource poor in 1950. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table A 15: Resource Discovery, Institutions and Political Survival: Single Risk Model in election years excluding resource dependent countries

	(1)	(2)	(3)	(4)
Institution:	x-polity	x-polity	xconst	xconst
Oil discovery	−0.518	−2.693	−0.555*	−3.030**
	(0.343)	(2.105)	(0.334)	(1.512)
Mineral discovery	−0.891**	−2.862	−0.956**	−2.939*
	(0.429)	(1.818)	(0.428)	(1.537)
Institution	0.200***	0.181***	0.369***	0.327***
	(0.032)	(0.033)	(0.066)	(0.068)
Oil # Institution		0.193		0.447*
		(0.160)		(0.234)
Mineral # Institution		0.197		0.414
		(0.159)		(0.280)
Observations	596	596	596	596
# of leaders	371	371	371	371
# of countries	83	83	83	83
LL	-301	-298	-304	-300

Notes: The table shows the impact of resource discoveries, institutions and their interactions on the hazard of leaving office in election years for countries considered as resource poor in 1950. Included control variables: *(log of) Population, leader entry age, first leader after independence, oil discovery*$_{t-10}$ and *mineral discovery*$_{t-10}$. Standard errors are robust and clustered at the country level; *, ** and *** stand for significant at the 10%, 5% and 1% level.

Appendix B

Appendix to chapter 3

B.1 Tables

Table B 1: Market shares of mineral and precious mineral producers

Country	**Commodity**	**Year**	**Production**	**Unit**	**Production in %**
Mongolia	Gold	1998	9990	kg	0.41
Papua New Guinea	Gold	1998	61641	kg	2.51
Guyana	Gold	1998	14146	kg	0.58
World	Gold	1998	2460000	kg	100.00
Chile	Copper	2003	4904200	tonnes	35.80
World	Copper	2003	13700000	tonnes	100.00
Guinea	Bauxite	2003	17072200	tonnes	10.74
World	Bauxite	2003	159000000	tonnes	100.00
Mauritania	Iron Ore	2003	10153000	tonnes	0.82
World	Iron Ore	2003	1237000000	tonnes	100.00

Notes: Data are from the British Geological Survey. Values for 1998 are from the World Mineral Statistics 1998-2002 and values for 2003 are from the World Mineral Production 2003-07.

Table B 2: Test for structural breaks in the resource price 1991-2010

Structural breaks in the oil price

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
χ^2	0.697	1.093	1.359	1.908	2.484	2.783	2.661	3.427	**6.775**	**6.236**
p-value	0.706	0.579	0.507	0.385	0.289	0.249	0.264	0.180	**0.034**	**0.044**
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
χ^2	4.321	**6.819**	**9.086**	**12.979**	**17.962**	**13.002**	**11.610**	**10.960**	**7.874**	**8.454**
p-value	0.115	**0.033**	**0.011**	**0.002**	**0.000**	**0.002**	**0.003**	**0.004**	**0.020**	**0.015**

Structural breaks in the precious mineral price index

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
χ^2	1.377	1.616	1.956	2.148	2.031	2.677	2.917	3.864	**4.623**	**5.676**
p-value	0.502	0.446	0.376	0.342	0.362	0.262	0.233	0.145	**0.099**	**0.059**
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
χ^2	**6.462**	**8.065**	**7.802**	**8.003**	**8.666**	**15.357**	**7.617**	**8.299**	**7.805**	**11.309**
p-value	**0.040**	**0.018**	**0.020**	**0.018**	**0.013**	**0.000**	**0.022**	**0.016**	**0.020**	**0.004**

Structural breaks in the minerla price index

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
χ^2	0.661	0.681	0.743	1.281	1.030	0.940	1.479	1.450	2.422	2.903
p-value	0.719	0.711	0.690	0.527	0.597	0.625	0.477	0.484	0.298	0.234
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
χ^2	2.475	3.313	4.488	**6.469**	**7.047**	**26.661**	**5.969**	**8.339**	**13.034**	**9.435**
p-value	0.290	0.191	0.106	**0.039**	**0.030**	**0.000**	**0.051**	**0.015**	**0.001**	**0.009**

Notes: The table shows the results of the Wald test for structural breaks of a regression of resource price (oil, precious minerals and minerals) on its lagged value. Bold values indicate significance at the 10% level, i.e. the years in which the null of no structural break could not be rejected.

Table B 3: Pre-treatment RMSPE for different specifications

Country	**Average**	**Last one**	**Last two**	**Last three**	**Last four**	**Last five**
Algeria	0.209394	0.227484	0.227484	0.259413	0.258011	0.268318
Azerbaijan	0.348738	0.492621	0.492621	0.480328	0.366515	0.348738
Brunei	0.214589	0.144999	0.144999	0.144999	0.144999	0.138707
Cameroon	0.081726	0.242671	0.242671	0.157677	0.056397	0.061256
Ecuador	0.094921	0.099655	0.099655	0.098910	0.096587	0.094659
Egypt	0.079122	0.097305	0.097305	0.129435	0.096731	0.051671
Gabon	0.134347	0.230730	0.230730	0.137486	0.140647	0.142252
Indonesia	0.060928	0.105735	0.105735	0.067354	0.061719	0.064171
Kazakhstan	0.120002	0.120002	0.120002	0.120002	0.120002	0
Kuwait	0.138102	0.125660	0.125660	0.141060	0.144727	0.138102
Libya	0.135874	0.151220	0.151220	0.139160	0.116046	0.143747
Malaysia	0.073897	0.103895	0.103895	0.097057	0.097039	0.094724
Norway	0.010089	0.021518	0.021518	0.011229	0.010089	0
Saudi Arabia	0.118347	0.106749	0.106749	0.125084	0.128814	0.118347
Syria	0.091288	0.214746	0.214746	0.198099	0.107504	0.092112
Trinidad and Tobago	0.118062	0.186572	0.186572	0.171844	0.166922	0.182515
Turkmenistan	0.160192	0.207279	0.207279	0.160192	0	0
Venezuela	0.091063	0.156282	0.156282	0.098616	0.088818	0.091063
Yemen	0.086801	0.106354	0.106354	0.105369	0.101327	0.102417
Chile	0.053291	0.087181	0.087181	0.128976	0.123073	0.122050
Guinea	0.091400	0.220861	0.220861	0.279881	0.170376	0.110831
Mauritania	0.089651	0.066503	0.066503	0.094146	0.139468	0.150084
Guyana	0.105608	0.098625	0.098625	0.076988	0.091265	0.101005
Mongolia	0.181123	0.215510	0.215510	0.239121	0.240301	0.220605
Papua New Guinea	0.055980	0.054798	0.055021	0.055167	0.055206	0.055347
Average	**0.117781**	**0.155398**	**0.155407**	**0.148704**	**0.130108**	**0.131487**

Notes: Table shows pre-treatment RMSPEs calculated with different lagged outcome variables. Minimum average RMSPE is achieved by including the average of the outcome variable which is used in the analysis.

Table B 4: Treatment countries, treatment periods and data adjustments

	Pre-treatment period		**Post-treatment period**		**Interpolated years**
Country	Start	End	Start	End	
Algeria	1989	1998	1999	2012	
Azerbaijan	1994	1998	1999	2012	
Brunei	1991	1998	1999	2012	2010
Cameroon	1993	1998	1999	2012	2007-2008
Chile	1994	2003	2004	2012	
Ecuador	1989	1998	1999	2012	1989
Egypt	1989	1998	1999	2010	
Gabon	1989	1998	1999	2012	
Guinea	1993	2003	2004	2012	
Guyana	1993	1998	1999	2012	
Indonesia	1989	1998	1999	2012	
Kazakhstan	1995	1998	1999	2004	
Kuwait	1994	1998	1999	2012	
Libya	1991	1998	1999	2010	
Malaysia	1989	1998	1999	2008	
Mauritania	1994	2003	2004	2012	1989
Mongolia	1992	1998	1999	2007	
Norway	1995	1998	1999	2012	
Papua New Guinea	1989	1998	1999	2012	
Saudi Arabia	1994	1998	1999	2012	2005-2008
Syria	1991	1998	1999	2007	
Trinidad and Tobago	1989	1998	1999	2005	
Turkmenistan	1996	1998	1999	2008	1999
Venezuela	1994	1998	1999	2012	
Yemen	1989	1998	1999	2003	1989

Notes: Values for interpolated years are calculated by linear interpolation.

Table B 5: Donor pools and weights

	Treatment countries				
Donor pool	**Venezuela**	**Ecuador**	**Trinidad and Tobago**	**Guyana**	**Chile**
Bahamas	0.0880	0.0000	0.1640	0.0000	0.1550
Guatemala	0.0000	0.0000	0.0000	0.0000	0.0000
Honduras	0.0000	0.2970	0.0000	0.3920	0.1100
El Salvador	0.0000	0.5450	0.0000	0.0000	0.0000
Nicaragua	-	-	-	-	0.0000
Costa Rica	0.0000	0.0000	0.0000	0.0000	0.1200
Panama	0.0000	0.1580	0.3290	0.6080	0.0000
Paraguay	0.6450	0.0000	0.0000	0.0000	0.0000
Uruguay	0.2670	0.0000	0.5070	0.0000	0.6150

	Treatment countries				
Donor pool	**Cameroon**	**Algeria**	**Egypt**	**Mauritania**	**Guinea**
Gambia	0.0000	0.0000	0.0270	0.0000	0.0000
Centr. Afr. Rep.	0.0000	0.0000	0.0770	0.0000	0.0630
Uganda	0.4760	0.0000	0.0930	0.0000	0.0050
Kenya	0.5240	0.3270	0.0010	0.6020	0.0000
Burundi	0.0000	0.0000	0.0000	0.0000	0.0000
Rwanda	0.0000	0.0000	0.0000	0.0000	0.0000
Eritrea	-	-	-	0.1610	0.0000
Mozambique	0.0000	0.0000	0.4380	0.0000	0.3470
Malawi	0.0000	0.0000	0.0000	0.0000	0.0000
Swaziland	0.0000	0.6730	0.3630	0.0290	0.0000
Madagascar	0.0000	0.0000	0.0000	0.2080	0.5850

Continuation from table B 5: Donor pools and weights

	Treatment countries					
Donor pool	**Saudi Arabia**	**Kuwait**	**Indonesia**	**Azerbaijan**	**Yemen**	**Turkmenistan**
Cyprus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Turkey	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lebanon	0.0000	0.0000	0.0410	0.0000	0.0880	0.0000
Jordan	0.4410	0.9260	0.0000	0.2040	0.0320	0.0000
Israel	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
South Korea	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Japan	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bhutan	0.0000	0.0710	0.0000	0.0000	0.0000	0.9100
Bangladesh	0.0000	0.0000	0.4300	0.1840	0.8530	0.0000
Sri Lanka	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nepal	0.0000	0.0000	0.1520	0.4200	0.0270	0.0000
Thailand	0.0000	0.0000	0.3780	0.0000	0.0000	0.0900
Singapore	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Philippines	0.5590	0.0030	0.0000	0.1920	0.0000	0.0000

Continuation from table B 5: Donor pools and weights

	Treatment countries				
Donor pool	**Kazakhstan**	**Syria**	**Malaysia**	**Brunei**	**Mongolia**
Cyprus	0.0000	0.0000	0.0000	0.0090	0.0000
Turkey	0.1770	0.0420	0.0000	0.6150	0.0000
Lebanon	0.0420	0.2580	0.1430	0.0120	0.0000
Jordan	0.0670	0.0000	0.0000	0.0000	0.1740
Israel	0.0000	0.0000	0.0000	0.0000	0.0190
South Korea	0.0000	0.0000	0.4150	0.1870	0.0000
Japan	0.0000	0.0000	0.0000	0.0000	0.0000
Bhutan	0.0000	0.0000	0.3310	0.1780	0.2290
Bangladesh	0.0000	0.5330	0.0000	0.0000	0.0000
Sri Lanka	0.0000	0.0000	0.0000	0.0000	0.3480
Nepal	0.0000	0.0000	0.0000	0.0000	0.2310
Thailand	0.0000	0.0100	0.1110	0.0000	0.0000
Singapore	0.0000	0.0000	0.0000	0.0000	0.0000
Philippines	0.7140	0.1570	0.0000	0.0000	0.0000

Continuation from table B 5: Donor pools and weights

	Treatment country
Donor pool	**Norway**
Ireland	0.0000
Netherlands	0.0000
Belgium	0.0000
Luxembourg	0.0000
France	0.0000
Switzerland	0.1310
Spain	0.0000
Portugal	0.0000
Germany	0.0000
Poland	0.0000
Austria	0.0000
Hungary	0.0000
Italy	0.0000
Finland	0.0000
Sweden	0.0000
Denmark	0.8690
Iceland	0.0000

	Treatment country
Donor pool	**Papua N. Guinea**
New Zealand	0.0000
Vanuatu	0.0000
Solomon Islands	0.9600
Fiji	0.0000
Tonga	0.0400

	Treatment country
Donor pool	**Gabon**
Honduras	0.5690
Paraguay	0.0540
Italy	0.1220
Kenya	0.2380
Turkey	0.0160

	Treatment country
Donor pool	**Libya**
Italy	0.0470
Centr. Afr. Rep.	0.2720
Kenya	0.1260
Lebanon	0.0810
Vanuatu	0.4740

Table B 6: Definition and source of variables used in the analysis

Variable	**Definition**	**Source**
Total tax per capita	Total tax per capita are total tax revenues (excluding revenues from the resource sector and social contributions) divided by population. Values are measured in constant 2010 US$.	Authors calculation with data from ICTD GRD for taxes and World Development Indicators for population
ODA (% of non-resource GDP)	Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 percent).	World Development Indicators
GDP per capita	GDP divided by population, converted to constant 2010 US-Dollar, expenditure approach	IMF World Economic Outlook
Population	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates.	World Development Indicators

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Table B 6 – continued from previous page

Variable	**Definition**	**Source**
Agriculture, value added (% of non-resource GDP)	Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	World Development Indicators
Inflation	Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.	World Development Indicators
Polity2	Combined Polity Score; measuring on a scale from -10 to +10 the polity of a country.	Centre of Systematic Peace
OPEC	Dummy variable equal one for OPEC member countries	www.opec.org
Tax to non-tax ratio	Government revenues from the resource sector derived by taxes divided by government revenues from the resource sector derived by non-tax instruments	Author calculation with data from ICTD GRD

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Table B 6 – continued from previous page

Variable	**Definition**	**Source**
Resource dependency	Resource revenues as percentage of total government revenues.	ICTD GRD
Nationalised resource sector	Dummy equal one if the resource sector is state owned.	Luong and Weinthal (2010)
Government final consumption expenditure (% of GDP)	General government final consumption expenditure (formerly general government consumption) includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.	World Development Indicators

Continued on next page

Table B 6 – continued from previous page

Variable	**Definition**	**Source**
Gross capital formation (% of GDP)	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." According to the 1993 SNA, net acquisitions of valuables are also considered capital formation.	World Development Indicators
Total reserves (includes gold, % of GDP)	Obtained by dividing total reserves (includes gold, current US$) by GDP (current US$).	Author calculation with data from Word Development Indicators
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.	Worldwide Governance Indicators

Continued on next page

Table B 6 – continued from previous page

Variable	**Definition**	**Source**
Non-resource GDP	Non-resource GDP is calculated from National accounts data calculating value added and GDP from the production side, published by the UN. NRGDP is defined as total value added minus value added in Mining and Utilities (ISIC C and E).	UN, National Accounts Main Aggregates Database

Table B 7: Summary statistics

	N	**Average**	**Std.**	**Min**	**Max**
Total tax p.c.	3671	2773.53	4671.23	2.75	28356.94
Non-resource GDP p.c.	4327	8356.96	12345.03	108.65	77243.10
Gov. Expenditure	3515	16.84	6.96	3.46	76.22
Capital formation	3555	23.15	8.49	-0.69	70.23
Reserves	3647	16.48	17.78	0.01	318.56
Corruption	2470	0.09	1.02	-1.72	2.47
Agriculture	4327	14.79	13.62	0.04	72.80
ODA	4099	7.65	16.24	-0.67	551.03
Inflation	4067	25.94	290.39	-32.03	13109.50
Polity2	3438	2.94	6.99	-10.00	10.00
Tax to non-tax ratio dummy	1188	0.39	0.49	0.00	1.00
Resource dependency	1735	0.16	0.25	0.00	0.96

Notes: Total tax p.c., non-resource GDP p.c. are in constant 2010 US$; Government expenditure, Capital formation, reserves are in percent of GDP; agriculture and ODA is in percent of non-resource GDP.

Table B 8: Total tax per capita, treatment and synthetic control countries

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	All oil countries		**Autocratic oil countries**		**Private oil sector**		**State oil sector**		**Tax to non-tax ratio>1**		**High oil dependent**	
Year	Treatm. countries	Synth. control	Treatm. countries	Synth. control	Treatm. countries	Synth. control	Treatm. countries	Synth. control	Treatm. countries	Synth. control	Treatm. countries	Synth. control
1998	1783.01	1782.92	466.09	465.96	852.58	852.58	2115.30	2115.15	3400.67	3401.05	653.43	653.50
1999	1732.17	1769.39	481.04	457.40	761.65	821.03	2114.02	2121.33	3043.47	3341.41	614.79	649.85
2000	1554.54	1876.01	424.30	493.55	735.11	909.62	1851.53	2214.50	2669.83	3783.20	532.52	687.25
2001	1677.48	1845.01	457.43	492.83	794.55	900.93	1996.82	2172.28	3166.00	3693.28	553.16	661.31
2002	1666.59	1930.62	429.27	522.56	840.56	965.17	1938.52	2253.20	3255.41	3918.71	545.77	675.48
2003	1668.12	2033.06	442.10	560.98	855.27	1019.61	1927.93	2369.89	3205.83	4126.95	542.23	705.87
2004	1786.80	2067.66	482.54	568.13	914.60	984.10	2077.12	2456.24	3327.18	4084.40	583.42	706.59
2005	1814.83	2224.00	491.79	619.14	729.58	1034.73	2226.52	2653.75	3261.49	4412.98	487.85	751.66
2006	1910.28	2425.36	528.17	661.72	750.75	1172.75	2323.94	2872.75	3383.23	4802.13	489.18	821.28
2007	2025.10	2505.88	561.20	685.99	723.52	1233.34	2489.28	2960.45	3457.88	4896.33	502.70	855.96
2008	2383.38	2580.35	711.76	712.82	779.24	1300.70	2965.12	3035.71	4522.19	4911.21	521.88	837.21
2009	2316.51	2439.92	629.96	720.22	833.24	1300.05	2872.03	2834.48	3536.55	4324.87	652.68	803.11
2010	2142.29	2577.46	557.90	803.42	773.54	1451.03	2654.69	2959.22	3410.24	4555.49	596.72	843.70
2011	2265.99	2715.91	604.31	861.11	840.23	1601.70	2822.43	3054.98	3654.60	4862.89	629.45	888.20
2012	2473.39	2850.89	667.19	903.13	851.51	1703.46	3116.94	3194.61	3665.22	4979.33	673.23	932.45
Av.	**1958.39**	**2274.40**	**533.50**	**647.36**	**798.81**	**1171.30**	**2384.06**	**2653.81**	**3397.08**	**4335.23**	**566.11**	**772.85**

Notes: Values in constant 2010 US$

Table B 9: Predictor weights for new producers

Vietnam

Variable	Weight
total tax(1988)	0.934194260
non-res. GDP p.c.	0.047342226
capital formation	0.013768641
agriculture	0.000615903
ODA	0.000032585
inflation	0.004046384

Equatorial Guinea

Variable	Weight
total tax(1984)	0.136357628
total tax(1988)	0.163690431
total tax(1992)	0.670930230
reserves	0.002773620
gov. expenditure	0.000229995
inflation	0.001132240
non-res. GDP p.c.	0.021511988
agriculture	0.001007070
ODA	0.002366799

East Timor

Variable	Weight
total tax(2002)	0.287637752
total tax(2003)	0.703315994
non-res. GDP p.c.	0.009030336
gov. expenditure	0.000000099
capital formation	0.000001497
ODA	0.000011108
agriculture	0.000001305
inflation	0.000001907

Sudan

Variable	Weight
total tax(1989)	0.024057518
total tax(1990)	0.084118182
total tax(1993)	0.031093122
total tax(1997)	0.433040660
total tax(1998)	0.426815067
capital formation	0.000108246
reserves	0.000433593
gov. expenditure	0.000217718
inflation	0.000115894

Chad

Variable	Weight
total tax(1994)	0.145433338
total tax(1995)	0.453272476
total tax(1997)	0
total tax(2001)	0
total tax(2002)	0.315070637
non-res. GDP p.c.	0.069753476
gov. expenditure	0.006045358
capital formation	0.001090368
reserves	0.001029538
corruption	0.005312116
ODA	0.000610302
agriculture	0.002170606
inflation	0.000211786

Table B 10: Pre-treatment RMSPE for new producers

	Included outcome variable to construct synthetic control					
Country	**average**	**last**	**two last**	**first, last**	**first, middle, last**	**first two, middle, last two**
Vietnam	0.1811948	**0.1808405**	0.1808878	0.1964921	0.1820008	0.2162516
Sudan	0.1047668	0.1096324	0.0972895	0.1229826	0.1048950	**0.0831126**
Eq. Guinea	0.2534069	0.2233420	0.3735048	0.2061530	**0.2026414**	0.2047065
Chad	0.0508203	0.0541413	0.0639323	0.0534216	0.0553685	**0.0487793**
East Timor	0.1047185	0.0955727	**0.0922129**	—	—	—

Notes: Table shows pre-treatment RMSPEs calculated with different lagged outcome variables. Bold indicates the minimum RMSPE and is used in the analysis.

B.2 Figures

Figure B.1: Oil price and World Bank forecasts

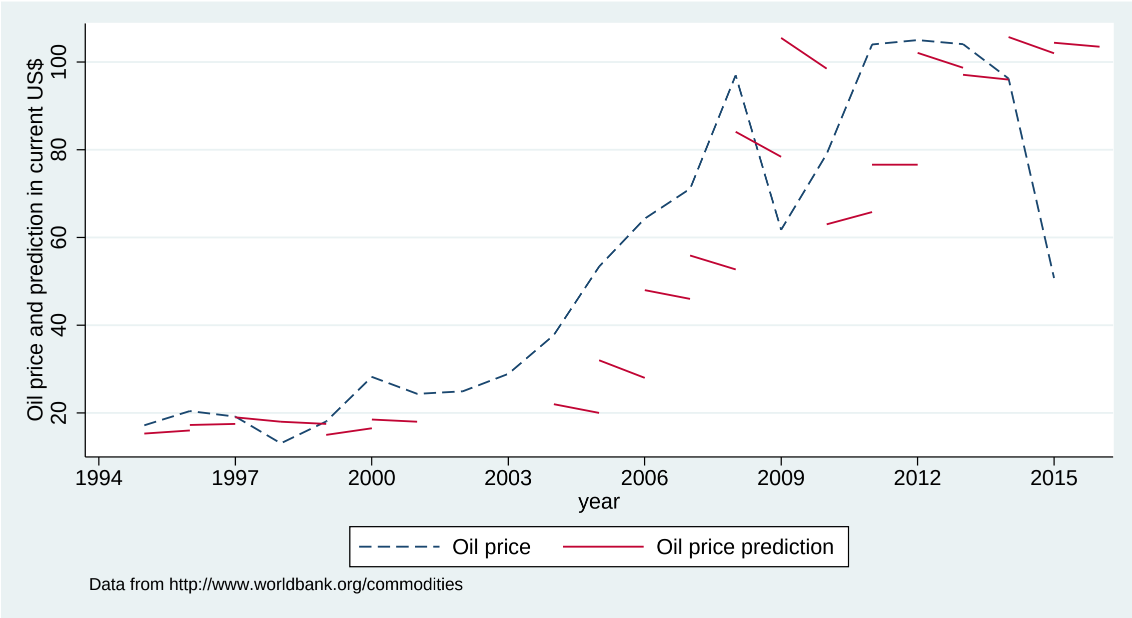


Figure B.2: Synthetic control estimates for mineral exporters

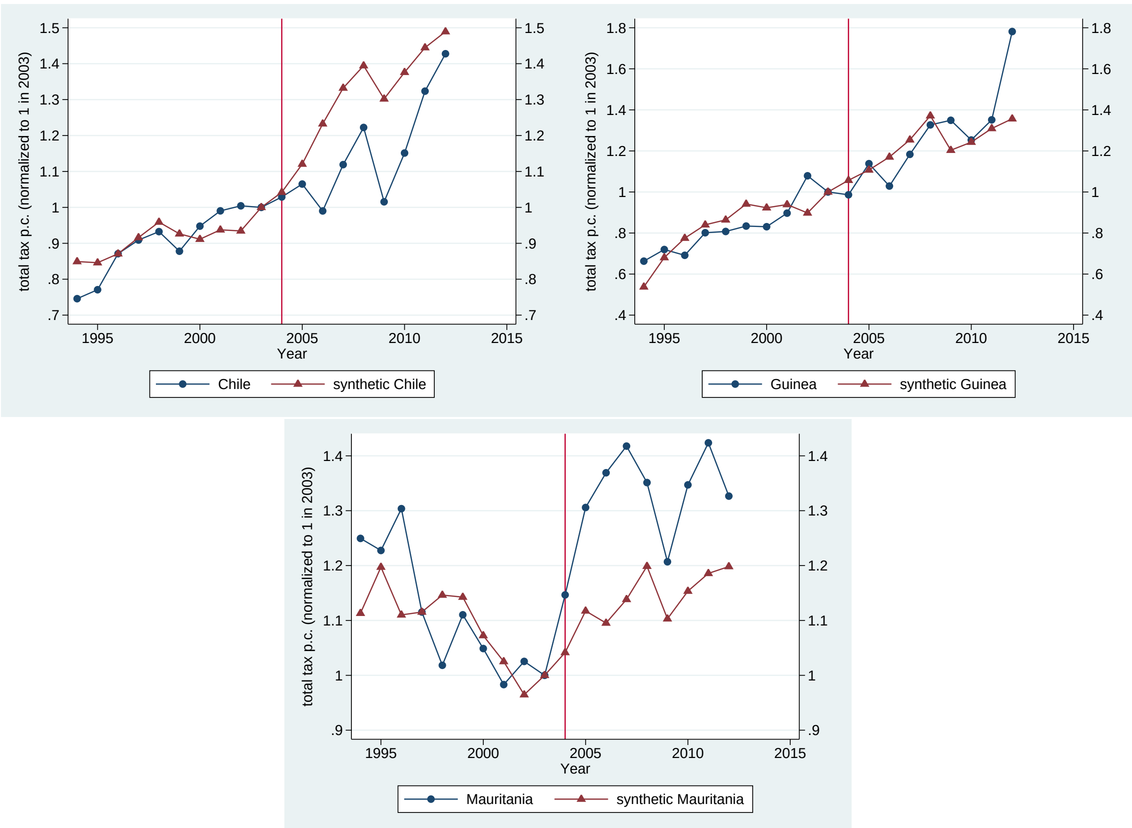


Figure B.3: Synthetic control estimates for precious mineral exporters

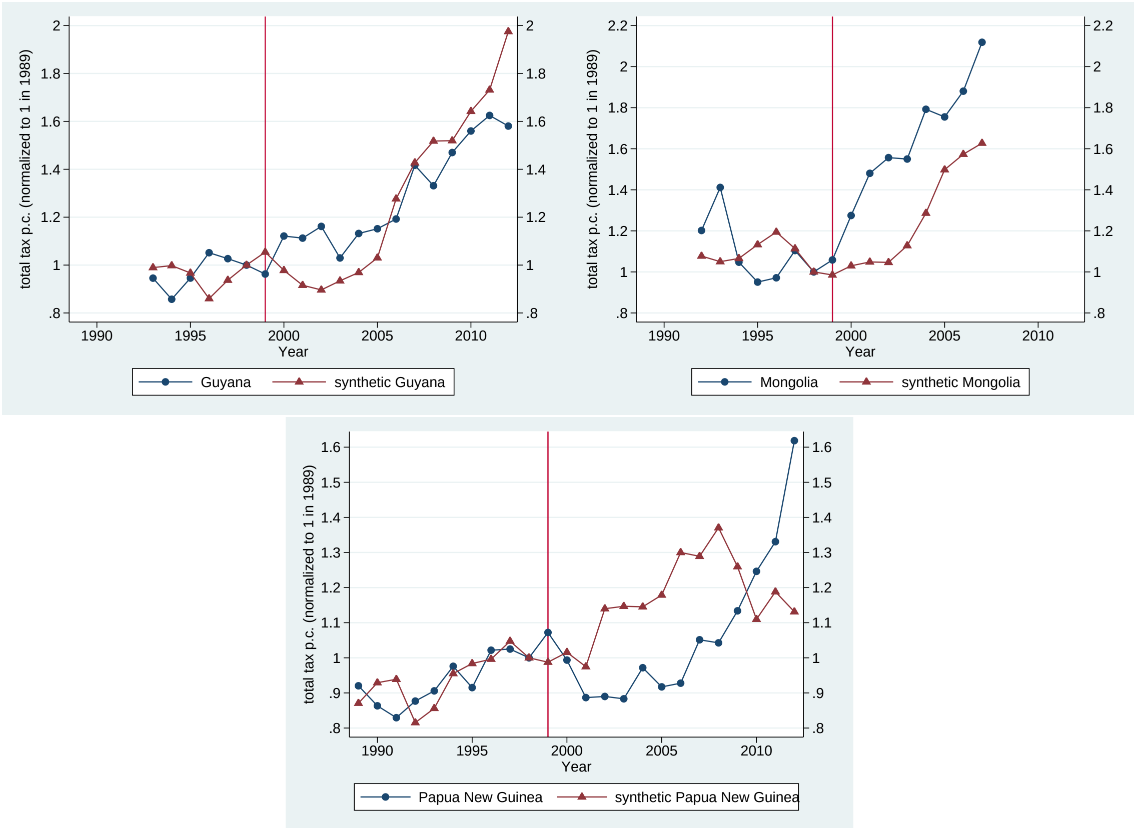


Figure B.4: Robustness check: Excluding Saudi Arabia

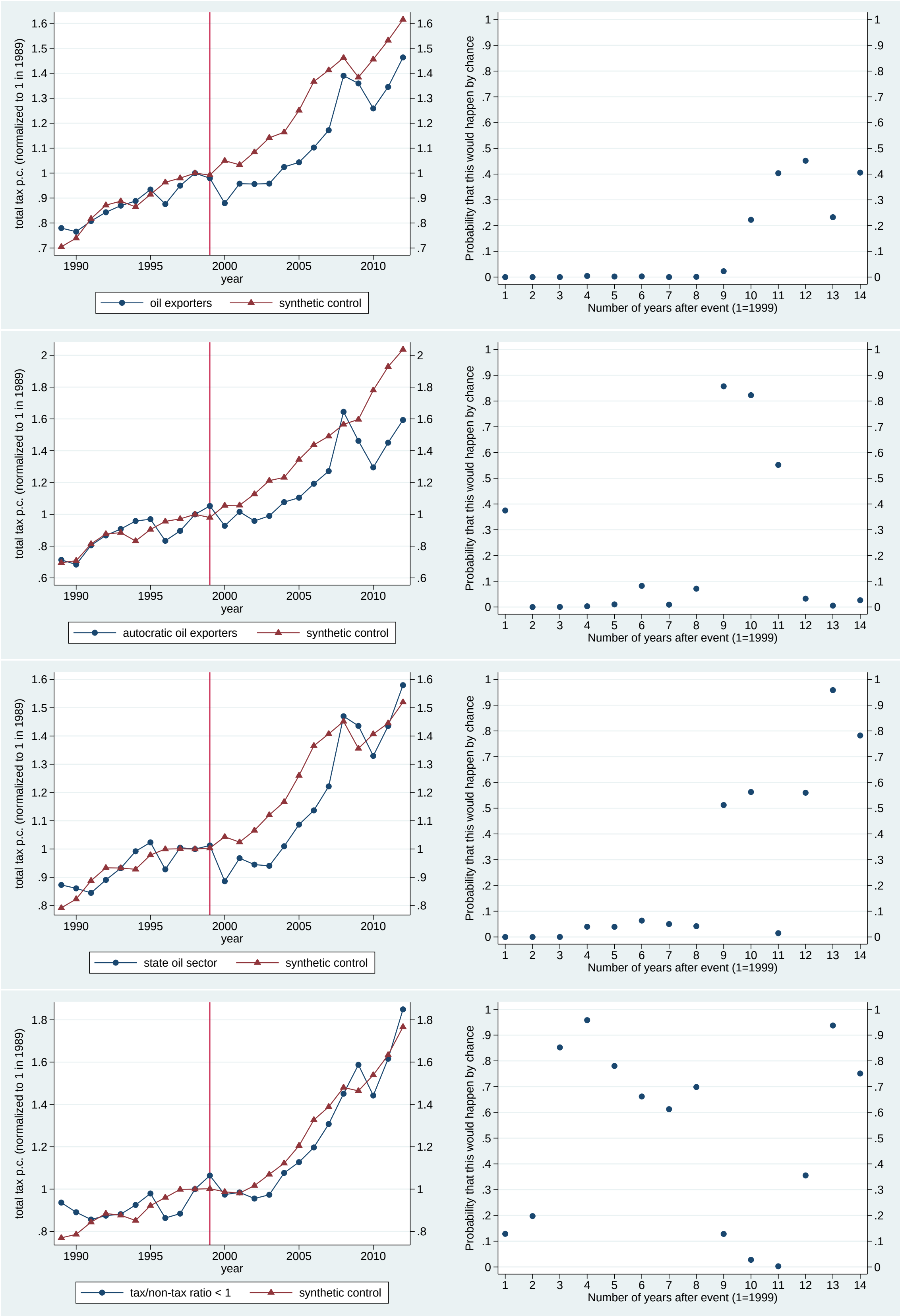


Figure B.5: Continuation of Fig. B.4

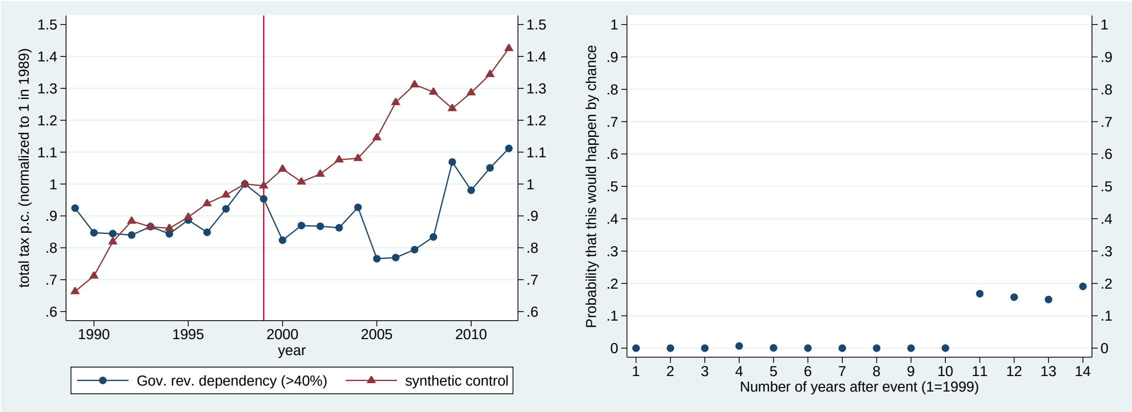


Figure B.6: Robustness check: Excluding Libya and Gabon

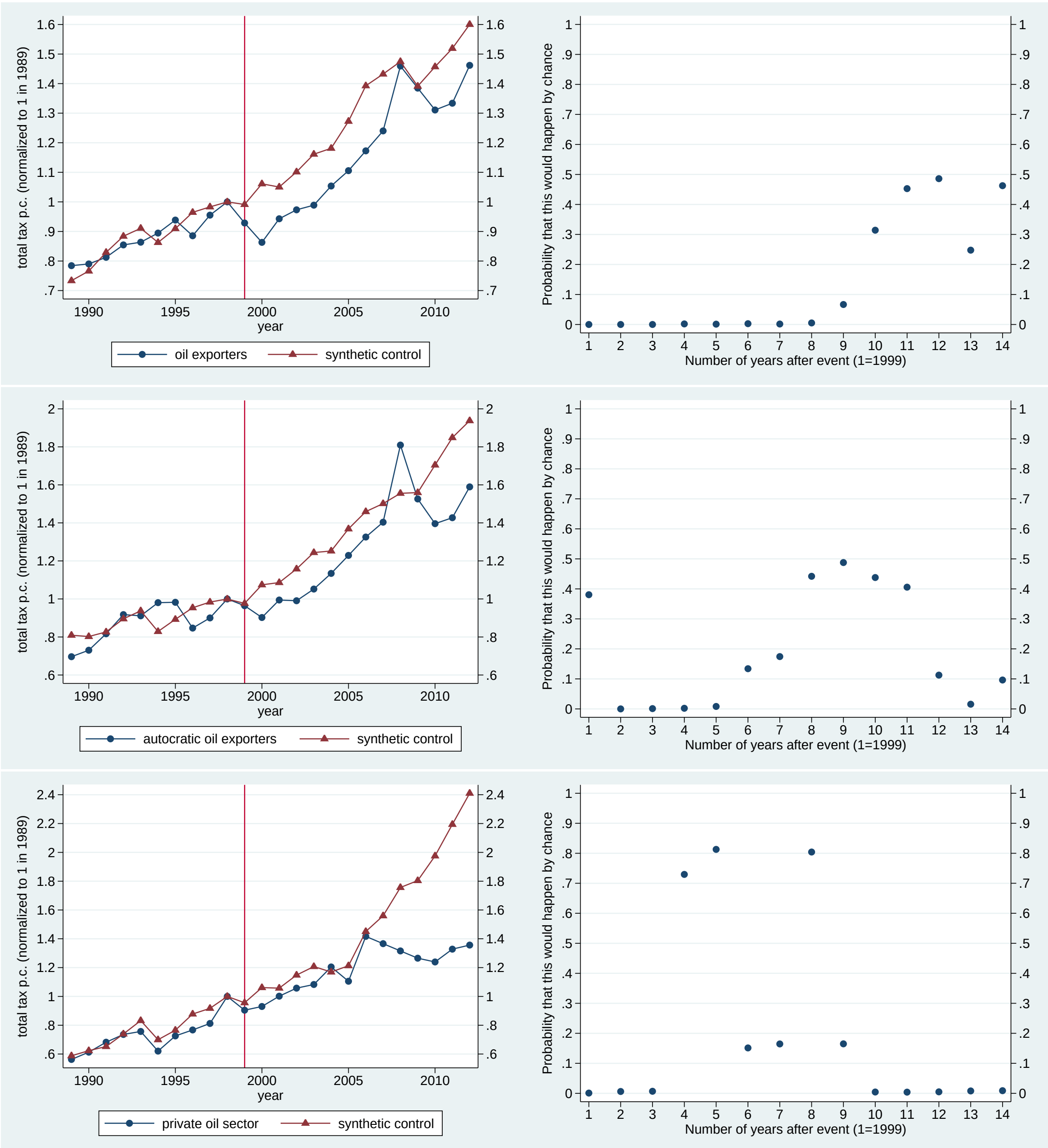


Figure B.7: Continuation of Fig: B.6

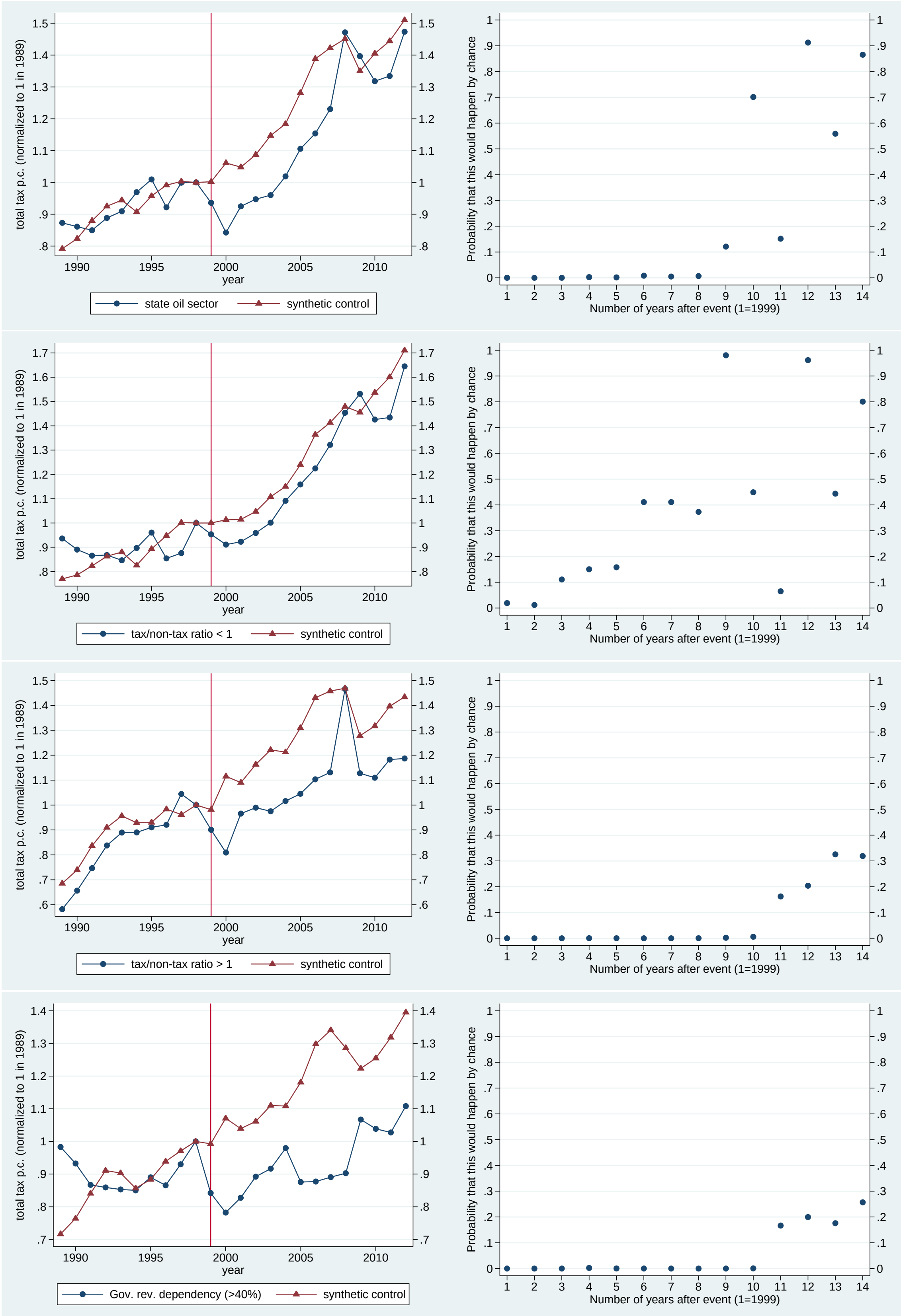
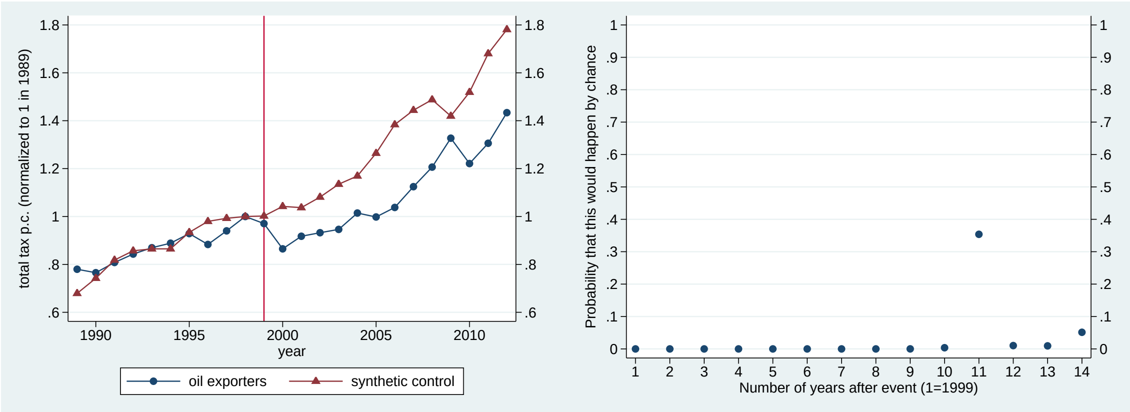
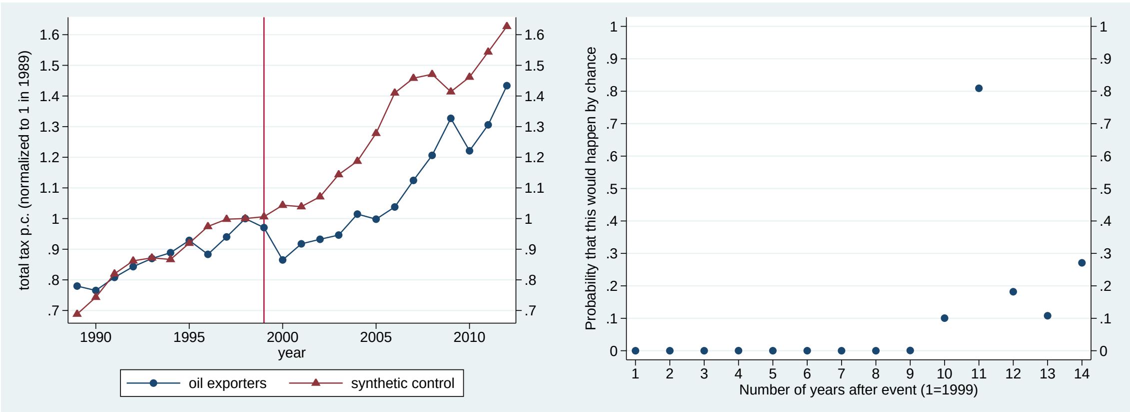


Figure B.8: Robustness check: Including additional predictor variable

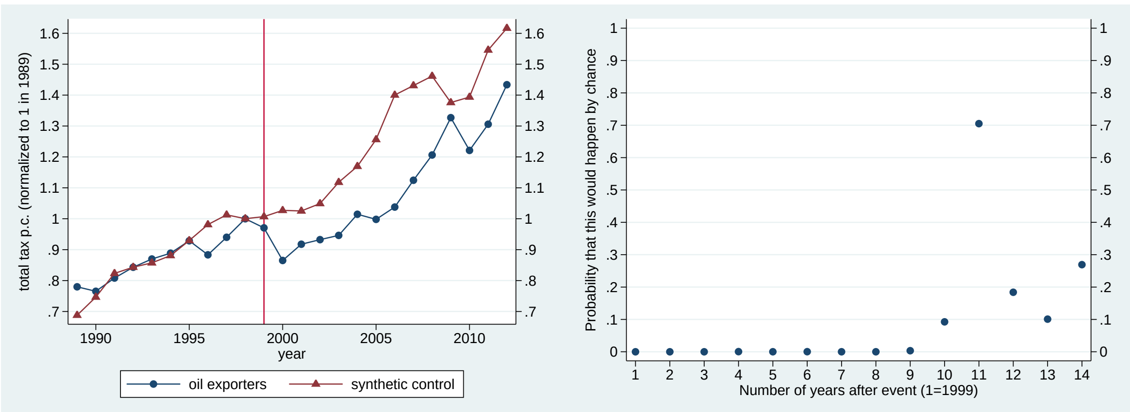
(a) Including inflation



(b) Including agriculture



(c) Including ODA



(d) Including all additional predictor variable (inflation, agriculture and ODA)

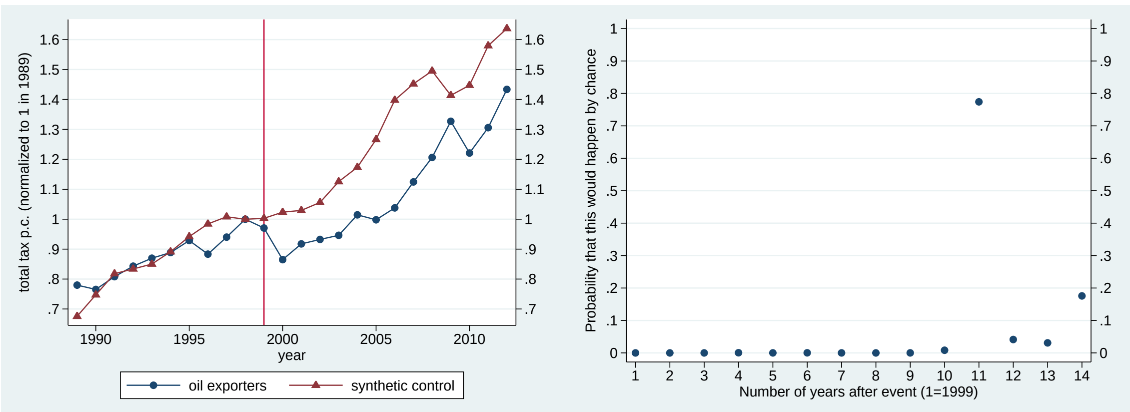


Figure B.9: Robustness check: Excluding Norway

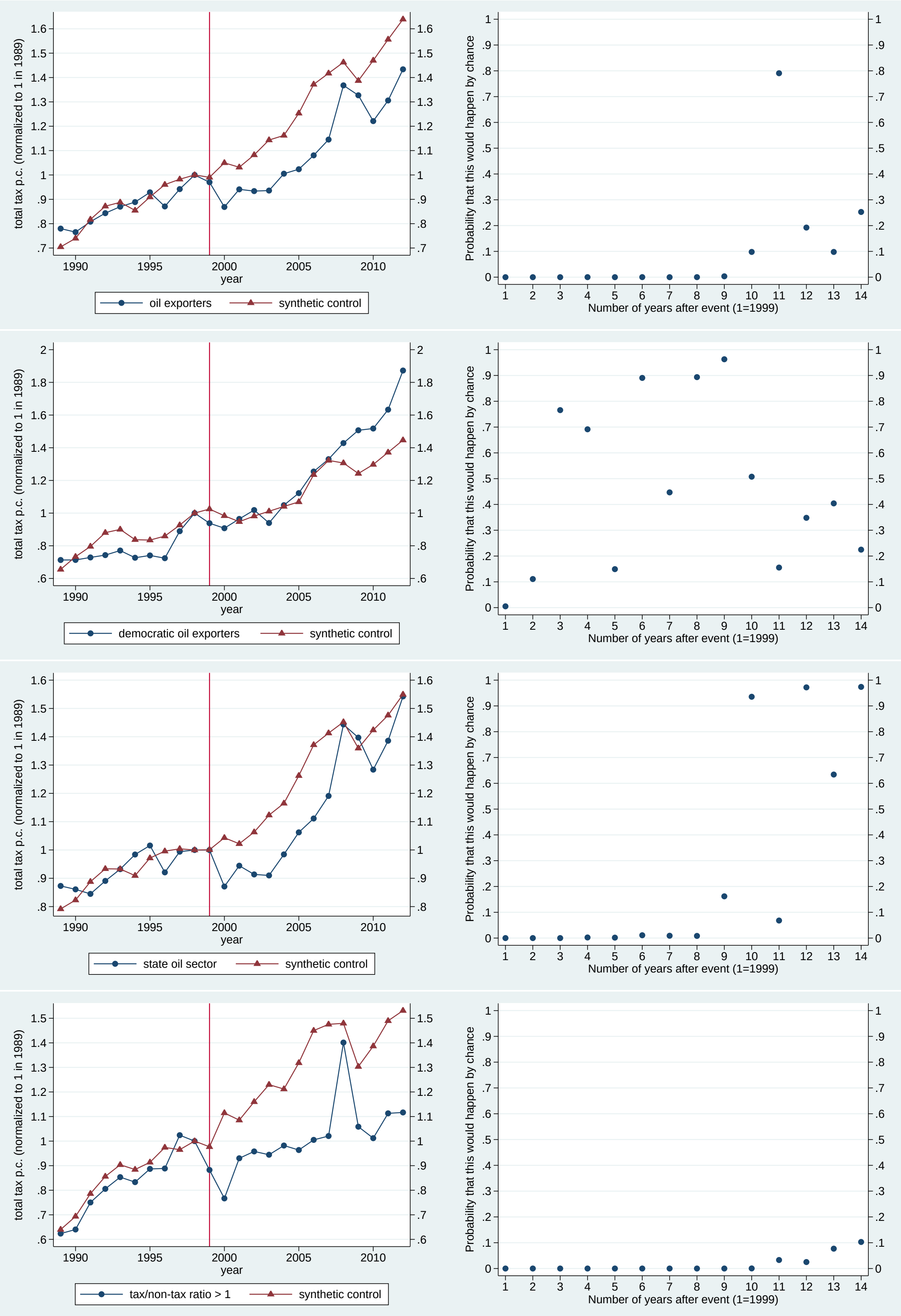
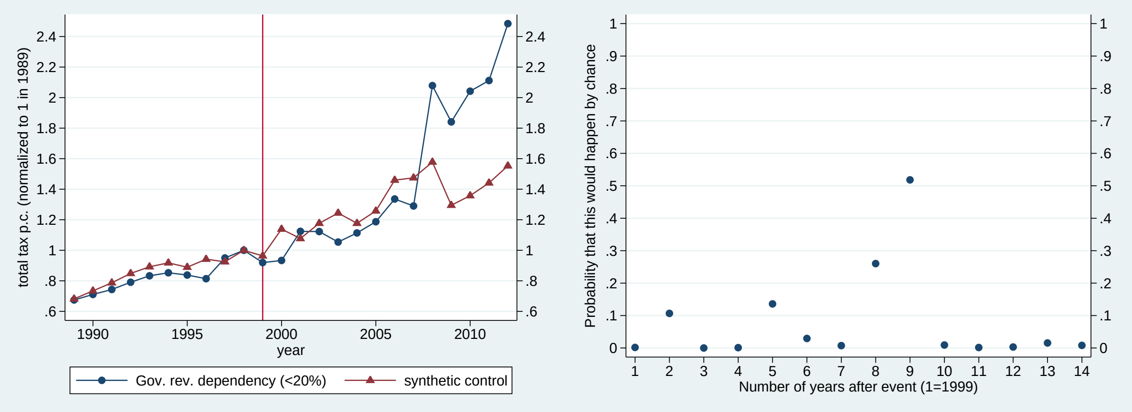


Figure B.10: Continuation of Fig: B.9



Appendix C

Appendix to chapter 4

C.1 Tables

Table C 1: List of countries in the sample

#	Country	Oil rent	Income group	Institution
1	Albania	1.47	Upper Middle Income	Democracy
2	Algeria	19.69	Upper Middle Income	Intermediate
3	Angola	41.67	Upper Middle Income	Intermediate
4	Argentina	3.21	Upper Middle Income	Democracy
5	Armenia	0.00	Lower Middle Income	Democracy
6	Azerbaijan	30.72	Upper Middle Income	Autocratic
7	Bahamas	0.00	High Income	
8	Bahrain	6.00	High Income	Autocratic
9	Bangladesh	0.95	Lower Middle Income	Intermediate
10	Belarus	1.10	Upper Middle Income	Autocratic
11	Belize	2.33	Upper Middle Income	
12	Benin	0.04	Low Income	Democracy
13	Bolivia	6.76	Lower Middle Income	Democracy
14	Botswana	0.00	Upper Middle Income	Democracy
15	Brazil	1.71	Upper Middle Income	Democracy
16	Brunei	21.79	High Income	
17	Bulgaria	0.07	Upper Middle Income	Democracy
18	Burundi	0.00	Low Income	Intermediate
19	Cambodia	0.00	Lower Middle Income	Intermediate

Continued on next page

Table C 1 – continued from previous page

#	Country	Oil rent	Income group	Institution
20	Cameroon	5.51	Lower Middle Income	Autocratic
21	Canada	2.73	High Income	Democracy
22	Cape Verde	0.00	Lower Middle Income	Democracy
23	Central Afr. Rep.	0.00	Low Income	Intermediate
24	Chad	18.80	Low Income	Intermediate
25	Chile	0.07	High Income	Democracy
26	China	1.43	Upper Middle Income	Autocratic
27	Colombia	4.39	Upper Middle Income	Democracy
28	Congo	44.43	Lower Middle Income	Autocratic
29	Costa Rica	0.00	Upper Middle Income	Democracy
30	Cote d'Ivoire	2.55	Lower Middle Income	Intermediate
31	Croatia	0.65	High Income	Democracy
32	Cyprus	0.00	High Income	Democracy
33	DR of Congo	1.72	Low Income	Intermediate
34	Denmark	1.37	High Income	Democracy
35	Dominican Rep.	0.00	Upper Middle Income	Democracy
36	Ecuador	11.61	Upper Middle Income	Democracy
37	Egypt	9.17	Lower Middle Income	Autocratic
38	El Salvador	0.00	Lower Middle Income	Democracy
39	Ethiopia	0.00	Low Income	
40	Finland	0.00	High Income	Democracy
41	Gabon	30.82	Upper Middle Income	Intermediate
42	Gambia	0.00	Low Income	Autocratic
43	Georgia	0.26	Upper Middle Income	Democracy
44	Germany	0.05	High Income	Democracy
45	Ghana	1.52	Lower Middle Income	Democracy
46	Guatemala	0.56	Lower Middle Income	Democracy
47	Guinea	0.00	Low Income	Intermediate
48	Guyana	0.00	Upper Middle Income	Democracy
49	Honduras	0.00	Lower Middle Income	Democracy
50	India	1.23	Lower Middle Income	Democracy

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Table C 1 – continued from previous page

#	Country	Oil rent	Income group	Institution
51	Indonesia	3.61	Lower Middle Income	Democracy
52	Iran	24.14	Upper Middle Income	Autocratic
53	Italy	0.11	High Income	Democracy
54	Jamaica	0.00	Upper Middle Income	Democracy
55	Jordan	0.04	Upper Middle Income	Intermediate
56	Kazakhstan	18.77	Upper Middle Income	Autocratic
57	Kenya	0.00	Lower Middle Income	Democracy
58	Kuwait	47.87	High Income	Autocratic
59	Kyrgyz Republic	0.52	Lower Middle Income	Intermediate
60	Laos	0.00	Lower Middle Income	Autocratic
61	Latvia	0.00	High Income	Democracy
62	Lesotho	0.00	Lower Middle Income	Democracy
63	Liberia	0.00	Low Income	Intermediate
64	Lithuania	0.16	High Income	Democracy
65	Luxembourg	0.00	High Income	Democracy
66	Madagascar	0.00	Low Income	Democracy
67	Malawi	0.00	Low Income	Democracy
68	Malaysia	5.67	Upper Middle Income	Intermediate
69	Mali	0.00	Low Income	Democracy
70	Malta	0.00	High Income	
71	Mauritania	3.16	Lower Middle Income	Intermediate
72	Mauritius	0.00	Upper Middle Income	Democracy
73	Moldova	0.04	Lower Middle Income	Democracy
74	Mongolia	1.08	Lower Middle Income	Democracy
75	Morocco	0.01	Lower Middle Income	Autocratic
76	Mozambique	0.93	Low Income	Democracy
77	Myanmar	2.68	Lower Middle Income	Autocratic
78	Namibia	0.00	Upper Middle Income	Democracy
79	Nepal	0.00	Low Income	Intermediate
80	Nicaragua	0.00	Lower Middle Income	Democracy
81	Niger	0.88	Low Income	Democracy

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Table C 1 – continued from previous page

#	Country	Oil rent	Income group	Institution
82	Oman	38.59	High Income	Autocratic
83	Pakistan	1.83	Lower Middle Income	Intermediate
84	Panama	0.00	Upper Middle Income	Democracy
85	Papua New G.	7.25	Lower Middle Income	Intermediate
86	Paraguay	0.00	Upper Middle Income	Democracy
87	Peru	1.67	Upper Middle Income	Democracy
88	Philippines	0.20	Lower Middle Income	Democracy
89	Portugal	0.00	High Income	Democracy
90	Qatar	32.88	High Income	Autocratic
91	Romania	1.77	Upper Middle Income	Democracy
92	Russia	14.42	Upper Middle Income	Democracy
93	Rwanda	0.00	Low Income	Intermediate
94	Samoa	0.00	Lower Middle Income	
95	Saudi Arabia	40.94	High Income	Autocratic
96	Senegal	0.01	Low Income	Democracy
97	Sierra Leone	0.00	Low Income	Democracy
98	Singapore	0.00	High Income	Intermediate
99	South Africa	0.07	Upper Middle Income	Democracy
100	South Korea	0.00	High Income	Democracy
101	Sri Lanka	0.00	Lower Middle Income	Democracy
102	Sudan	10.90	Lower Middle Income	Autocratic
103	Swaziland	0.00	Lower Middle Income	Autocratic
104	Tajikistan	0.15	Lower Middle Income	Intermediate
105	Tanzania	0.07	Low Income	Intermediate
106	Thailand	1.42	Upper Middle Income	Democracy
107	Togo	0.00	Low Income	Intermediate
108	Trin. and Tobago	14.66	High Income	Democracy
109	Tunisia	3.95	Lower Middle Income	Intermediate
110	Uganda	0.00	Low Income	Intermediate
111	Ukraine	1.95	Lower Middle Income	Democracy
112	UAE	21.19	High Income	Autocratic

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Table C 1 – continued from previous page

#	Country	Oil rent	Income group	Institution
113	United Kingdom	0.84	High Income	Democracy
114	United States	0.63	High Income	Democracy
115	Uruguay	0.00	High Income	Democracy
116	Uzbekistan	19.62	Lower Middle Income	Autocratic
117	Vietnam	5.92	Lower Middle Income	Autocratic
118	Yemen	26.05	Lower Middle Income	Intermediate
119	Zambia	0.00	Lower Middle Income	Democracy

Table C 2: Definition and source of variables used in the analysis

Variable	**Definition**	**Source**
Life expectancy at birth, total, male, female (years)	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same.	World Development Indicators
Oil rents (% of GDP)	Is the sum of oil and gas rents from WDI. Oil and gas rents are the difference between the value of crude oil and gas production at world prices and total costs of production.	World Development Indicators
Oil price	Crude oil, average spot price of Brent, Dubai and West Texas Intermediate, equally weighed in real 2010 US$	World Bank Commodity Price Data (The Pink Sheet)

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Table C 2 – continued from previous page

Variable	**Defintion**	**Source**
GDP per capita	GDP per capita based on purchasing power parity (PPP). PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as the U.S. dollar has in the United States. GDP at purchasers prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2011 international dollars.	World Development Indicators
Schooling (years)	Mean years of education of population over 25	Human Development Indicators
Mortality rate, adult (per 1,000 live births)	Adult mortality rate is the probability of dying between 15 and 60 years per 1000 population	World Health Organization
Mortality rate, child (per 1,000 live births)	Under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to age-specific mortality rates of the specified year.	World Development Indicators
Mortality rate, infant (per 1,000 live births)	Infant mortality rate is the number of infants dying before reaching one year of age, per 1,000 live births in a given year.	World Development Indicators

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Table C 2 – continued from previous page

Variable	Defintion	Source
Maternal mortality ratio (per 100,000 live births)	Maternal mortality ratio is the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100,000 live births. The data are estimated with a regression model using information on the proportion of maternal deaths among non-AIDS deaths in women ages 15-49, fertility, birth attendants, and GDP.	World Development Indicators
Mortality rate, neonatal (per 1,000 live births)	Neonatal mortality rate is the number of neonates dying before reaching 28 days of age, per 1,000 live births in a given year.	World Development Indicators
Polity2	Combined Polity Score; measuring on a scale from -10 to +10 the polity of a country.	Centre of Systematic Peace
Public health expenditure per capita	Mandatory payments or contributions to the health care sector including transfers from government domestic revenues, social insurance contribution and compulsory prepayment other than social contribution (variable FS1, FS2 and FS4 in the SHA2011 framework)	World Health Organization
Private health expenditure per capita	Voluntary contributions to the health care sector including voluntary prepayments and other domestic revenues (FS5 and FS6 in the SHA2011 framework)	World Health Organization

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Table C 2 – continued from previous page

Variable	**Defintion**	**Source**
Transparency	Transparency is measured as the Release of Information index and is based on the quantity of reported socio- economic data contained in the World Development Indicators and the International Finance Statistics databases.	(Williams 2015)
Inequality	Inequality is measured as the Gini index. The Gini index is defined as the deviation of the income distribution from a perfectly equal distribution.	World Income Inequality Dataset

Table C 3: Technical efficiency ranking by income groups

Low income			Lower middle income			Upper middle income			High income		
#	**Country**	**Eff.**	**#**	**Country**	**Eff.**	**#**	**Country**	**Eff.**	**#**	**Country**	**Eff.**
1	Nepal	0.9880	1	Vietnam	0.9927	1	Costa Rica	0.9946	1	Italy	0.9920
2	Senegal	0.9460	2	Morocco	0.9866	2	Albania	0.9911	2	Singapore	0.9909
3	Ethiopia	0.9360	3	Cape Verde	0.9859	3	China	0.9887	3	UK	0.9891
4	Niger	0.9058	4	Sri Lanka	0.9841	4	Panama	0.9863	4	Canada	0.9885
5	Gambia	0.8974	5	Bangladesh	0.9834	5	Jamaica	0.9814	5	South Korea	0.9882
6	Madagascar	0.8973	6	Nicaragua	0.9799	6	Ecuador	0.9802	6	Malta	0.9880
7	Guinea	0.8883	7	Tunisia	0.9779	7	Thailand	0.9754	7	Cyprus	0.9849
8	Rwanda	0.8848	8	Samoa	0.9747	8	Algeria	0.9736	8	Chile	0.9840
9	Benin	0.8839	9	Honduras	0.9743	9	Georgia	0.9727	9	Finland	0.9814
10	Liberia	0.8687	10	Armenia	0.9727	10	Argentina	0.9725	10	Germany	0.9810
11	Mali	0.8487	11	Guatemala	0.9565	11	Peru	0.9686	11	Luxembourg	0.9775
12	Tanzania	0.8469	12	Tajikistan	0.9472	12	Malaysia	0.9684	12	Portugal	0.9771
13	Burundi	0.8404	13	El Salvador	0.9404	13	Colombia	0.9633	13	Denmark	0.9738
14	DRC	0.8345	14	PNG	0.9388	14	Mauritius	0.9605	14	Brunei	0.9675
15	Mozambique	0.8333	15	Myanmar	0.9366	15	Romania	0.9590	15	Croatia	0.9658
16	Togo	0.8293	16	Kyrgyz Rep.	0.9349	16	Dominican Rep.	0.9577	16	Uruguay	0.9621
17	Malawi	0.8163	17	Uzbekistan	0.9334	17	Jordan	0.9561	17	Qatar	0.9589
18	Chad	0.7871	18	Egypt	0.9294	18	Paraguay	0.9556	18	Oman	0.9582
19	Uganda	0.7844	19	Yemen	0.9251	19	Bulgaria	0.9504	19	Bahrain	0.9551
20	Centr. Afr. Rep.	0.7113	20	Philippines	0.9192	20	Iran	0.9488	20	UAE	0.9443
21	Sierra Leone	0.6911	21	Moldova	0.9178	21	Brazil	0.9450	21	United States	0.9424
			22	Ukraine	0.9142	22	Belize	0.9275	22	Bahamas	0.9340
			23	Cambodia	0.9139	23	Belarus	0.9256	23	Kuwait	0.9297
			24	Indonesia	0.9125	24	Azerbaijan	0.9254	24	Lithuania	0.9275
			25	Pakistan	0.9099	25	Kazakhstan	0.8939	25	Latvia	0.9258
			26	India	0.9095	26	Guyana	0.8933	26	Saudi Arabia	0.9234
			27	Laos	0.8880	27	Russia	0.8832	27	Trinidad and Tobago	0.8789
			28	Mongolia	0.8865	28	Gabon	0.8214			
			29	Sudan	0.8776	29	Angola	0.7709			
			30	Mauritania	0.8771	30	Namibia	0.7567			
			31	Bolivia	0.8720	31	Botswana	0.7438			
			32	Kenya	0.8215	32	South Africa	0.7318			
			33	Ghana	0.8177						
			34	Congo	0.8015						
			35	Cameroon	0.7559						
			36	Zambia	0.7367						
			37	Cote d'Ivoire	0.7022						
			38	Lesotho	0.6870						
			39	Swaziland	0.6710						

Table C 4: SFA: Inefficiency by age-groups and institutions

Neonatal mortality	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	0.4002***	−3.7839***	−1.6531***	2.2471***
	(0.0927)	(0.9926)	(0.347)	(0.5486)
Oil rent boom	0.0086***	0.0405***	0.0193***	0.0136***
	(0.001)	(0.0097)	(0.0022)	(0.0016)
Oil rent bust	0.0145 ∗ ∗∗	0.0537 ∗ ∗∗	0.0309***	0.0189***
	(0.0024)	(0.0189)	(0.0047)	(0.0032)
Oil rent valley	0.0101***	0.0526***	0.025***	0.015***
	(0.0014)	(0.012)	(0.0031)	(0.0019)
GDP per capita	−0.0355***	0.3849***	0.158***	−0.2322***
	(0.0094)	(0.0856)	(0.0364)	(0.0614)

Infant mortality	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	4.1171***	−3.7998***	−0.8486***	3.2416
	(0.2404)	(1.1158)	(0.1066)	(9.042)
Oil rent boom	0.0152***	0.0613***	0.0231***	0.0106***
	(0.0011)	(0.017)	(0.0019)	(0.0016)
Oil rent bust	0.0221***	0.0832***	0.0363***	0.0152***
	(0.0019)	(0.0288)	(0.0052)	(0.0034)
Oil rent valley	0.0173***	0.0808***	0.0283***	0.012***
	(0.0016)	(0.0208)	(0.0029)	(0.0021)
GDP per capita	−0.3864***	0.3224***	0.068***	−0.1946***
	(0.0246)	(0.0862)	(0.0127)	(0.0697)

Child mortality	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	4.8574***	−3.2242**	−1.5642***	8.441***
	(0.4631)	(1.5055)	(0.573)	(0.8466)
Oil rent boom	0.0161***	0.0779***	0.0302***	0.0119**
	(0.001)	(0.0248)	(0.0032)	(0.0049)
Oil rent bust	0.0235***	0.1068**	0.0461***	0.0197***
	(0.0024)	(0.0481)	(0.0064)	(0.0053)
Oil rent valley	0.0185***	0.1074***	0.0368***	0.0176***
	(0.0014)	(0.0353)	(0.0048)	(0.0042)
GDP per capita	−0.39***	0.1897*	0.1271**	−0.8078***
	(0.0285)	(0.0971)	(0.0636)	(0.1231)

Table C 4 - continued from previous page

Adult mortality	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	−0.1775	−2.2541	1.4332***	0.0035
	(0.538)	(2.096)	(0.2422)	(0.9455)
Oil rent boom	0.01**	0.1196*	0.0135***	0.0066
	(0.0043)	(0.0691)	(0.0028)	(0.0093)
Oil rent bust	0.0129	0.1883*	0.0228***	0.0083
	(0.0077)	(0.0997)	(0.0066)	(0.0247)
Oil rent valley	0.0072*	0.1317*	0.0175***	0.006
	(0.0041)	(0.0673)	(0.0045)	(0.0424)
GDP per capita	−0.0952**	−0.0796	−0.1769***	−0.0216
	(0.0396)	(0.1161)	(0.0352)	(0.084)

Adult mort., male	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	−0.8783	−1.3159*	1.3232***	−0.0619
	(0.6697)	(0.6984)	(0.3297)	(0.976)
Oil rent boom	−0.0005	0.0451***	0.0111***	0.0068**
	(0.0031)	(0.0141)	(0.0025)	(0.0032)
Oil rent bust	−0.0016	0.0772***	0.0223***	0.0085
	(0.007)	(0.0271)	(0.0065)	(0.0285)
Oil rent valley	−0.0049	0.0481***	0.0151***	0.0054
	(0.0052)	(0.0175)	(0.0044)	(0.0072)
GDP per capita	0.0383	0.0835	−0.1368***	−0.0139
	(0.0399)	(0.0557)	(0.0425)	(0.0611)

Adult mort., female	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	−0.5664	−4.22	2.0047	0.0167
	(1.8459)	(7.6279)	(2.9722)	(0.9912)
Oil rent boom	0.0502**	0.3226	0.0142***	0.0077
	(0.0221)	(0.3024)	(0.0025)	(0.0086)
Oil rent bust	0.0682	0.4867	0.0217***	0.0103
	(0.0515)	(0.4196)	(0.0066)	(0.0436)
Oil rent valley	0.047**	0.3756	0.0183***	0.0076
	(0.0193)	(0.2845)	(0.0044)	(0.0296)
GDP per capita	−0.5753**	−0.7615	−0.2617	−0.024
	(0.2506)	(0.5435)	(0.2748)	(0.1218)

Table C 4 - continued from previous page

Maternal mortality	(1)	(2) Democracy	(3) Intermediate	(4) Autocracy
Mean inefficiency				
Constant	0.0293*	−2.2496**	−0.7823***	0.5746
	(0.0162)	(1.0926)	(0.2453)	(0.7361)
Oil rent boom	0.0042***	0.0339**	0.0086***	0.0112
	(0.0003)	(0.0138)	(0.002)	(0.0091)
Oil rent bust	0.0054*	0.0788***	0.0164***	0.0113
	(0.0028)	(0.0202)	(0.005)	(0.0134)
Oil rent valley	0.0032	0.0529***	0.0116***	0.0081
	(0.0023)	(0.0176)	(0.0031)	(0.0111)
GDP per capita	−0.0242***	0.2217*	0.1216***	−0.0947
	(0.0051)	(0.1136)	(0.0296)	(0.1179)

Notes: Neonatal are newborn babies between 0 and 28 days. Infants are children between 0 and 1 years. Children are between 0 and 5 years old. Adults are between 15 and 60 years old. Maternal mortality measures pregnancy-related deaths. Production functions (not shown) includes public, private health care expenditure, schooling, schooling2 (measured all in natural logarithm), income dummies and time dummies. GDP per capita is converted to natural logarithm. *, ** and *** stand for signifcant at the 10%, 5% and 1% level.

Table C 5: Robustness check: Excluding potential oil price setters

Excluded countries:	(1) Saudi Arabia	(2) USA	(3) Saudi Arabia + USA	(4) OPEC	(5) OPEC + USA
Prod. function					
Constant	3.7926***	3.805***	3.797***	3.7473***	3.7495***
	(0.0369)	(0.0366)	(0.0354)	(0.0358)	(0.0361)
Public exp.	0.0141***	0.0141***	0.0141***	0.0147***	0.0147***
	(0.0013)	(0.0013)	(0.0013)	(0.0012)	(0.0013)
Private exp.	0.0154***	0.0179***	0.0177***	0.0157***	0.0182***
	(0.002)	(0.002)	(0.002)	(0.0021)	(0.0021)
Schooling	0.3197***	0.2958***	0.3055***	0.3656***	0.3526***
	(0.0367)	(0.0364)	(0.0356)	(0.0363)	(0.0366)
Schooling^2	−0.0706***	−0.0645***	−0.067***	−0.0823***	−0.079***
	(0.0087)	(0.0087)	(0.0084)	(0.0087)	(0.0087)
LM income	0.021***	0.0209***	0.0206***	0.0192***	0.0187***
	(0.0062)	(0.0062)	(0.0062)	(0.006)	(0.006)
UM income	0.0135*	0.011	0.011	0.0114	0.0084
	(0.008)	(0.0079)	(0.0078)	(0.0079)	(0.0078)
High income	0.0315***	0.0256***	0.0266***	0.0299***	0.0245***
	(0.0097)	(0.0095)	(0.0094)	(0.0096)	(0.0094)
Mean inefficiency					
Constant	1.5914***	1.5865***	1.6082***	1.6573***	1.6945***
	(0.1627)	(0.1458)	(0.1594)	(0.2008)	(0.21)
Oil boom	0.0079***	0.0079***	0.008***	0.008***	0.0083***
	(0.0011)	(0.0012)	(0.0012)	(0.0014)	(0.0018)
Oil bust	0.0111***	0.0112***	0.0112***	0.0107***	0.011***
	(0.0018)	(0.0017)	(0.0017)	(0.0024)	(0.0033)
Oil valley	0.0085***	0.0086***	0.0086***	0.0096***	0.0098***
	(0.0013)	(0.0012)	(0.0012)	(0.0017)	(0.0022)
GDP pc	−0.2173***	−0.2166***	−0.2202***	−0.2322***	−0.2387***
	(0.0262)	(0.0235)	(0.0255)	(0.033)	(0.0347)
Distribution					
σ^2	0.0347***	0.0343***	0.0352***	0.0413***	0.0425***
	(0.0051)	(0.0048)	(0.0051)	(0.0071)	(0.0074)
λ	0.9954***	0.9952***	0.9954***	0.9966***	0.9965***
	(0.001)	(0.001)	(0.0009)	(0.0008)	(0.0008)
LL	2567.409	2565.406	2540.294	2362.162	2335.029

Notes: Production functions include time dummies. Public, private health care expenditure, schooling, schooling^2 and GDP per capita are converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.

Table C 6: Robustness check: Lagged outcome variable

Outcome in:	(1) t+1	(2) t+2	(3) t+3	(4) t+4	(5) t+5
Prod. function					
Constant	3.8196***	3.8349***	3.8499***	3.8646***	3.8817***
	(0.0374)	(0.0375)	(0.039)	(0.0399)	(0.043)
Public exp.	0.0135***	0.0129***	0.0122***	0.0115***	0.0107***
	(0.0013)	(0.0015)	(0.0015)	(0.0014)	(0.0016)
Private exp.	0.0152***	0.0149***	0.0147***	0.0144***	0.0139***
	(0.0021)	(0.0022)	(0.0022)	(0.0023)	(0.0024)
Schooling	0.3022***	0.2965***	0.291***	0.2874***	0.2801***
	(0.0375)	(0.0379)	(0.0396)	(0.0407)	(0.0435)
Schooling^2	−0.0667***	−0.0657***	−0.0648***	−0.0645***	−0.0632***
	(0.009)	(0.009)	(0.0095)	(0.0098)	(0.0105)
LM income	0.0211***	0.0207***	0.0206***	0.0206***	0.0215***
	(0.0064)	(0.0065)	(0.0071)	(0.007)	(0.0076)
UM income	0.0144*	0.0148*	0.0154*	0.0166*	0.0188*
	(0.0082)	(0.0083)	(0.0091)	(0.0091)	(0.0098)
High income	0.0325***	0.0337***	0.0355***	0.0383***	0.0423***
	(0.01)	(0.0102)	(0.0111)	(0.0112)	(0.012)
Mean inefficiency					
Constant	1.5236***	1.4667***	1.4003***	1.323***	1.2423***
	(0.15)	(0.1444)	(0.146)	(0.1371)	(0.1344)
Oil rent boom	0.0075***	0.0072***	0.0068***	0.0065***	0.0061***
	(0.0011)	(0.0011)	(0.001)	(0.0009)	(0.0009)
Oil rent bust	0.0103***	0.0099***	0.0095***	0.009***	0.0084***
	(0.0019)	(0.0019)	(0.0018)	(0.0018)	(0.0018)
Oil rent valley	0.0082***	0.0078***	0.0074***	0.0073***	0.0068***
	(0.0014)	(0.0014)	(0.0014)	(0.0015)	(0.0015)
GDP per capita	−0.2071***	−0.199***	−0.1895***	−0.1782***	−0.1664***
	(0.0243)	(0.0234)	(0.0234)	(0.0218)	(0.0214)
Distribution					
σ^2	0.0328***	0.0315***	0.0299***	0.0281***	0.026***
	(0.0048)	(0.0047)	(0.0043)	(0.0041)	(0.0041)
λ	0.9952***	0.9953***	0.9952***	0.9952***	0.995***
	(0.001)	(0.001)	(0.001)	(0.0011)	(0.0014)
LL	2437.355	2283.78	2131.401	1979.129	1825.46

Notes: Production functions include time dummies. Public, private health care expenditure, schooling, schooling^2 and GDP per capita are converted to natural logarithm. *, ** and *** significant at the 10%, 5% and 1% level.

Table C 7: Robustness check: Different definition of price shocks

	(1)	(2)	(3)	(4)
Price shock:	5%	10%	15%	20%
Production function				
Constant	3.8001***	3.8004***	3.8002***	3.8002***
	(0.037)	(0.0365)	(0.0364)	(0.0366)
Public exp.	0.0141***	0.014***	0.014***	0.014***
	(0.0013)	(0.0013)	(0.0013)	(0.0013)
Private exp.	0.0156***	0.0157***	0.0156***	0.0157***
	(0.002)	(0.0021)	(0.0021)	(0.002)
Schooling	0.3105***	0.31***	0.3104***	0.3104***
	(0.0371)	(0.0365)	(0.0368)	(0.0365)
Schooling^2	−0.0682***	−0.0681***	−0.0682***	−0.0682***
	(0.0089)	(0.0087)	(0.0088)	(0.0087)
LM income	0.0212***	0.0213***	0.0213***	0.0213***
	(0.0063)	(0.0062)	(0.0063)	(0.0062)
UM income	0.0135*	0.0134*	0.0136*	0.0135*
	(0.0079)	(0.0078)	(0.0078)	(0.0079)
High income	0.0305***	0.0305***	0.0307***	0.0306***
	(0.0096)	(0.0095)	(0.0094)	(0.0094)
Mean inefficiency				
Constant	1.5734***	1.5706***	1.5781***	1.5768***
	(0.1524)	(0.1557)	(0.1559)	(0.1557)
Oil rent boom	0.0078***	0.0078***	0.0077***	0.0079***
	(0.0012)	(0.001)	(0.001)	(0.0012)
Oil rent bust	0.0107***	0.0111***	0.0133***	0.0133***
	(0.0016)	(0.0017)	(0.0024)	(0.0026)
Oil rent valley	0.0084***	0.0085***	0.009***	0.0084***
	(0.0012)	(0.0014)	(0.0014)	(0.0011)
GDP per capita	−0.2142***	−0.2138***	−0.2149***	−0.2147***
	(0.0247)	(0.0249)	(0.025)	(0.025)
Distribution				
σ^2	0.0339***	0.0339***	0.0339***	0.0339***
	(0.0048)	(0.0049)	(0.0049)	(0.0048)
λ	0.9952***	0.9952***	0.9952***	0.9952***
	(0.001)	(0.001)	(0.001)	(0.001)
LL	2592.331	2592.348	2592.727	2592.358

Notes: Production functions include time dummies. Public, private health care expenditure, schooling, schooling^2 and GDP per capita are converted to natural logarithm. *, ** and *** stand for significant at the 10%, 5% and 1% level.