THE POLITICAL ECONOMY OF NON-RENEWABLE RESOURCE OWNERSHIP AND CONTROL

by

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A thesis submitted to the Faculty and the Board of Trustees of the Colorado School of Mines in partial fulfilment of the requirements for the degree of Doctor of Philosophy (Mineral and Energy Economics).

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ABSTRACT

A large body of literature finds a negative relationship between natural resource abundance and economic efficiency. With few notable exceptions, this literature does not account for variations in the ownership and control of the resources. Through an analytical interpretation of results from a game-theoretic political economy model, this study examines how economic rents, the opportunity cost of firms, potential cost or market access advantages of the private sector and time preferences of politicians combine to affect a politician's preferences for ownership and control of a non-renewable resource. I find that the resulting choice of ownership type, public or private, is context-specific and that no generalisations can be made: among other factors politicians will consider the size of the resource, expected price paths, whether the private sector has a cost or market access advantage over the state when making its decision, prices and the degree to which the government holds a non-controlling equity stake in the firm. With respect to the efficiency of public versus private ownership, I find that either model can be efficient and that the result is driven mainly by: (i) the differences in time preferences between politicians, the private sector and the social optimum; and (ii) the degree to which the private sector holds a non-appropriable competitive advantage over the government. The model provides a rich and nuanced interpretation of the incentives governments face in making ownership decisions over non-renewable resources. The results act as a reminder to advisers to take into consideration country specifics when making recommendations to governments about which forms of ownership and control lead to a more efficient outcome. Results are corroborated by observations in empirical literature and the model's explanatory power is highlighted through a range of country case studies.

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CHAPTER 1

INTRODUCTION

Developing countries account for a considerable proportion of the world's mineral and energy output, but the bulk of consumption is concentrated among high-income industrialised countries and the emerging (BRICS)[1] economies who are also in some cases significant producers themselves. These consumer countries are also home to large multinational corporations with deep technical and financial capacity and a global footprint of resource production. In many resource rich developing economies, the skills and capital often needed to develop mineral and energy resources efficiently can be a barrier to entry for smaller and less sophisticated domestic players resulting in the sector often being dominated by large, foreign corporations. This asymmetry of opportunity creates tensions for policy makers as they trade off the need to maximise the value of revenue flowing from the development of subsoil assets with the need for to maintain an equitable stake in the national patrimony.

In addition to intra-generational considerations, the finite nature of mineral and energy resources introduces a unique inter-generational equity element into the analysis and formulation of mineral policy, rendering questions of mineral ownership, the interests of producers and the State, and the timing of exploitation of particular importance. When the State is represented by a politician facing reelection uncertainty, timing of the rents and the degree to which they are captured introduces important political economy considerations.

In many countries the right to extract and capture economic rents associated sub-soil resources are held by the private sector, or some combination of private and public-sector ownership. However, despite this blending of extraction rights, in most countries the ownership of underlying sub-soil resource is vested in the State who holds these assets in trust on behalf of its citizens. With this in mind it is of interest to ask: can the variety of resource ownership in developing countries be both rational and efficient?

[1] Brazil, Russia, India, China and South Africa

As will be discussed in detail throughout this paper, this research effort finds that politicians might rationally choose either public or private ownership; their choice depends on a country-specific combination of factors (size of the resource, the opportunity cost of firms, reelection uncertainty, prices, and any competitive advantages of firms). Furthermore, this research finds that public ownership can be efficient, and in some cases, private ownership can be inefficient; what determines which is the case is a combination of exogenous factors including (i) time preferences of the politician, firm and society, (ii) price paths; and (iii) any non-appropriable competitive advantage of firms.

These results were obtained by taking a holistic view of technical and structural factors, individual incentives facing differing agents and the political economy. Among the many possible factors that may influence this decision, this research effort will explore, through the framework of a stylised two-period, game-theoretic political economy model, how economic rents, the opportunity cost of firms, reelection uncertainty and risk tolerances of politicians, and a potential competitive advantage of the private sector may combine to affect the government's incentives and preferences for public ownership and control over a non-renewable resource.

The remainder of the paper is organised as follows. After a discussion of the political economy of resource extraction and review of existing theoretical and empirical literature on the topic in Chapter 2, two economic models are set up and solved. The first is described in Chapter 3 for the case where extraction of a non-renewable resource is costless, while the second is described in Chapter 4 where costs and the potential for a non-appropriable competitive advantage of private ownership is introduced. In both Chapters 3 and 4 the politician's preferred form of ownership and control is noted and discussed. Comparative statics are then performed to understand how these preferences are influenced by changes to exogenous parameters. The optimal choice of ownership (as seen by the politician) is then also compared with the socially optimal choice to draw conclusions regarding which form of ownership and control is more socially efficient. In order to deepen an understanding of the model's workings, the model is then parameterised, and results are simulated; this discussion is included in Chapter 5. In Chapter 6, the model is parameterised once again, but this time it is done in an attempt to emulate ownership outcomes in four different countries and test the model's explanatory power against these countries' choices of ownership and control. Chapter 7 summarises and concludes.

CHAPTER 2

THE POLITICAL ECONOMY OF NATURAL RESOURCE EXTRACTION

Incentive structures, policy outcomes and their resulting efficiency are the principal focus of political economics. Due in part to increasing attention to the extractive industries over the past decade several political economy models have examined aspects of natural resource extraction as these relate to resource rich countries. (Robinson et al. 2014; Mehlum et al. 2006; Caselli and Cunningham 2007; Robinson and Torvik 2005; Tornell and Lane 1999; Baland and Francois 2000; Matsen et al. 2016). Though making interesting contributions and generally supporting the resource curse thesis - that countries with an abundance of natural resources tend to experience slower economic growth, less democracy, and worse development outcomes than countries with fewer natural resources - the models are often highly stylised and ignore important characteristics of resource extraction. Some of the weaknesses present in the existing literature are as follows:

1. Despite the models having a focus on sub-soil resources, with the exception of Robinson et al. (2014) and Matsen et al. (2016), they all ignore the finite nature of these resources, which is critical to an examination of the intertemporal trade-offs unique to the extraction of non-renewable sub-soil resources.
2. The existing literature generally assumes that the rights of ownership and control over the resource are held by the State and that rents flow freely from the ground without need for investment or extraction costs.[2] Although rents associated with sub-soil resources can be very large, results are not robust to the exclusion of costs. As will be shown later, the introduction of costs, even if minimal, nuances the interpretation of the results considerably.
3. The existing literature falls short of analytically examining the effects of one ownership type over another; it takes ownership as a given and does not examine how outcomes differ between private and public forms of ownership and control and what factors might

[2] Alternatively, the capital stock is a non-excludable (but rivalrous) common pool resource as in the case of Tornell and Lane (1999) and in Hodler (2006) the resource is a public good. For the different equilibrium to hold in Hodler's model one needs to assume the resource is infinite in size which therefore renders it non-rivalrous in consumption.

influence a politician's choices. As will be shown throughout this thesis, the efficient rate of extraction, generation of rents and their corresponding response to prices and other shocks are all affected by the form of ownership and control. This is important since the form of ownership institutions is a choice by politicians.

4. Finally, although public ownership and control of natural resources is a common feature of many countries, the political economy literature does not contain any modelling to explain how, under varying circumstances, politicians' incentives for adopting certain property rights bundles are formed and changed.[3] Chang et al. (2017) show how politicians can respond opportunistically to booming prices but as noted by Cole and English (1991), increased incentives for public ownership can also be driven by desperation during low price environments.

A summary of existing political economy models relating to the depletion of non-renewable resources is provided in Table 2.1 below. The models all treat ownership and control as exogenous and do not examine the effect that a change in ownership and control would have on the resulting equilibrium. Although they did not develop an analytical model to support their theory, Luong and Weinthal (2010) give a comprehensive account of different state ownership and control structures and show how these structures create different incentives to adopt strong or weak institutions that either support or hinder the development trajectories of Soviet successor states. Their analysis comprehensively examines four different ownership scenarios: (i) state ownership with control; (ii) state ownership without control; (iii) private domestic ownership; and (iv) private foreign ownership. They highlight that weak institutions are not endogenous to non-renewable resource wealth and those states that don't inherit strong institutions can build them. Luong and Weinthal conclude that "mineral rich states are "cursed" not by their wealth but rather by the structure of ownership they choose to manage their mineral wealth." (Luong and Weinthal 2010, pg. 6) That is, development outcomes are not a product of natural resource wealth, the type of resource or its geographic concentration but instead, they are the product of the chosen ownership structure. Luong and Weinthal conclude that the worst form of private ownership is preferred to the best form of public ownership. Their analysis is summarised in Table D.1 of Appendix D.

[3] Henry Maine first conceptualised bundles of rights in his classic book, Ancient Law, published in 1861

Table 2.1 Summary of political economy literature related to natural resource extraction and development.

Author(s), (citations)[4]	**"Title of paper" and summary description of the model and paper**
Robinson et al. 2006 (1339); 2014 (27)	Title: "Political Foundations of the Resource Curse" In their original 2006 paper the authors develop a two-period model of the political economy to explain the various experiences of countries during resource booms. The model contains two sectors, a private sector and a government sector. The government sector holds the exclusive ownership and control rights over a fixed stock resource from which extraction is costless. Extraction in period one beyond a certain rate more than proportionally reduces the remaining resource in period two. Uncertainty over the outcome of an impending election and the ability to influence the probability of winning by employing voters in government causes the incumbent to make inefficient choices regarding rates of extraction and public-sector hiring. A subsequent (2014) correction to the original paper simplifies the model and removes the choice for government to increase its probability of reelection through inefficient use of public resources through hiring. Extraction is costless in both models.
Robinson and Torvik 2005. (391)	Title: "White Elephants" Two politicians competing for political support invest in politically important but socially inefficient projects termed "white elephants". They show that when some politicians find it difficult to make credible promises the inefficiency of certain socially inefficient projects can increase political support. In contrast, socially efficient projects are credible to all politicians and do not affect election outcomes. The study is generalisable beyond natural resources and is cited in the political economy literature regarding the "resource curse" to show how politicians can affect election results when institutional constraints are weak.
Matsen et al. 2016. (14)	Title: "Petro Populism" The authors develop a two-period model of the economy where a politician, who faces reelection uncertainty, has control over the depletion of a fixed-stock natural resource and can affect reelection outcomes. There are two types of politicians: a benevolent and rent-seeking type. Resource rents are used to finance public utility while a portion is consumed by the incumbent politician. The authors find that both types of politicians will over-extract the resource relative to the social optimal but that the rent-seeking incumbent will over-extract more than the benevolent one. The authors' result is due entirely to: (i) the choice of functional forms, whereby they set the government's budget constraint to be concave in resource extraction; and (ii) the ability of both politicians to 'buy' political support. Extraction of the resource is costless.

[4] Citations from Google Scholar as of November 30, 2017.

Table 2.1 Continued.

Author(s), (citations)[4]	"Title of paper" and summary description of the model and paper
Hartley and Medlock 2008. (107)	Title: "A Model of the Operation and Development of a National Oil Company" The authors develop a dynamic model of the exploration and development activities of a National Oil Company (NOC), which uses similar technology to a private firm to extract a depletable resource. The model developed is similar to Pindyck (1978), except that the NOC has a wider range of objectives to maximise than the firm who focuses on maximising the present value of profits. The authors use optimal control to solve their model and find that the shorter-term time preferences of the politician together with the NOC's multiple objectives drive inefficient decisions regarding timing of production, levels of employment and level of reserves.
Caselli and Cunningham 2007. (16)	Title: "Political Decision Making in Resource Abundant Countries" A "Leader" has some probability of losing power and collects exogenous resource rents and then decides to spend them among either efficiency improving private sector activities or self-preservation activities. The authors vary the characteristics of the leader as: (i) the Busy Leader; (ii) the Unconstrained Leader; (iii) the Visionary Leader; (iv) the Resigned Leader and (v) the Lazy Leader. These different leaders adopt different strategies to stay in power including: deployment of patronage, increasing private investment, minimizing resource depletion, suppressing opposition etc. Results regarding whether a resource curse exists vary depending on the model set-up.
Bulte and Damiana 2008. (167)	Title: "Resources for Sale: Corruption, Democracy and the Natural Resource Curse" The authors develop a static model that combines rent-seeking firms with a corrupt and strategically acting government to explore the welfare effects of resource booms in autocratic versus democratic governments. There are three sectors in the economy with varying returns to factor inputs: manufacturing (increasing returns to scale), agriculture (constant returns to scale) and resources (decreasing returns to scale). Labour can only move between manufacturing and the resource sector and given the production technologies in each sector, the authors assume external benefits from entrepreneurs moving into manufacturing. The resource stock is not modelled explicitly but rather it is treated as a shift in the resource sector's production function.[5] The model predicts that, in autocratic regimes, resource endowments allow governments to extract greater surplus (bribes) by pursuing policies that are detrimental to growth. In democratic regimes, the surpluses available from resource endowments are more likely to be used in ways that promote welfare and growth.

[5] The authors use the term "stock" erringly throughout as they are effectively referring to a flow variable.

Table 2.1 Continued.

Author(s), (citations)[4]	**"Title of paper" and summary description of the model and paper**
Mehlum et al. 2006. (2104)	Title: "Institutions and the Resource Curse " Entrepreneurs are allocated between productive and unproductive (rent extracting) or "*grabbing*" activities where the productive sector exhibits positive demand externalities among producers. The authors then vary institutions from "grabber friendly" to producer friendly. They find that institutions matter and a resource curse results when the effect from the substitution away from the productive sector towards rent seeking is greater than the resource boom effect. In their empirical analysis, the authors define the resource curse by examining the effect of resource dependence on economic (i.e. GDP) growth. They do not go into detail regarding what "*grabbing friendly*" institutions might look like but their empirical analysis alludes to a general lack of institutions or poor institutional quality. Although highly cited, robustness testing of the results by Kaffine and Davis (2013) have later shown that the results are sensitive to sample selection, thus failing statistical replication as defined by Hamermesh (2007).
Tornell and Lane 1999. (1185)	Title: "The Voracity Effect" The authors examine a case of multiple powerful groups that capture the government and use its discretionary power to transfer wealth from the private sector to themselves. In their model, capital invested in the productive sector (i.e., the resource sector) is a common pool resource which, diminishes the incentive for powerful groups to accumulate capital and lowers the economy's growth rate. In response to increases in productivity in the efficient private sector, the authors coin the term "*voracity effect*: a more-than-proportional increase in discretionary redistribution [to powerful groups] in response to an increase in the raw rate of return in the efficient sector." (page 34) The authors draw parallels between their results and those of Sachs and Warner (1997) on the basis that elites appropriate transfers from Governments. However, they fail to address how the critical assumption in their model (a common pool resource of capital) relates to production decisions in the extractive industries.[6]

[6] Most mineral and energy resources are not considered common pool resources. The exception is the case of lootable resources, or "technically appropriable" resources such as those produced through the artisanal mining of alluvial or fluvial deposits (e.g., gold, diamonds) under non-existent or informal property rights systems. Although expropriation or a sudden change to existing property rights are possible, these are matters that are very different from those modeled by Tornell and Lane (1999).

Table 2.1 Continued.

Author(s), (citations)[4]	**"Title of paper" and summary description of the model and paper**
Hodler 2006 (418)	Title: "The Curse of Natural Resources in Fractionalized Countries" The author develops a static model to examine the case of entrepreneurs in fractionalised countries choosing between investing in productive activities or fighting activities. All agents play a one-off Cournot game to decide how to allocate effort between productive and fighting activities. Hodler finds that increased fractionalisation leads to increased fighting thus weakening property rights and reduces incentives for productive activities. Property rights are endogenously modelled as the fraction of income from productive activities that is retained. The author assumes that the effectiveness of property rights decreases in the input share allocated to fighting activities. Therefore, the greater the amount of rent to be appropriated from non-productive activities, the less incentive there is to enforce property rights. As a result, increases in natural resources leads to increased fighting and a downward spiral ensues. The resource is modelled as common pool resource whose extraction is costless. Stock constraints are not relevant or are assumed infinite since the model is static.[7]
Dalgaard and Olsson 2008 (65)	Title: "Commodity Prices, Growth, and the Natural Resource Curse: Reconciling a Conundrum" The authors examine the impact of "windfall gains" that may occur through either natural resources or foreign aid. They develop a static model where agents allocate efforts between constant returns to scale production or rent seeking and predation. The country benefits from a rent flow, which can consist of either foreign aid or resource rents. The resource is not explicitly modelled and there is no effort required to produce the resource, only in appropriating it. Only a fraction of the rents are appropriable by the citizenry and the degree to which these rents are appropriable reflects the discretionary ability of government. (Resources rents have more discretion than foreign aid due to the conditionality of official foreign aid.) The government, together with its loyal elite balances their efforts between production and defending the rents from appropriation. The authors find that the degree to which windfalls have a negative impact on income (i.e., the degree to which the "resource curse" is present) depends critically on institutional quality and the ease of appropriation of the rents. The "institutions" through which governments may appropriate rents are not explicitly modelled.

[7] A criticism of the decentralised conflict model of the political economy is the notable absence of the government, which is a central player in any civil conflict.

Table 2.1 Continued.

Author(s), (citations)[4]	**"Title of paper" and summary description of the model and paper**
Baland and Francois 2000. (410)	Title: "Rent-Seeking and Resource Booms" The authors develop a model where, similar to Tornell and Lane (1999), agents choose between rent-seeking and entrepreneurship activities, except that instead of financial capital, human capital is applied to each sector. They find that a resource boom can lead to an increase in rent-seeking activity and those activities which induce entrepreneurship. However, the degree to which one activity will increase more than the other depends on the initial equilibrium: in economies with few initial entrepreneurs, rent-seeking ensues, whereas in an economy with many entrepreneurs, a boom incentivises further entrepreneurship, which crowds out rent-seeking.[8] Other than in the title, there is very little in this model that makes the shock resemble a resource boom: (i) the resource is not modelled (rents accrue from trade licenses and import restrictions); and (ii) agents move between sectors freely as though the resource is a common pool resource.

Although many of the models include the notion of a state-owned entity that makes production choices regarding a non-renewable resource, none of the models explicitly examine government's *a priori* decision to own and control the depletion of that resource. Given Luong and Weinthal's (2010) hypothesis that the worst form of private ownership is better than the best form of public ownership, it is of interest to understand under what circumstances governments would choose public ownership and control over its private alternative.

2.1 Institutions and choice

Institutions, whether they consist of constitutions, laws, regulations and agencies or bureaus are a choice: countries draft and amend their constitutions and laws from time to time and agencies and bureaus are reformed and reorganised. For example, Mexico has in recent years undertaken amendments to its constitution to allow for foreign participation in its oil sector (BBC News 2013); and state agencies are regularly created or dismantled to participate in the extractive industries as exemplified by Zambia's former Zambia Consolidated Copper Mines and now

[8] Critical assumptions are that: (i) rent-seekers possess entrepreneurial skills; and (ii) profits to entrepreneurs increase with aggregate income – this latter assumption violates microeconomic theory, which would have profits driven to zero as the number of entrepreneurs increased.

Investment Holding company (ZCCM, and ZCCM-IH respectively), which was formed initially as a vehicle through which all mines would be nationalised in Zambia and later reorganised to a holding company (ZCCM-IH) to facilitate the privatization of all those same mines.

In exploring ownership choice, Chang et al. (2017) present one of the few efforts that attempts to analytically explain the rationale for public or private ownership choices in the extractive industries by modelling repeated cycles of nationalisation and privatisation among countries. They focus on a pure efficiency versus equity trade-off faced by a benevolent and omnipotent government whose preferences for state or private institutions changes opportunistically in response to exogenously determined commodity prices. The role of the political economy is seen by many as a driver for institution choice.[9] However, Chang et al. (2017) ignore aspects of the political economy in their research, thus limiting the explanatory power of their model and specifically emphasises opportunistic explanations (i.e., optimal institutional choice in response to price signals), as opposed to political economic explanations of ownership.

As Guriev et al. (2011, pg. 19) conclude when empirically examining state participation in the oil sector: "*nationalizations are indeed more likely to occur when the oil price… is high* ***and*** *in countries with weak political institutions*." [emphasis added.] Through a qualitative analysis, Wilson (2015) lends further support for a pluralistic explanation of variances in state ownership; following a survey of twelve countries he concludes that resource nationalism takes a range of distinct forms, which are connected to differences in political institutions that structure the objectives and policies of governments. He therefore argues that while changes to external prices or other market dynamics play a role, political institutions are equally important thereby conditioning the timing and shape of resource ownership or 'nationalism'. Mahdavi (2014) further supports this with his empirical finding that states nationalise their oil resources for a variety of reasons: in periods of high prices, where executive constraints are limited, and after other countries have nationalised reflecting the reduced likelihood of international retaliation. Not only do these findings support the assertion that more than price is at play, it also supports the assumption made throughout this paper that institutions are a choice. In his qualitative review, Singh (2014) shows that although idealism may have certainly motivated the state control of natural resources in the

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[9] References supporting the role of the political economy as central to regime choice are: Kobrin (1984), Minor (1994), Chua (1995), Manzano and Manaldi (2008), Guriev et al. (2011)

1970s, modern decisions by politicians link shifting political opportunities and strategic actions. In other words, decisions for public ownership result from a careful consideration of the benefits and costs and the timing is inevitably linked to price cycles and other market dynamics.

Since more than price is at play, the goal must be to advance a politico-economic model that can explain institutional choice due to: (i) opportunistic responses to price changes and market dynamics; (ii) politico-economic reasons, and also (iii) capture the notion that politician's face institutional constraints that vary in strength from country to country and over time. A model that only examines only one of these aspects in isolation oversimplifies the issue and limits real insights and appropriate policy response. The models described in the subsequent chapters attempt to fill this gap, however before turning to the model, it is of benefit to first describe the range of policies and instruments that government use to participate in their sector; be it through ownership stake, the statutory fiscal regime or some form of private contract between the state and the firm.

2.2 State equity

State participation through ownership has been particularly prominent in the oil and gas sector since the 1970s, when a wave of nationalisations in Organisation of Petroleum Exporting Countries (OPEC) countries shifted the balance of control from private to state companies. Many governments take a direct ownership stake in oil, gas or mineral ventures, either as the sole commercial entity or in partnership with private companies. In many cases this participation is exercised through a state-owned entity, though in some countries the government exercises its ownership stake via ministries or other government institutions. (NRGI 2015)

The way in which countries choose to structure how they participate in the financial and other benefits of the extractive industries is unique. In addition to direct ownership stakes, in many countries this is achieved through the statutory fiscal regime, contractually, through a state-owned enterprise with full control, or alternatively as mentioned previously through equity participation in private firms held by an SOE or other government body. This variety evident from the summary of different fiscal regimes and state participation models contained Table A.1, Table A.2 and Table A.3 of Appendix A. As can be seen, state equity participation can take a variety of forms including free equity, carried interest participation or paid equity. Each of these have pros, cons and similarities with statutory fiscal instruments.

i. Free equity: In this situation government acquires an equity position free of charge as in the case of Ghana (10%, oil, gas and mining) or Guinea (35%, mining only). This has the same economic impact as levying a dividend tax at a rate equal to government's free equity holding.
ii. Carried interest: Under these arrangements the state acquires its equity share in the project from the production proceeds including an interest charge. This structure is comparable to a resource rent tax where the tax rate is equal to the equity share and the threshold rate of return is equal to the interest rate on the carry.
iii. Paid equity: Under these arrangements, the state becomes a partner with all the obligations of other equity holders. Provided that the sale price is set on fair commercial terms, this arrangement is similar to a "Brown tax" where the tax rate is equal to the share of equity participation (Lund 2009).

Although there are many similarities between state equity and other forms of taxation the two are not identical. An ownership interest may provide additional benefits for governments since it may allow the government to exert direct influence on operations for strategic reasons and provide access to better company information that it can use for tax administration purposes. In relation to strategic reasons, as the case of Botswana discussed later in Section 6.1 shows, state ownership has allowed the government joint control of domestic operations, insights into the broader diamond market and influence on the general strategy of the De Beers Group. In relation to tax administration state equity participation may assist to reduce tax leakage by: (i) reducing information asymmetries between it and the taxpayer; and (ii) capture through dividends what it fails to collect through taxes provided the equity state is comparable to the tax rate. Furthermore, there may be potential political economy benefits to state equity since ownership may reduce populistic pressures to capture more rents through adjustments to statutory fiscal instruments in response to changing market conditions. This in turn can lead to improved regulatory stability and investor certainty.

In the next chapter a simple two-period model is set up to explore government incentives for ownership and control of non-renewable resources. Although it is not a major focus of this research effort the possibility for state equity in the private firm is specifically examined as a special topic later in Section 3.2 where this research effort finds that state equity is one possible solution that might allow both an efficient result while remaining incentive compatible for government.

CHAPTER 3

MODEL 1: A SIMPLE MODEL WITH COSTLESS EXTRACTION

As discussed previously most models of the political economy that examine issues of non-renewable natural resource extraction ignore many features of resource extraction such as costs, allocation of property rights and the finite nature of the sub-soil resources. Furthermore, in the singular analytical case where the literature review identified that issues of public ownership and control of natural resources have been examined (Chang et al. 2017), the authors oversimplify the analysis by ignoring the political economy and institutional quality, which limits insights and policy recommendations.

This chapter attempts to address this gap with the development of a deterministic, game theoretic, two-period political economy model that explores how a politician's utility changes between public and private forms of ownership and control over a non-renewable resource. Two variations of private control are explored. The first, which is examined in detail in Section 3.1 looks at full public ownership and control and compares this with full private ownership and control. The second case in Section 3.2 then examines the possibility of a partial non-controlling equity interest in the firm by the politician and compares this case of partial private ownership and full private control with full public ownership and control. Agents in both variations include a politician facing reelection uncertainty and a private sector investor; both have perfect information, no externalities exist, and the politician cannot influence her probability of reelection.[10] Since the focus of this study is to examine preferences for one form of ownership or another under various possible prevailing conditions, this study will examine how the politician's utility changes in response to various exogenous parameters.

[10] Although including the ability to affect reelection enriches the model, it also introduces significant and unnecessary additional complexity by introducing an additional choice variable for the politician. By making reelection probability exogenous, the reelection model can now be characterised as a case that is not limited to two politicians with uniform reelection probability as in Robinson et al. 2006. In this generalised form, there can be a number of different politicians rivalling for power. Robinson et al. themselves simplify their voting model in their 2014 revision of the paper where they also argue that the additional complexity is not required to generate the results they are seeking.

This study proceeds to use the terms 'ownership' or 'ownership and control' interchangeably. When the intent is to discuss joint private-public partnerships, which could be characterised by a government ownership interest with private control, this is explicitly mentioned. For clarity, when 'ownership' is subsequently referred, this ownership right is not limited to the underlying resource, but also includes ownership of the right to deplete and market the resource and to any economic gains associated with those activities.[11]

3.1 Full public ownership and control vs. full private ownership and control

The model is set up and solved by following three distinct steps. In the first step, the utility function is defined for the politician under public ownership and control. Here the incumbent politician chooses the first period production rate in the face of reelection uncertainty, Π, to optimise her two-period expected utility.[12] The term 'Π' is equivalent to the politician's time horizon, time preference or "discount rate". A politician with a low probability of reelection (a high discount rate) places little value on the future as she is more concerned with making decisions that maximise her own short-term political benefits. In contrast, political leaders with higher perceived security, or reelection probability, can be more confident that they will eventually reap the benefits of their policies and thus have greater incentives to make more long-term decisions. Therefore, given an expectation of reelection, the politician must decide how much of the resource to extract in the first period and consequently how much will be left for the future. The more she extracts today, the less there is for the future. Since she values resource income today more than in the future her utility function can be expressed as:

$$U_{PUB} = p_1 e + \Pi p_2 R(e) \qquad (3.1)$$

The prices of the natural resource in the two periods are p_1 in period 1 and p_2 in period 2. The politician and private sector are both price takers and prices are exogenously determined on world markets. The physical quantity of the resource extracted in the first period is denoted 'e'. In the period after the election there is $R(e)$ left of the resource. Although it may appear that the

[11] As mentioned in Chapter 1, ownership of sub-soil natural resources is normally vested in the State. However, ownership of the underlying mineral or energy resource transfers at some to the company extracting the resource. The point at which ownership transfers varies from country to country. In the case of metals this can range from as early as when the resource is removed from the mine, to after it is refined or some other level value additional has occurred, or only on export.

[12] The probability of reelection is bounded as follows: $\Pi \in [0,1]$,

politician's utility is linear as first and second period utility are additive, non-linearity of the two-period utility is introduced via curvature of the depletion function. As per the depletion model of Robinson et al. (2014) this study assumes that R is a strictly decreasing and strictly concave function with $R' < 0$, $R'' < 0$ and $R''' = 0$ where the primes denote first, second and third derivatives, respectively. These assumptions mean that when more of the resource is extracted in the first period, less is left for the second period. Moreover, the assumption about the second derivative captures the idea that the total amount of resources that can be extracted depends on the time path of extraction. If too much is taken out in the first period, the total stock over the two periods falls. This model of depletion can represent conditions observed in oil, gas and mining operations. For example, in oil and gas, if too much of an oil field is depleted early on, this can have an impact on reservoir pressure and negatively affect the total amount of oil recoverable. Similarly, if a mining company chooses to selectively deplete only the high grade (i.e., high quality) portions of a deposit early in the life of a mine, this can have a negative effect on the total resource available for depletion.[13] Under this depletion model the resource stock is thus defined endogenously as $S\left(e\right)=e\ +\ R(e)$ and is completely exhausted, akin to exhausting the "economic" portion of a fixed stock.

As can be seen from equation (3.1), the politician has no other sources of income apart from resource rents (either directly appropriated under public ownership and control or taxed under private ownership and control – as shown later) and that resource income can only be consumed by the politician whose utility is monotonically increasing in income and is non-satiable.

In the second step to solve the model, ownership and control rights over the natural resource are now allocated to the private sector. The objective functions for both the politician and the private sector are shown in equations (3.2) and (3.3) respectively where 'P' in (3.3) denotes the firm's two-period private after-tax profits. The firm now chooses the first period production rate, e, to maximise its two-period after tax profits. Note that one difference between the firm's optimisation and the politician's is that the firm values first and second period production equally.[14] The probability of reelection can take on a dual interpretation: in addition to representing probability of reelection, it can also represent the relative rate of impatience or risk

[13] Another interpretation is that within each period the marginal cost of extraction is increasing.

[14] In other words equation (3.3) can be rewritten as $P = p_1\left(1-\tau\right)e + \Pi_{PRI}\, p_2\left(1-\tau\right)R(e)$ where $\Pi_{PRI} = 1$.

tolerance of the politician relative to the firm, where values of *Π< 1* reflect that the government has less risk tolerance than the firm and values of *Π > 1* reflects greater risk tolerance.

$$U_{PRI} = p_1 \tau e + \Pi p_2 \tau R(e) \tag{3.2}$$

$$P = p_1 (1-\tau) e + p_2 (1-\tau) R(e) \tag{3.3}$$

In this set-up, τ is the tax (or royalty) that is set by the politician who again faces reelection uncertainty. The royalty, τ, (distortionary tax) can be expressed as an income tax, $\hat{\tau}$, (non-distortionary tax) through the following transformation: $\tau = (p_i - c)\hat{\tau}/p_i, \forall i = \{1,2\}$ where *'c'* represents unit extraction costs which in this case are set to zero. Tax collection is assumed to be fully efficient, and since utility is linear in taxes the politician will always tax the maximum amount possible, subject to constraints that will be described later.[15] Since all parties have perfect information, the politician anticipates the private sector's optimal response when setting the tax rate and the private sector anticipates the politician's optimal tax rate when making production decisions.

In the third and final step, optimal utility across the two forms of ownership and control are compared by examining the differential optimal utility between public and private ownership: $\Delta U^* = U^*_{PUB} - U^*_{PRI}$. Comparative statics are then performed to examine how the politician's differential utility, and therefore her preference for one form of ownership and control over another is affected by factors such as prices, the size of the resource, reelection probability and the opportunity cost of the firm.

In Chapter 4 the above process is repeated. However, the analysis is extended to include a cost or market access advantage of the firm. This first model of costless extraction is first developed and explored for two reasons. First, much of the literature listed in Table 2.1 assumes costless extraction, thus using similar assumptions in this analysis improves the comparability with previous literature. Secondly, when keeping all parameters and the structure of the model constant, the inclusion of costs highlights the sensitivity of the model to this parameter and thereby provides

[15] Although beyond the scope of this study, the effect of this assumption could be easily tested by defining total taxes collected as: $\tau^*_{collected} = (1-l)\tau^*$, where '*l*' represents the percentage of tax leakage.

an indication of the robustness of the results. If this research can be considered a useful proxy for preexisting models exploring this subject, it also may give insights into the robustness of those models' conclusions.

3.1.1 Equilibrium for models of public and private ownership and control

This next section focuses on solving the first of the three steps where resource ownership and control rests with the politician. The politician's optimisation is expressed as $\max_{\{e\}} U_{PUB} = p_1 e + \Pi p_2 R(e)$. To allow for closed form solutions, *R(e)* is defined as $R(e) = a - e^2$ and *'e'* is restricted such that $e \leq \sqrt{a}$ to ensure that second period extraction is non-negative.[16] This is subsequently referred to as the 'production constraint'. In this arrangement, if the production constraint binds second period extraction is prevented from being negative and forced to be the lowest feasible value, zero, which means a resource of size $\sqrt{a}$ will be fully extracted in the first period of the model. If the production constraint does not bind, second period production in equilibrium will be some positive number and production will occur over both periods with full resource depletion occurring in the second period.

Under the above parameterisation the curvature of the stock equation defined by Robinson et al. (2014) is maintained: $R'=-2e < 0$; $R''= -2 < 0$ and $R'''= 0$. With the signs of the first, second and third derivatives of *R(e)* preserved, the specified functional form for *R(e)* does not restrict the model beyond the depletion model already defined by Robinson et al. (2014).[17] The stock parameter, *'a'*, is non-negative and a large value for *'a'* is associated with a large total resource stock. Full economic exhaustion is expected, given costless extraction and the politician's non-satiable utility from production. The Lagrangian for this constrained optimisation is $L = p_1 e + \Pi p_2 \left(a - e^2\right) + \lambda_R \left(\sqrt{a} - e\right)$ and the Kuhn-Tucker conditions are:

KTC (1) $\quad \dfrac{\partial L}{\partial e} = p_1 - 2\Pi p_2 e - \lambda_R \leq 0; \quad e \geq 0;$ and $\quad e\dfrac{\partial L}{\partial e} = 0.$

KTC (2) $\quad \dfrac{\partial L}{\partial \lambda_R} = \sqrt{a} - e \geq 0; \quad \lambda_R \geq 0;$ and $\quad \lambda_R \dfrac{\partial L}{\partial \lambda_R} = 0.$

[16] Under general parameterisation, *S(e)* can be expressed as: $S(e)= e + R(e) = e + a - e^2$

[17] A separate analysis not included in this report shows that the equilibrium solution is sensitive to the general functional form of the depletion function. It concludes that either (i) a non-linear depletion model; or (ii) a non-linear two period utility function (that is non-linear in resource depletion) are required for an interior solution to exist.

Using the Kuhn-Tucker technique, two scenarios are explored to find the feasible solution set: Scenario 1, where the production constraint binds, and Scenario 2, where the production constraint does not bind.

Scenario 1: The production constraint binds. In this scenario $\lambda_R^* > 0$ and, from KTC (2) the entire resource is depleted in the first period: $e^* = \sqrt{a}$ and $R(e^*) = 0$. From KTC (1), the shadow price of the stock parameter can then be expressed as $\lambda_R^* = p_1 - 2\Pi p_2 \sqrt{a}$. Since the shadow price takes on a positive value, the system requires that $p_1 > 2\Pi p_2 \sqrt{a}$ for a feasible solution. The equilibrium utility function for the politician can be expressed as $U_{PUB}^* = p_1 \sqrt{a} > 0$ subject to the restriction that $p_1 > 2\Pi p_2 \sqrt{a}$. This could be satisfied if prices are in backwardation (i.e. if first period prices are very large compared with second period prices) so that there is no incentive to preserve a portion of the resource for depletion in the second period. However, backwardation is not necessary or sufficient to satisfy this inequality, it depends on the specific combination of all parameters.

Scenario 2: The production constraint does not bind. In this scenario $\lambda_R^* = 0$ and from KTC (2) it must be the case that $e^* < \sqrt{a}$. The possibility for two cases are then separately examined: $e^*=0$ and $0 < e^* < \sqrt{a}$. If $e^*=0$ and first period production does not occur, then the entire resource is depleted in the second period ($R(e^*) = a$) and from KTC (1), $\partial L/\partial e < 0$. Trying this solution, it can be seen that when substituting $e^* = \lambda_R^* = 0$ into KTC (1) first period prices would need to be negative ($p_1 < 0$) in order to satisfy this inequality, which cannot be the case; thus $e^*=0$ is not a feasible solution. Now turning to the second case where some production takes place in the first period, $e^*>0$, from KTC (1) $\partial L/\partial e = 0$, and the equilibrium solution is characterised as: $e^* = \dfrac{p_1}{2\Pi p_2} < \sqrt{a}$; $R(e^*) = a - e^{*2}$; and $\lambda_R^*=0$. This is a feasible solution set defined by production taking place in both the first and second periods and where the politician's maximum utility under public ownership is expressed as $U_{PUB}^* = \dfrac{p_1^{\,2}}{4\Pi p_2} + \Pi p_2 a > 0.$

Proceeding to the second of the three steps to explore the model set-up where the firm holds ownership and control rights over the resource and is subject to taxation by the politician. Since both parties have perfect information the politician anticipates the private sector's optimal response when setting the tax rate, and the private sector anticipates the politician's optimal tax rate. From equation (3.3), the firm's two-period optimisation problem can be expressed as: $P^* = \max_{\{e\}} p_1(1-\tau)e + p_2(1-\tau)R(e)$ subject to the same production constraint as before. The firm values income in both periods equally and is therefore indifferent whether more production occurs in the first or second period.

The game between the politician and the firm is sequential and the timing of the game is as follows:

1. The incumbent politician chooses the optimal tax rate (τ), taking into consideration current and future prices, prospects for reelection and the firm's optimal response to the tax rate.
2. The firm chooses the first period production rate (*e*), and consequently the depletion path for the resource in response to the politician's optimal tax rate.
3. First period resource extraction, taxation and consumption take place.
4. Finally, second period production, resource extraction, taxation and consumption take place.

The game is solved using backward induction: the private sector's optimisation is first solved, and then the firm's optimal choices for extraction are substituted into the politician's optimisation problem to solve for the optimal level of taxation. Again, '*e*' is restricted such that $e^* = \sqrt{a}$ and the resulting Lagrangian for the private sector's constrained optimisation is: $L = p_1(1-\tau)e + p_2(1-\tau)(a-e^2) + \lambda_R(\sqrt{a}-e)$. The associated Kuhn-Tucker conditions for a maximisation are:

KTC (1) $\dfrac{\partial L}{\partial e} = p_1(1-\tau) - 2p_2(1-\tau)e - \lambda_R \leq 0;$ $e \geq 0;$ and $e\dfrac{\partial L}{\partial e} = 0.$

KTC (2) $\dfrac{\partial L}{\partial \lambda_R} = \sqrt{a} - e \geq 0;$ $\lambda_R \geq 0;$ and $\lambda_R \dfrac{\partial L}{\partial \lambda_R} = 0.$

As before, two scenarios are explored using the Kuhn-Tucker technique to find the feasible solution set.

Scenario 1: The production constraint binds. This scenario is once again characterised by full resource depletion in the first period: $e^* = \sqrt{a}$ and $R(e^*) = 0$. After making the appropriate substitutions the shadow price of the production constraint can be expressed as $\lambda_R^* = \left(p_1 - 2p_2\sqrt{a}\right)(1-\tau^*)$ and, since the shadow price takes on a positive value the following inequality must hold for complete resource depletion in the first period: $p_1 > 2p_2\sqrt{a}$.

Scenario 2: The production constraint does not bind. In this scenario $\lambda_R^* = 0$ and from KTC (2) it can be seen that $e^* < \sqrt{a}$. The possibility for two cases are then separately examined: $e^*=0$ and $0 < e^* < \sqrt{a}$. Examining first the case where first all the resource must be extracted in the second period it can be seen that this solution set requires that $p_1(1-\tau^*) < 0$, which cannot be the case since the politician cannot tax more than 100% of rents and prices must be positive. Turning now to the case where some, but not all, production of the resource takes place in the first period, the firm's optimal utility is $p_1(1-\tau^*) - 2p_2(1-\tau^*)e^* = 0$ and the equilibrium solutions for first and second period production can be expressed as follows: $e^* = \dfrac{p_1}{2p_2} < \sqrt{a}$; $R(e^*) = a - \dfrac{p_1^{\,2}}{4p_2^{\,2}}$. As can be seen, since τ is not represented in the equilibrium solution for e^* the optimal production decisions are made by the firm without regard to taxation. This result occurs because the firm's objective function is linear in taxation and, as a result, increased overall two-period tax rate will not affect the firm's decisions regarding timing of depletion. In other words, the politician is not able to skew the firm's production path to match her own time preferences.

Turning now to the politician's two period maximisation problem which can be expressed as $U_{PRI}^* = \max\limits_{\{\tau\}} p_1\tau e + \Pi p_2 \tau R(e)$ subject to a 'participation constraint' of the firm: $p_1(1-\tau)e + p_2(1-\tau)R(e) \geq b$. The participation constraint ensures that the politician does not levy taxes so onerous as to prevent the firm from producing. In the above expression the term 'b' represents a level of minimum profit required to induce the firm to produce, or in other words, 'b' represents the opportunity cost of the firm. If the firm has a number of high quality competing production opportunities 'b' might be very large. Conversely, if the firm has no other opportunities then 'b' could be very small or irrelevant. (The term 'b' is restricted to be non-negative, $b \geq 0$.) The Lagrangian for the politician's optimisation is as follows

$L = p_1\tau e + \Pi p_2 \tau R(e) + \lambda_P \left(b - p_1(1-\tau)e - p_2(1-\tau)R(e)\right)$ and the associated Kuhn-Tucker conditions for a maximisation are:

KTC (1) $\frac{\partial L}{\partial \tau} = p_1 e + \Pi p_2 R(e) + \lambda_P \left(p_1 e + p_2 R(e)\right) \le 0;$ $\tau \ge 0;$ $\tau \frac{\partial L}{\partial \tau} = 0.$

KTC (2) $\frac{\partial L}{\partial \lambda_P} = b - p_1(1-\tau)e - p_2(1-\tau)R(e) \ge 0;$ $\lambda_P \le 0;$ and $\lambda_P \frac{\partial L}{\partial \lambda_P} = 0.$

The Kuhn-Tucker technique is once again used to find the feasible solution set where two additional scenarios are explored: Scenario 1, where the participation constraint binds, and Scenario 2, where the participation constraint does not bind.

Scenario 1: The participation constraint binds. In this scenario $\lambda_P^* < 0$ and, from KTC (2) the optimal tax rate can be expressed as: $\tau^* = 1 - b/\left(p_1 e + p_2 R(e)\right)$. Since $\tau^* \in [0,1]$, for τ^* to form part of the feasible solution set '*b*' must be restricted as follows: $b \in \left[0,\, p_1 e + p_2 R(e)\right]$. Two additional sub-scenarios are now explored where the firm's optimisation varies depending on whether the production constraint binds or not. Both of the subsequent scenarios, 1a (when the production constraint binds) and 1b (when the production constraint does not bind), provide feasible solution sets.

Scenario 1a: Recalling from above that when the production constraint binds $e^* = \sqrt{a}$ and $R(e^*) = 0$. After making the necessary substitutions it can be seen that the equilibrium in this case is characterised by $e^* = \sqrt{a}$; $R(e^*) = 0$, $\tau^* = 1 - b/p_1\sqrt{a}$ and $\lambda_P^* = -1$. Optimal utility for the politician in this scenario is therefore expressed as $U_{PRI}^* = p_1\sqrt{a} - b \ge 0$, subject to the restrictions that $b \in \left[0, p_1\sqrt{a}\right]$ and $p_1 > 2p_2\sqrt{a}$.

As can be seen, if '*b*' is at the upper limit then the politician must let all rents be captured by the firm to incentivise production. This would result in her own utility being zero ($U^*_{PRI} = 0$). However, if '*b*' is at the lower limit, then $U_{PRI}^* = p_1\sqrt{a} \ge 0$.

Scenario 1b:[18] When the production constraint does not bind production takes place in both periods and optimal first period production is a function of first and second period prices, $e^* = p_1 / 2p_2$. After making the necessary substitutions into KTC (1) and KTC (2) the equilibrium for this scenario is characterised by: $e^* = \frac{p_1}{2p_2}$; $R(e^*) = a - \frac{p_1^2}{4p_2^2}$; and $\tau^* = 1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}$. In order to keep the equilibrium tax rate within the feasible range, 'b' is constrained as follows: $b \le p_1^2 / 4p_2 + ap_2$. After making the appropriate substitutions into the politician's utility function optimal utility can be expressed as $U_{PRI}^* = \left(\frac{p_1^2}{2p_2} + \Pi p_2 \left(a - \frac{p_1^2}{4p_2^2} \right) \right) \left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2} \right)$ subject to the restriction on *'b'*.

Scenario 2: The participation constraint does not bind. The case where the firm's participation constraint does not bind is not described in detail. After making the necessary substitutions and examining both cases of where the production constraint binds (or not) it can be seen that there is no feasible solution set.

Solution sets exist only where the participation constraint binds. This is not surprising since it is optimal for the politician to try to capture all rents through taxation and leave only the minimum required to incent the firm to produce. In other words, allowing the firm to capture rents in excess of those required to incentivise production would not be optimal given that the politician's utility is monotonically increasing and non-satiable in resource rents. With respect to the production constraint there are two feasible possibilities: it can bind or not and both scenarios provide feasible solutions.

For ease of reference, the equilibrium conditions and constraints required to satisfy the equilibrium are summarised in Table B.1 of Appendix B.

3.1.2 Comparing public and private forms of ownership.

A comparison of the politician's optimised utility under public and private forms of ownership and control is the focus of this sub-section with the objective to gain insights regarding

[18] For the purpose of brevity, we only explore the case where $e^*>0$ since we know from the firm's optimisation that the case of $e^*=0$ cannot occur as this requires $p_1(1-\tau^*)<0$, which cannot be the case given the restrictions imposed on taxation,.

which ownership structure the politician would prefer. However, since the equilibrium expressions for the politician's utility are feasible only over specific combinations of '*a*' and '*b*', the equilibrium expressions of optimal utility are first mapped to the feasible solution space to ensure proper comparison. The constraints that define the feasible solution space are graphically represented in Figure 3.1, which organises the feasible solution set according to values for: (i) the stock parameter '*a*'; and, in the case of private ownership and control, (ii) to the firm's opportunity cost, '*b*'. In Figure 3.1, the square root of the stock parameter, $\sqrt{a}$, defines the horizontal axis while the firm's opportunity cost defines the vertical axis.

The feasible solution space under public ownership and control is represented by the one-dimensional diagram at the top of Figure 3.1, while the feasible solution space for public ownership and control is represented by the two-dimensional diagram in the lower half of Figure 3.1. Under public ownership and control (i.e. when $0 < \sqrt{a} < p_1/2\Pi p_2$) and the production constraint binds, optimal utility is defined by $U^*_{PUB} = p_1\sqrt{a}$. When the production constraint does not bind, $p_1/2\Pi p_2 \leq \sqrt{a}$, and production occurs in both periods and optimal utility is defined by $U^*_{PUB} = \frac{p_1^{\ 2}}{4\Pi p_2} + \Pi p_2 a.$

Now turning to the feasible solution space under private ownership and control. The solution space is two-dimensional and is defined by feasible values of the firm's opportunity cost while the participation constraint binds (recalling that the participation constraint must always bind for there to be a feasible solution) and the resource stock parameter '*a*'. When $0 < \sqrt{a} < p_1/2p_2$ the production constraint binds and the resource is depleted in the first period. Over this space, the firm's opportunity cost must be less than $p_1\sqrt{a}$ for a feasible solution to exist. When $p_1/2p_2 \leq \sqrt{a}$, the production constraint does not bind and production under private ownership occurs in both periods. For a feasible solution to exist, the firm's opportunity cost must be less than $b \leq p_1^2/4p_2 + ap_2$.

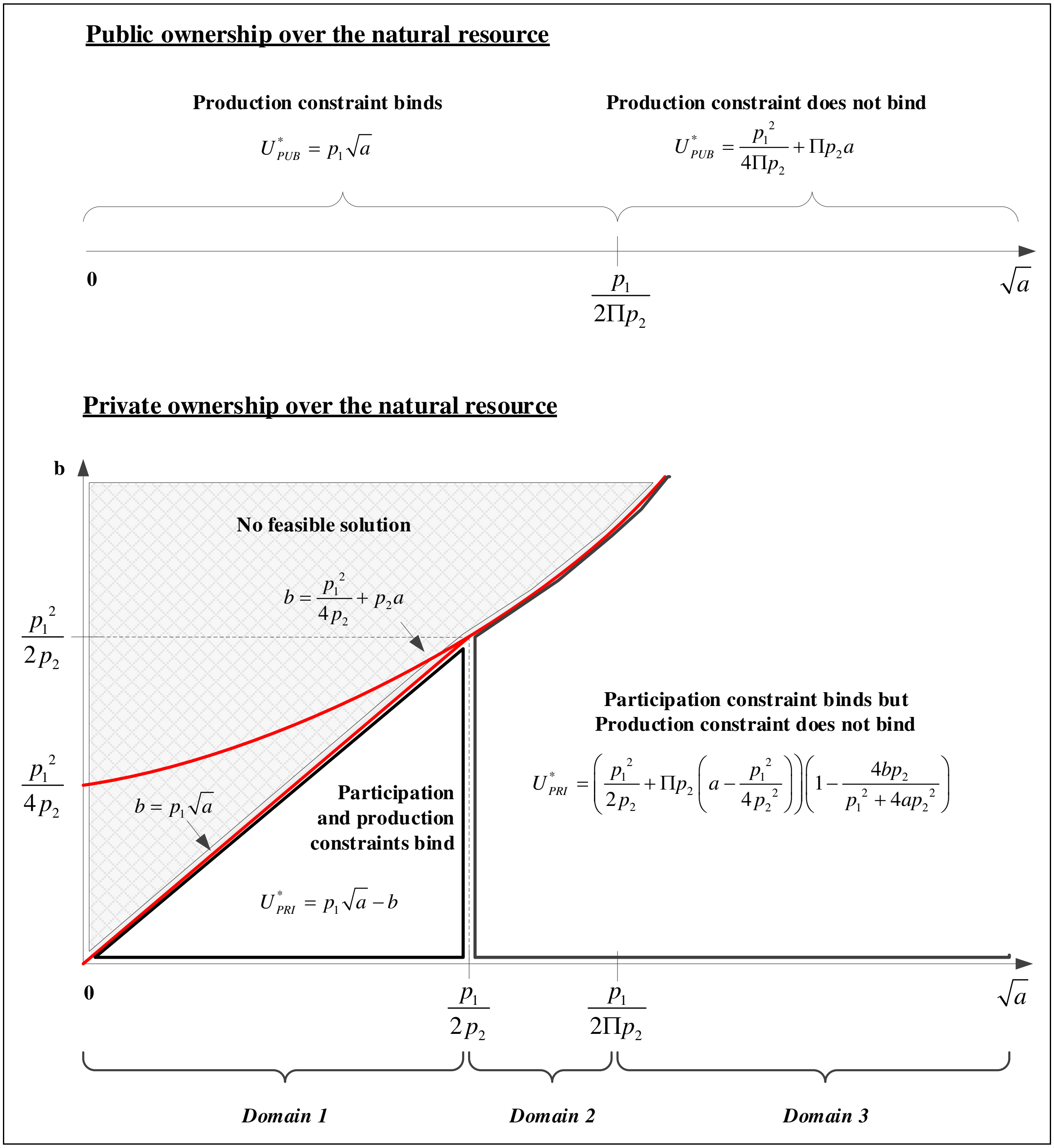

Figure 3.1 Feasible solution space as functions of the square root of 'a' and 'b' under costless extraction.

The feasible solution spaces for both public and private ownership are classified into three specific domains defined by values of 'a'. In domain 1, both models of public and private ownership are constrained by the production constraint and as a result, in both of those cases the entire resource is depleted in the first period. In domain 2, the production constraint applies only to the model of public ownership and not for private ownership. As a result, over this range of size of the resource stock the politician would deplete the entire resource in the first period while the firm would deplete it more slowly over two periods. In domain 3, neither model is constrained by the production constraint and production occurs in both periods under both public and private ownership. For ease of reference the equilibrium utility functions are summarised and categorised by domain in Table 3.1 below. These utility functions will be used in the subsequent subsections where differential optimal utility over the three domains will be compared, and the differential equilibriums' response to changes in exogenous parameters are examined through four propositions.

Table 3.1 Summary of optimal utility over three domains by ownership and control model under costless extraction.

<table>
<tr><th>Model / Domain</th><th>Domain 1
$0 < \sqrt{a} \le p_1/2p_2$</th><th>Domain 2
$p_1/2p_2 < \sqrt{a} < p_1/2\Pi p_2$</th><th>Domain 3
$p_1/2\Pi p_2 \le \sqrt{a}$</th></tr>
<tr><td>Public ownership and control</td><td colspan="2">Production constraint binds.
$U^*_{PUB} = p_1\sqrt{a}$</td><td>Production constraint does not bind.
$U^*_{PUB} = \frac{p_1^2}{4\Pi p_2} + \Pi p_2 a.$</td></tr>
<tr><td>Private ownership and control with taxation</td><td>Production and participation constraints bind.
$U^*_{PRI} = p_1\sqrt{a} - b$</td><td colspan="2">Production constraint does not bind but participation constraint binds.
$U^*_{PRI} = \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right)$</td></tr>
</table>

The sign and the expression for the optimised incremental utility of public ownership over private ownership is summarised below in Table 3.2 for all three domains. As can be seen, in all cases except for one special case the politician prefers public ownership and control over private ownership. The exception occurs when production takes place only in the first period under both ownership types (domain 1), and where the opportunity cost of firms is nil and all rents can be taxed away. In this case, the politician is indifferent to ownership type.

Table 3.2 Summary of incremental utility of public ownership by domain without state equity in the firm.

Domain 1	$\Delta U^* = b \geq 0$
Domain 2	$\Delta U^* = p_1\sqrt{a} \ - \left(\frac{p_1^{\ 2}}{2p_2} + \Pi p_2\left(a - \frac{p_1^{\ 2}}{4p_2^{\ 2}}\right)\right)\left(1 - \frac{4bp_2}{p_1^{\ 2} + 4ap_2^{\ 2}}\right) > 0$
Domain 3	$\Delta U^* = \frac{p_1^{\ 2}}{4\Pi p_2} + \Pi p_2 a \ - \left(\frac{p_1^{\ 2}}{2p_2} + \Pi p_2\left(a - \frac{p_1^{\ 2}}{4p_2^{\ 2}}\right)\right)\left(1 - \frac{4bp_2}{p_1^{\ 2} + 4ap_2^{\ 2}}\right) > 0$

The intuition for these results is as follows: in the first domain the time preference of the politician (i.e., her probability of reelection) has no effect since both the politician and the firm deplete the entire resource in the first period. Due to the perfect alignment of production in this domain, the only difference affecting the choice of one ownership type over another is the firm's opportunity cost. If the opportunity cost is non-zero, the politician would prefer public ownership. However, if the firm's opportunity cost is nil, the politician is indifferent to who owns and controls the resource.

In the second domain, the politician produces the entire resource in the first period, but the firm produces over two periods. As a result, the firm's rate of extraction is sub-optimally slow from the politician's perspective. Since the politician's utility is linear in taxation, she is unable to incent the firm to skew its production profile in favour of period one. Furthermore, due to the firm's opportunity cost she is unable to fully capture all the rents generated by the firm. She therefore prefers public ownership and control in this domain.

In the third domain, both the politician and the firm produce the resource over two periods. However, due once again to the difference in time preference between the politician and the firm, the firm sub-optimally underproduces the resource in the first period from the politician's perspective. This together with the politician's inability to capture all the rents due to the firm's opportunity cost result in the politician again preferring public ownership and control.

3.1.2.1 Equilibrium over the first domain

Over the first domain the resource is fully depleted in the first period under both ownership models. Incremental utility of public ownership and compared with its private counterpart is:

$$\Delta U^* = U^*_{PUB} - U^*_{PRI} = b. \tag{3.4}$$

Since ΔU^* represents the incremental utility of public ownership over private ownership to the politician, if ΔU^* is a positive value she prefers public ownership, whereas if ΔU^* is a negative value, she prefers private ownership. From equation (3.4) it can be seen that if the opportunity cost of the firm, b, is any positive value, the politician will prefer public ownership and control of the resource over private ownership. If the opportunity cost of the firm is nil, the politician is indifferent between ownership types since she can capture all profits through taxation of first period production.

Four propositions are tested throughout this chapter over each of the three domains to better understand the effect of exogenous parameters on the equilibrium. In the subsection below, the effect of changes to different parameters on preferences for different forms of ownership are explored. As the equilibrium expression for ΔU^* in equation (3.4) only contains one parameter, only one of four propositions are examined over the first domain, for all other positions the result is 0. The results are summarised in Table B.5 of Appendix B.

Proposition 1: An increase in the firm's opportunity cost, 'b', increases incentives for public ownership. ($\partial\Delta U^*/\partial b>0$)

The partial derivative of differential optimal utility with respect to the firm's opportunity cost is:

$$\frac{\partial \Delta U^*}{\partial b} = 1 > 0. \tag{3.5}$$

When examining how ΔU^* changes with exogenous changes to the firm's opportunity cost it can be seen that over this domain an increase in 'b' will unambiguously increase preferences for public ownership. The greater the opportunity cost of the firm (the greater the cost of incentivising its production), the less rents available for capture by the politician and therefore the greater the preference for public ownership. If the interpretation of '*b*' is generalised to proxy returns to the firm of an equal deposit in another location that is not available to the politician, then the higher the return from potential alternative investments, the greater will be the pressure on the politician to lower taxes to meet the investor's minimum profitability requirement. (This can be proved by examining the results from the previous section and equilibrium conditions summarised in Table B.1 of Appendix B to see that $\partial\tau^*/\partial b = -1/p_1\sqrt{a} < 0$.) The increased opportunity cost of the firm forces the politician to allocate more of the rents to the investor leaving less for herself. In this case the model predicts a preference for greater public ownership in environments where more than simple break-even profits are required to induce a firm to produce. This could be due to a potential political risk premium associated with the host country, or because the firm may have readily available alternative deposits to develop.

The result is unaffected by any other model parameter including prices or the probability of re-election.

3.1.2.2 Equilibrium over the second domain

Over the second domain the production constraint binds only in the case of public ownership and control. The difference in optimal utility between public and private forms of ownership is expressed as:[19]

$$\Delta U^* = p_1\sqrt{a} - \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) > 0. \tag{3.6}$$

Over this domain, the firm chooses to extract the resource over two periods under private ownership, whereas the politician would prefer to extract the entire resource in the first period. The deferral of production by the firm cannot be corrected via the tax mechanism since the tax applies to both periods equally and is non-distortionary between the two periods. The result is that the politician prefers public ownership. If reelection approaches certainty *(Π=1)*, domain 2 collapses to a single point, $p_1/2p_2$, which is the upper boundary to the first domain and in this case only the opportunity cost of the firm would affect the politician's ownership preference.

[19] The sign of equation (3.6) is confirmed through an examination of the limits of the function over the domain.

Turning now to examine how incremental utility from public ownership is affected by exogenous changes to the minimum profitability requirement, '*b*' (Proposition 1), the size of the resource stock '*a*' (Proposition 2), first and second period prices p_1 and p_2 (Proposition 3) and to re-election uncertainty (Proposition 4).[20] It should be noted that although the following propositions may increase or decrease preferences for ownership and control, the effect is never enough to change the preferred form of ownership from public to private.

Proposition 1: An increase in the firm's opportunity cost, 'b', increases incentives for public ownership. (∂ΔU*/∂b>0)

The partial derivative of differential utility with respect to the firms' opportunity cost yields:

$$\frac{\partial \Delta U^*}{\partial b} = -\Pi \frac{\left(p_1 - 2\sqrt{a}\,p_2\right)\left(p_1 + 2\sqrt{a}\,p_2\right)}{p_1^{\,2} + 4ap_2^{\,2}} > 0. \qquad (3.7)$$

It follows from equation (3.7) that an increase in the firm's opportunity cost will unambiguously increase preferences for public ownership. The interpretation is the same as that from before: the greater the opportunity cost of the firm, the less rents available for capture by the politician and therefore the greater the preference for public ownership.

Proposition 2: A resource stock boom increases incentives for public ownership. (∂ΔU*/∂a>0)

The partial derivative of differential utility with respect to the stock parameter, '*a*', yields:

$$\frac{\partial \Delta U^*}{\partial a} = \frac{p_1}{2\sqrt{a}} + p_2\Pi\left(\frac{8bp_1^{\,2}p_2}{\left(p_1^{\,2} + 4ap_2^{\,2}\right)^2} - 1\right) > 0. \qquad (3.8)$$

An examination of equation (3.8) at the limits of the boundaries constraining '*a*' over the second domain shows that an increasing resource stock will unambiguously increase preferences for public ownership. This is because the politician's time preference ensures that she produces the entire resource in the first period, while the firm spreads production over two periods, and so

[20] With respect to changes in prices, the price path is varied to investigate the implications of temporary and future anticipated resource booms and well as permanent resource booms, which are defined as increased prices in both periods.

as the resource increases in size the politician can capture more rents today through public ownership than she can under private ownership.

Proposition 3: Temporary, anticipated and permanent increases in prices increase incentives for public ownership. ($\partial\Delta U^*/\partial p_1>0$, $\partial\Delta U^*/\partial p_2>0$ and where $p_1=p_2=p$, $\partial\Delta U^*/\partial p>0$)

The partial derivatives of differential utility with respect to first period prices (p_1), second period prices (p_2) and then to a permanent price increase ($p_1=p_2=p$) yields the following which were signed by an examination of the limits over the domain:

$$\frac{\partial\Delta U^*}{\partial p_1}=\frac{p_1(\Pi-2)}{2p_2}-\frac{16abp_1p_2^2\Pi}{\left(p_1^2+4ap_2^2\right)^2}+\sqrt{a}<0;$$

$$\frac{\partial\Delta U^*}{\partial p_2}=\frac{p_1^2(1-\Pi)}{2p_2^2}+\left(\frac{4bp_2}{p_1^2+4ap_2^2}\right)\left(2\Pi\left(a-\frac{p_1^2}{4p_2^2}\right)+\frac{p_1^2\Pi}{2p_2^2}\right)-\Pi\left(a-\frac{p_1^2}{4p_2^2}\right)\left(1+\frac{32abp_2^3}{\left(p_1^2+4ap_2^2\right)^2}\right)\gtreqless 0; \quad (3.9)$$

$$\left.\frac{\partial\Delta U^*}{\partial p}\right|_{p_1=p_2=p}=\frac{1}{4}\left(4\sqrt{a}+\Pi(1-4a)-2\right)\gtreqless 0.$$

As can be seen from the expressions grouped under equation (3.9), temporary price booms weaken preferences for public ownership while anticipated and permanent price booms ambiguously affect preferences for the form of ownership. By better aligning the firm's production path with that of the politician a temporary price boom (an increase in p_1) unambiguously decreases preferences for public ownership. Conversely, by further exacerbating differences between the production path of the politician and the firm, an anticipated price boom increases preferences for public ownership when the resource size is at its lower limit but has an ambiguous effect as the resource size increases towards its upper limit over domain 2. A permanent price boom has an ambiguous effect at both limits of the domain.

These results are of interest because contrary to the theoretical model of Chang et al. (2017) who rely on price alone to explain preferences for ownership. This model shows that although price does indeed have an impact, in the second domain its effect is nuanced by many other relevant factors under consideration – price booms are not in themselves enough of an explanation and the type of boom also matters.

Proposition 4: An increase in the probability of reelection decreases incentives for public ownership. (∂ΔU*/∂Π<0)

The partial derivative of differential optimal utility with respect to the probability of reelection is:

$$\frac{\partial \Delta U^*}{\partial \Pi} = -p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) \leq 0. \tag{3.10}$$

From equation (3.10) it can be seen that an increase in the probability of reelection unambiguously decreases or has no effect on the politician's preferences for public ownership.

If the firm's opportunity cost approaches its upper feasible limit, as $b \rightarrow p_1^2/4p_2 + ap_2$, an increase in the probability of reelection will have less of an effect on the choice of ownership and control. This occurs because as '*b*' approaches its limit, the firm captures all the rents. Under this scenario, a change in probability of reelection has no effect since the politician will always chooses public ownership and control rather than cede all rents under private ownership and control. However, if '*b*' is less than this upper limit, an increase in the probability of reelection decreases incentives for state ownership since the production path of the politician becomes more aligned with that of the firm.

3.1.2.3 Equilibrium over the third domain

Over the third domain, production takes place in both periods under both forms of ownership. The difference in optimal utility can be expressed as:[21]

$$\Delta U^* = \frac{p_1^2}{4\Pi p_2} + \Pi p_2 a \; - \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) > 0. \tag{3.11}$$

As can be seen, the politician unambiguously prefers public ownership over this domain regardless of how large the resource is. This result occurs because the firm defers more production to the second period than the politician, who prefers to produce more of the resource in the first period given her time preferences. Furthermore, the firm's opportunity cost, '*b*', limits the politician's ability to fully capture rents through taxation. The firm's sub-optimally slow

[21] The sign of equation (3.11) is confirmed through an examination of the limits of the function over the domain.

production from the politician's perspective, combined with the requirement to cede rents to the firm to cover its opportunity cost culminates into an unambiguous preference for public ownership and control over this domain.

Turning now to once again examine how the politician's preference for public ownership is affected by changes to exogenous parameters through the four propositions. It is worth noting again that although the following propositions may increase or decrease preferences for ownership and control, because equation (3.11) is unambiguously positive their effect is never enough to change the preferred form of ownership from public to private.

Proposition 1: An increase in the firm's opportunity cost, 'b', increases incentives for public ownership. ($\partial\Delta U^*/\partial b>0$)

The partial derivative of differential utility with respect to the firms' opportunity cost yields:

$$\frac{\partial \Delta U^*}{\partial b} = \frac{4ap_2^2\Pi - p_1^2(\Pi - 2)}{p_1^2 + 4ap_2^2} > 0. \qquad (3.12)$$

As can be seen, all else remaining equal, an increase to the opportunity cost of the firm will unambiguously increase preferences for public ownership. The interpretation is identical to that for the results over domains 1 and 2: the greater the firm's opportunity cost, the less rents available for capture by the politician and therefore the greater the preference for public ownership.

Proposition 2: A resource stock boom increases incentives for public ownership. ($\partial\Delta U^*/\partial a>0$)

The partial derivative of differential utility with respect to the stock parameter, '*a*', yields:

$$\frac{\partial \Delta U^*}{\partial a} = \frac{8bp_1^2 p_2^2(\Pi - 1)}{(p_1^2 + 4ap_2^2)^2} \le 0. \qquad (3.13)$$

From equation (3.13), it follows that over the third domain an increasing resource stock will unambiguously decrease the politician's preference for public ownership as long as reelection is uncertain (i.e., when $\Pi<1$).

Recall that the resource stock function, $S(e)$, used in the model is non-linear and is affected by the choice of first period production, e^*. As the resource stock increases towards infinity, the amount of production that can take place in period one remains limited. For public ownership, this is $e_{PUB}^{*} = p_1/2\Pi p_2$, while for private ownership first period production is $e_{PRI}^{*} = p_1/2p_2$. (These equilibrium conditions are summarised in Table B.1 of Appendix B.) Second period production is defined as the remainder of the resource stock. As the resource increases, the additional stock is added to second period production, of which the firm already has more relative to the politician due to its slower production path. Increasing the stock by an absolute amount has a greater relative impact on the politician's second period stock and thereby minimises the relative difference between public and private production paths and decreasing incentives for public ownership.

From equation (3.13) it can be seen that if, either the firm's opportunity cost is nil or the politician's reelection is certain (in other words either $b=0$ or $\Pi=1$), then an increase in the resource stock will have no effect on the politician's preferences for ownership type.

Proposition 3: Temporary, anticipated and permanent increases in prices increase incentives for public ownership. ($\partial\Delta U^*/\partial p_1>0$, $\partial\Delta U^*/\partial p_2>0$ and where $p_1=p_2=p$, $\partial\Delta U^*/\partial p>0$)

The partial derivatives of differential utility with respect to first period prices (p_1), second period prices (p_2) and then to a price shift ($p_1=p_2=p$) yields:

$$\frac{\partial\Delta U^*}{\partial p_1} = \frac{p_1(\Pi-1)\left[p_1^4(\Pi-1)+8ap_1^2p_2^2(\Pi-1)+16ap_2^3\left(ap_2(\Pi-1)-2\Pi b\right)\right]}{2\Pi p_2\left(p_1^2+4ap_2^2\right)^2} \geq 0;$$

$$\frac{\partial\Delta U^*}{\partial p_2} = \frac{-p_1^2(\Pi-1)\left[p_1^4(\Pi-1)+8ap_1^2p_2^2(\Pi-1)+16ap_2^3\left(ap_2(\Pi-1)-4\Pi b\right)\right]}{4\Pi p_2^2\left(p_1^2+4ap_2^2\right)^2} \leq 0; \quad (3.14)$$

$$\left.\frac{\partial\Delta U^*}{\partial p}\right|_{p_1=p_2=p} = \frac{(\Pi-1)^2}{4\Pi} \geq 0.$$

An examination of the comparative statics above shows that price booms affect preferences for ownership and control, but only if the probability of reelection is uncertain. If reelection is certain, then regardless of whether the price boom is temporary, anticipated or permanent, a change in price will have no effect on the choice of ownership and control. This is because as the probability of reelection becomes certain (i.e., as $\Pi\rightarrow 1$) the politician's production path mirrors the firm's and the re-allocation of production between periods resulting from temporary, anticipated or permanent price booms is the same for both the firm and the politician. However, if the probability of reelection is uncertain, then a temporary price boom will unambiguously increase incentives for public ownership and control since booming first period prices reinforce the politician's preference to capture rents in the first period rather than in the second period. On the other hand, an anticipated price boom will unambiguously decrease incentives for public ownership and control since anticipated price booms make second period production more valuable relative to first period production. Since the firm defers more production to the second period (relative to the politician) incentives for public ownership and control are decreased. Finally, a permanent price boom unambiguously increases preferences for public ownership and control since a permanent price boom increases the total value of the resource and further exacerbates the differences in utility generated between the politician's and the firm's equilibrium production paths due to differences in time preference.

Comparing this last result with the result from Proposition 2 shows that when the resource is modelled explicitly, price booms have a very different effect from resource booms. This is an important result since most of the literature uses the two types of booms interchangeably where the finite nature of resources is not explicitly modelled. A resource 'stock' boom decreases preferences for public ownership, while a permanent 'price' boom increases preferences for public ownership.[22]

Proposition 4: An increase in the probability of reelection decreases incentives for public ownership. (∂ΔU*/∂Π<0)

The partial derivative of differential utility with respect to the probability of reelection yields:

$$\frac{\partial \Delta U^*}{\partial \Pi} = b + \frac{p_1^2}{4p_2}\left(\frac{\left(\Pi^2 - 1\right)}{\Pi^2} - \frac{8bp_2}{p_1^2 + 4ap_2^2}\right) \gtreqless 0;\ \text{though}\ \left.\frac{\partial \Delta U^*}{\partial \Pi}\right|_{b=0} < 0\ . \qquad (3.15)$$

Examining equation (3.15) shows that an increase in the probability of reelection has an ambiguous effect on preferences for ownership and control. This is confirmed through an examination of the limits of equation (3.15) for $\Pi \to 0$ and $\Pi \to 1$. However, if the firm's opportunity cost is very small, or the resource is very large, an increase in the probability of

[22] Recall from equations (3.4), (3.6) and (3.11) that although a shock to the resource stock may decrease preferences for public ownership, the politician will always prefer public ownership over all three domains.

reelection will align the politician's production path with the firm and decrease incentives for public ownership.[23]

3.1.3 Institutional constraints – the cost of institutional change

In addition to external market dynamics and political economy considerations an additional consideration for politicians weighing up a decision to change ownership from public to private relates to institutional constraints. When considering ownership choice States are also most likely to prefer public ownership and control where: (1) the cost of operating these public enterprises are low; and as supported by Mahdavi (2014), when (2) institutional constraints on politicians are limited; (3) after other countries have nationalised, reflecting reduced likelihood of international retaliation; and, (4) in countries where there is a pre-existing history of resource nationalism. This is intuitive since, creating the legislative framework for, or removing constraints to, operate a state-owned mining, oil or gas company introduces additional institutional costs for the politician. Furthermore, the manner through which a politician decides to change ownership (purchase, or expropriation) can be costly, difficult and problematic. For example, nationalisation of oil, gas and mining companies could be met by international retaliation by other countries. Finally, to run a state-owned enterprise efficiency additional effort and expenditure must be exerted for its oversight and management.

To capture these aspects of public ownership, the model is now extended to include an additional variable to capture the idea that the politician incurs an incremental cost (or loss of utility) when pursuing public ownership, 'C_{inst}'. 'C_{inst}' is defined as a non-negative constant that is subtracted from the incremental optima utility of public ownership, ΔU^*. If C_{inst} is large, the institutions that restrict the politician are strong or the costs are high. Conversely, if C_{inst} is small or zero, institutions that restrict the politician can be said to be weak and costs of public ownership are low. C_{inst} could take on all kinds of functional forms that depend on the resource size or probability of reelection. However, this study is more interested in the 'concept' of institutional costs and so for simplicity, C_{inst} is treated as a fixed cost over the two periods that does not change with the level of production or any other parameter. The politician will choose public ownership over private ownership when the incremental additional utility of public ownership exceeds the

[23] This can be verified by taking the limit of equation (3.15) as $b \to 0$ and $a \to \infty$.

institutional costs of ownership, C_{inst}. As a fixed cost, the introduction or this new variable does not affect any of the preceding comparative statics, it merely shifts the threshold differential utility (ΔU^*) required by the politician to choose public ownership over private ownership.

Results for the preferred ownership type and the propositions over each of the three domains are summarised Table B.3 and Table B.5 of Appendix B respectively. The effect of C_{inst} will become clearer when simulated results from the model are shown in Chapter 5 and Chapter 6.

3.1.4 Socially optimal extraction rate.

It is of interest to now examine the socially optimal equilibrium production path to determine whether any conclusions can be drawn regarding the efficiency of public or private ownership and control.

An omniscient, omnipotent and benevolent social planner is introduced to the model. The social planner has no time preference and values present utility equally to the future in the same manner that a benevolent leader would not favour present generations over future ones. The economy has only one sector, the resource sector, and all rents generated are used for welfare maximisation. The social planner maximises the following two period income function $\max_{\{e\}} Y = p_1 e + p_2 R(e)$, subject to the previously described production constraint. There is no private sector to tax since the social planner owns and controls the resource. The Lagrangian for this constrained optimisation is: $L = p_1 e + p_2\left(a - e^2\right) + \lambda_R\left(\sqrt{a} - e\right)$ and the associated Kuhn-Tucker conditions are:

KTC (1)	$\frac{\partial L}{\partial e} = p_1 - 2p_2 e - \lambda_R \le 0;$	$e \ge 0;$ and	$e\frac{\partial L}{\partial e} = 0.$
KTC (2)	$\frac{\partial L}{\partial \lambda_R} = \sqrt{a} - e \ge 0;$	$\lambda_R \ge 0;$ and	$\frac{\partial L}{\partial \lambda_R} = \sqrt{a} - e \ge 0.$

When the production constraint binds the socially optimal value of e^* is $e^*_{SOCIAL\ PLANNER} = e^* = \sqrt{a}$; which is the same as for the previously examined cases of private and public ownership. Therefore, in the first domain all forms of ownership are socially efficient.

In the second and third domains the socially optimal production path is the same as that under private ownership and extraction is less than under public ownership:

$e^*_{SOCIAL\ PLANNER} = e^*_{PRI} = p_1 / 2p_2 < p_1 / 2\Pi p_2 = e^*_{PUB}$. As a result, whenever election outcomes are uncertain (whenever $\Pi<1$) the politician will always sub-optimally overproduce the resource in the first period relative to private ownership and the socially optimal amount. However, the politician's overproduction is entirely attributable to her reelection uncertainty (or time preference) relative to the firm and the social planner. If time preferences of Π_{SP} and Π_{PRI} are introduced for the social planner and firm respectively, the optimal production path of the social planner and the firm would be: $e^*_{SOCIAL\ PLANNER} = p_1/2\Pi_{SP} p_2$ and $e^*_{PRI} = p_1/2\Pi_{PRI} p_2$, where $e^*_{SOCIAL\ PLANNER} \gtreqless e^*_{PRI} \gtreqless e^*_{PUB}$. In this case, depending on the relative time preferences either form of ownership could be socially efficient. Furthermore, if the politician's time preference is equal to the firm's her production path would be identical to the firm's but not necessarily efficient unless her time preference matched the social planner's as well.

As can be seen, when the resource is produced over two periods, the determination of which ownership model yields the efficient result is largely due to the difference between the time preferences of the politician, the firm and the social planner.[24] This is because, given the non-distortionary nature of the tax both the firm and social planner value production in both periods equally and their production paths are perfectly aligned as a result.

In a review of relevant literature, Juzhong (2007) and Harrison (2010) found that the social discount rate for a range of countries varies from 2% to 15% with the rate changing over time and by the methodology adopted to derive the discount rate. By comparison, this range overlaps considerably with typical weighted average costs of capital for large, oil, gas and mining companies that range from 7-15%. (See Damodaran (2017), and Mercer Capital (2016).) Political time horizons could differ from the social and private time preferences, however, Kendall-Taylor (2009) used ranges for the chance of political regime failure of 1% to 14% when determining that more secure leaders take longer term perspectives when making policy choices.[25] By way of a comparison, when considering that the average term for an elected politician is approximately 4

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[24] In a subsequent section, this study will also show how a non-appropriable cost or market access advantage of the firm over the politician could also affect the efficiency of one ownership model over the other.

[25] Kendall-Taylor (2009) uses these values to represent the predicted value of survival for each autocrat in every year of rule. The probabilities are based on observable causes of regime failure and measure the likelihood that an autocrat will be replaced in any given year.

years, reelection probabilities of 0.25, 0.50, 0.75 and 1.00 used in this model are equivalent to weights of 0.25, 0.50, 0.75 and 1.00 to utility generated in the second four-year term. This corresponds to annual discount rates of approximately 24%, 11%, 5% and 0% respectively after taking into consideration the duration of each term.[26]

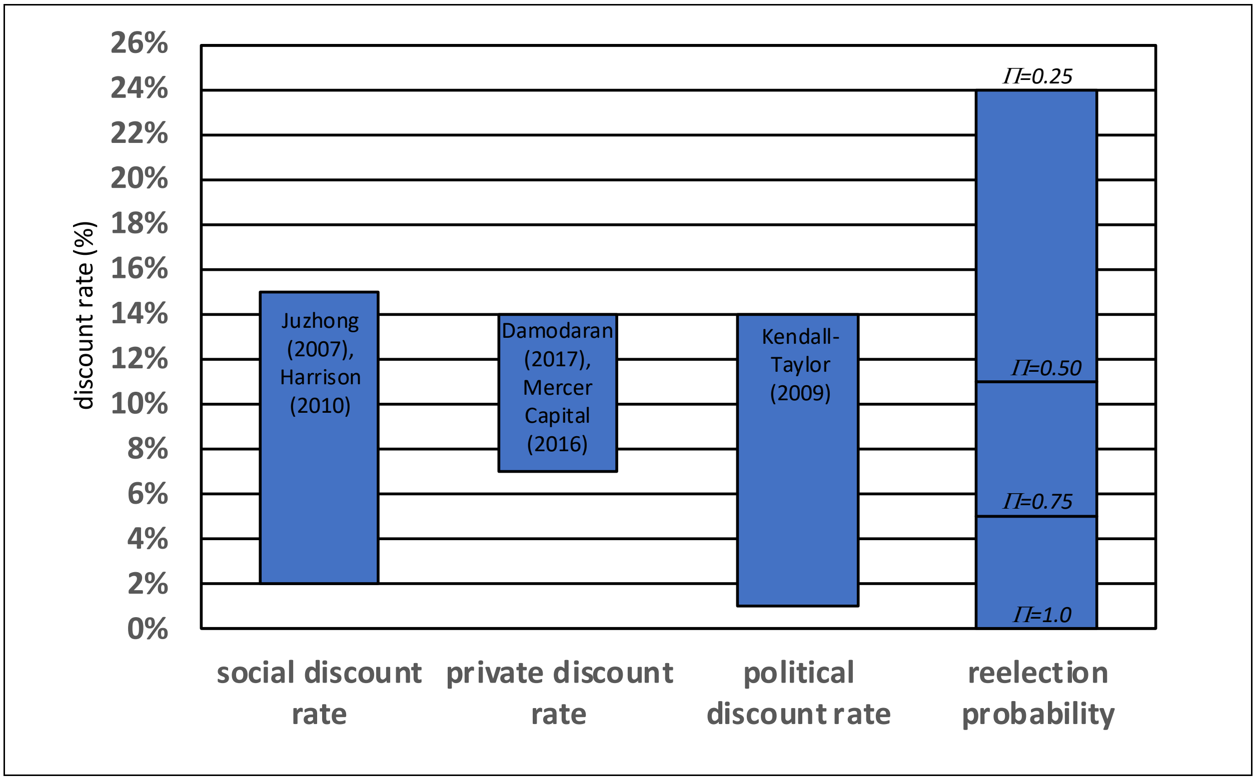

Figure 3.2 Review of time preferences between society, politicians, and the private sector. (Juzhong (2007); Harrison (2010); Damodaran (2017); Mercer Capital (2016); and Kendall-Taylor (2009))

As shown in Figure 3.2, these discount rates also overlap considerably with the social and private discount rates, challenging the common assumption in the political economy literature that politician's *always* have higher discount rates and shorter time horizons than would be considered socially optimal. Care must therefore be taken to not draw too strong a conclusion regarding comparisons of efficiency that are driven mainly by differing time preferences since it is possible for the politician to have a lower discount rate than the firm and social planner, and therefore, for

[26] Please contact the author should readers wish to obtain calculations for this conversion.

the politician's time preferences to be more aligned to the social planner's than the firm. In the literature review, the models of Robinson et al. (2014), Matsen et al. (2016), Hartley and Medlock (2008), Caselli and Cunningham (2007) all incorporate this time preference bias which provides a basis for their efficiency arguments.

3.1.5 Summary of results

The signs and the expressions for the optimised incremental utility of full public ownership over full private ownership were summarised in Table 3.2. Despite preferring ownership and control over all three domains whenever the firm's opportunity cost is non-zero, the degree to which the politician prefers one over the other depends critically on many exogenous parameters. For example, under all the domains identified, the propositions examined in Section 3.1.2 show that the politician will favour public ownership more as the opportunity cost of the firm increases. (Please see the summary of propositions in Table B.5 of Appendix B.) All other exogenous parameters have different impacts depending on which domain is being examined – this leads to a rich and nuanced understanding of the incentives affecting politician's choices of ownership. Rather than repeat the discussion from the preceding sections, focus is placed on summarising and interpreting the effect of changes to exogenous parameters on the politician's preferences for ownership and control type over domain 3, which can be argued to be more representative of the types of large resources with long lives that span multiple electoral terms. Here, unlike in domain 2, an increase in the resource stock parameter 'a' decreases incentives for public ownership and control. Since the total resource stock, '$S(e)$', is non-linear in first period depletion, a resource stock boom dampens the relative differences between the politician and the firm's production path thus decreasing incentives to adopt public ownership. However, to be clear, although her preferences for public ownership are decreased as the resource stock increases, she still unambiguously prefers public ownership and control.

Turning next to an examination of prices it can be seen that in domain 3 price booms affect preferences for ownership and control, but only if the probability of reelection is uncertain. When reelection is uncertain, a temporary price boom unambiguously increases incentives for public ownership by reinforcing the politician's preference to capture rents in the first period; anticipated second-period price booms have the opposite effect. Permanent price booms increase preferences for public ownership and control since they increase the total value of the resource while exacerbating differences in the production path due to time preference differences between the politician and the firm.

An increase in the relative risk tolerance or reelection certainty of the politician provides for a rich interpretation of the political economy as it interacts with the opportunity cost of the firm, available rents and non-linearity of the depletion model. Increased re-election certainty aligns the production paths of the firm and politician thereby decreasing the incentive for public ownership and control through one mechanism, however, this interacts with other parameters in the model. If the firm's opportunity cost is nil, then increased reelection certainty will unambiguously decrease preferences for public ownership. However, if the firm's opportunity cost is non-zero, then it is possible that an increase in reelection uncertainty could increase preferences for either public or private ownership.

With respect to constraints on the politician, as was discussed in Section 3.1.3, if the politician faces specific institutional costs to public ownership and control, an increase in those institutional costs will decrease incentives for public ownership and control.

Finally, with respect to the efficiency of ownership, as was discussed in Section 3.1.4 when the entire resource is produced in the first period under both private and public ownership models, both forms of ownership are socially efficient. However, when the entire resource is not produced in the first period the determination of which ownership model yields the efficient result is largely due to the difference between the time preferences of the politician, the firm and the social planner. Because the time preferences for the firm and social planner are not explicitly modelled in the preceding sections, equal weight is placed on their first and second period production and as a result, their production paths are perfectly aligned and render the production path under public ownership socially inefficient.

Contrary to other models of ownership such as Chang et al. (2017), the model shows that although price does indeed have an impact on ownership choices, its effect is nuanced by many other relevant factors under consideration. This study therefore finds that price is not enough in itself to fully explain politicians' preferences for, and choices regarding, ownership type. Furthermore, in line with Robinson et al. (2014) and Matsen et al. (2016), the model shows that the politician will inefficiently extract the resource relative to the socially optimal rate, but that this result is dependent on assumptions made regarding the politician's time preferences relative to the social optimal and the firm's. If the firm's time preferences are assumed to be more in line with the social planner's, this model advances the work of Robinson et al (2014) to show that private ownership and control of the resource is one potential institutional remedy to the inefficiencies they identify. Finally, as shown by Proposition 3 in Section 3.1.2.3 the model shows that when the resource is modelled explicitly, price booms have a very different effect from resource booms. This is an important result since most of the literature assumes the two types of booms have the same effect, even when the finite nature of resources is not explicitly modelled.

3.2 Full public ownership and control vs. private control with partial public ownership

As mentioned in Section 2.2 and shown in Table A.1, Table A.2 and Table A.3 of Appendix A when considering the form of ownership and how rents are captured from sub-soil natural resources many countries choose to take an equity stake in the private sector firm and combine this with a statutory fiscal regime. To capture this concept this next section modifies the model slightly to include an additional choice variable '*I*' that represents the politician's equity interest in the firm. In addition to taxes, '*I*' represents a separate income stream for the politician. However, to ensure that the firm retains control over the underlying resource '*I*' is restricted as follows: $I \in [0, 0.5)$. This effectively limits the politician's maximum equity interest to a fifty percent less one share equity interest in the firm. The data from Table A.3 in Appendix A generally supports this restriction (particularly in the mining sector) where it can be seen that governments tend to limit their equity interests to 50% or less.

One possible explanation for the limit to government's equity interest is that intellectual property, management know-how and relationships with clients (i.e. market access) are valued and therefore protected by firms, making it difficult to incent a firm to deploy its competitive advantages when it cannot control how these advantages are used and protected by a government partner. Another explanation is that firms may be reluctant to enter into arrangements and invest when they hold a minority interest in partnership with a state-owned company due to lower profitability expectations.[27] The exception is with oil and gas under production- or risk-sharing arrangements that create a legal framework that allows for private sector control and management of the resource under a minority equity stake. These "operating rights" are normally defined in

[27] The competitive (cost or market access) advantages of the private sector over government is discussed in greater detail in Chapter 4.

management contracts, technical service agreements or other side-agreements that specify the rights and decision-making powers of the private partner(s) vis-à-vis the government.

With the above in mind and turning now to modelling partial public ownership, the politician's optimisation problem under private ownership previously defined in Section 3.1.1 can be rewritten as $\max_{\{\tau,I\}} U_{PRI(equity)} = p_1\tau e + \Pi p_2 \tau R(e) + I\left(p_1\left(1-\tau\right)e + \Pi p_2\left(1-\tau\right)R(e)\right)$, subject to the following participation constraint $\left[p_1(1-\tau)e + p_2(1-\tau)R\left(e\right)\right]\left(1-I\right) \geq b\left(1-I\right)$.[28] The terms on the left-hand side of the politician's maximisation problem represent her utility from taxation while the terms on the right-hand side is her two-period utility from her non-controlling equity stake. In turn, the firm's profit maximisation problem is rewritten as $\max_{\{e\}} P = \left(p_1\left(1-\tau\right)e + p_2\left(1-\tau\right)R(e)\right)\left(1-I\right)$ subject to the production constraint which remains unchanged from Section 3.1. The firm once again chooses the optimal production path while the politician chooses optimal taxation and her non-controlling equity stake. The game between the politician and the firm is unchanged from before with the exception that the equity stake is chosen at the same time as the tax rate taking into consideration current and future prices, prospects for reelection and the firm's optimal response to the equity stake and tax rate.

The resulting Lagrangian for the private sector's constrained optimisation is $L = \left(p_1\left(1-\tau\right)e + p_2\left(1-\tau\right)\left(a-e^2\right)\right)\left(1-I\right) + \lambda_R\left(\sqrt{a}-e\right)$ and the associated Kuhn-Tucker conditions for a maximisation are similar to before, with the one exception that the new *(1-I)* term is present in KTC (1):

KTC (1) $\quad \frac{\partial L}{\partial e} = \left(p_1\left(1-\tau\right) - 2p_2\left(1-\tau\right)e\right)\left(1-I\right) - \lambda_R \leq 0; \quad e \geq 0;$ and $\quad e\frac{\partial L}{\partial e} = 0.$

KTC (2) $\quad \frac{\partial L}{\partial \lambda_R} = \sqrt{a} - e \geq 0; \quad \lambda_R \geq 0;$ and $\quad \lambda_R \frac{\partial L}{\partial \lambda_R} = 0.$

As before, two scenarios are explored using the Kuhn-Tucker technique to find the feasible solution set. When the production constraint binds the firm once again depletes the entire resource in the first period and $e^* = \sqrt{a}$. When the production constraint does not bind, $e^* = p_1/2p_2$ and the

[28] The additional term *(1-I)* on the left and right-hand sides of the participation constraint cancel each other and the resulting participation constraint remains unchanged from Section 3.1.

firm chooses the optimal production path by taking only prices into consideration. These results are identical to the case without partial state equity participation highlighting that the politician's decision to take an equity stake in the firm will not affect the firm's chosen production path. This intuitively makes sense since the firm's two-period profits are linear in state equity and therefore the timing of production is unaffected.

Turning now to the politician's two-period maximisation problem the Lagrangian for her optimisation can be expressed as follows $L = p_1\tau e + \Pi p_2\tau R(e) + I\left(p_1(1-\tau)e + \Pi p_2(1-\tau)R(e)\right) + \lambda_P\left(b - p_1(1-\tau)e - p_2(1-\tau)R(e)\right)$ and the associated Kuhn-Tucker conditions for a maximisation are:

KTC (1) $\frac{\partial L}{\partial \tau} = \left(p_1 e + \Pi p_2 R(e)\right)(1-I) + \lambda_P\left(p_1 e + p_2 R(e)\right) \le 0;$ $\quad \tau \ge 0;$ $\quad \tau\frac{\partial L}{\partial \tau} = 0.$

KTC (2) $\frac{\partial L}{\partial I} = p_1(1-\tau)e + \Pi p_2(1-\tau)R(e) \le 0;$ $\quad I \ge 0;$ $\quad I\frac{\partial L}{\partial I} = 0.$

KTC (3) $\frac{\partial L}{\partial \lambda_P} = b - p_1(1-\tau)e - p_2(1-\tau)R(e) \ge 0;$ $\quad \lambda_P \le 0;$ and $\quad \lambda_P\frac{\partial L}{\partial \lambda_P} = 0.$

Solving again using the Kuhn-Tucker technique it can be shown that feasible solutions are only possible when the participation constraint binds. Optimal taxation is found to be $\tau^* = 1 - b/\left(p_1 e + p_2 R(e)\right)$, which is identical to the previous case without partial government equity. Since utility is linear in the equity stake, it is always optimal for the politician to set this at its upper limit: a 50% less one share interest in the firm.[29] When the production constraint binds and production takes place in the first period only, the values of production, taxation and state equity are defined as $e^* = \sqrt{a}$; $R(e^*) = 0$, $\tau^* = 1 - b/p_1\sqrt{a}$ and $I^* = 50\%$ less one share. After making the necessary substitutions the politician's optimal utility can be expressed as: $U^*_{PRI(equity)} = p_1\sqrt{a} - b\left(1 - I^*\right)$.

Although the optimal state equity share of 50% less one share is larger than those prevalent in many of the countries listed in Table A.3 of Appendix A there are several possible explanations for this. One compelling explanation is that when setting competitive limits to state equity

[29] Since the production decision and path are not negatively affected by the partial equity stake, the politician's utility under private control with partial public ownership is monotonically increasing in *'I^*'*.

governments will typically look at the total fiscal burden and compare this with other competing jurisdictions. This calculation will normally include the cumulative impact of many widely used fiscal instruments such as royalties, profits-based taxes, surface or other fees, withholding taxes on interest and dividends, etc.[30] The inclusion of other fiscal instruments and the need to compete with other jurisdictions could be an important consideration for government that have a limiting impact on their state equity interest. Another explanation is that many companies undertake oil, gas and mineral development in partnership with other firms and must therefore already share equity with other private partners. If for example, the remaining 50.1% is divided among two private partners, say on a 40.1% and 10% basis, there is no single controlling party and government would be the largest shareholder with more board members and votes than any other private partner individually.[31] Many companies would be reluctant to enter into this kind of arrangement due to the possibility of an impasse among shareholders and the potential undue power that this could give the smaller private shareholder vis-à-vis the larger private shareholder as they would hold the "swing" vote. Restricting the stake equity limit to a lower range of ~10-30% is one way to allow for minority private partners while also providing the necessary comfort to a controlling private partner.

When the production constraint does not bind production takes place in both periods and optimal first period production is a function of first and second period prices, $e^* = p_1 / 2p_2$. After making the necessary substitutions into KTC (1) and KTC (3) the equilibrium for this scenario is characterised by: $e^* = \frac{p_1}{2p_2}$; $R(e^*) = a - \frac{p_1^2}{4p_2^2}$; $\tau^* = 1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}$; and $I^* = 50\%$ less one share. The politician's optimal utility can be expressed as $U^*_{PRI(equity)} = \left(p_1 e + \Pi p_2 R(e)\right)\left(\tau + I^*(1-\tau)\right)$ or alternatively after making all the necessary substitutions for *e**, *R(e*)* and *τ** as follows, $U^*_{PRI(equity)} = \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) + I^*\left(1 + \frac{4bp_2}{p_1^2 + 4ap_2^2}\right)\right)$.

[30] Recall from Section 2.2 that a dividend withholding tax has the same fiscal effect as a free equity interest.

[31] It is not uncommon in many oil, gas and mining ventures to have one minority private partner. Often this shareholder structure results from a situation where the junior mining company or wildcat driller makes the resource discovery but needs to take on a larger partner to provide the technical skills and capital to develop the property.

The expressions and signs for the optimised incremental utility of public ownership and control over private control with partial public ownership are summarised in Table 3.3. These expressions can be compared with the results for full public ownership and control vs. full private ownership and control by referring to Table 3.2 in Section 3.1.2. As can be seen the introduction of a non-controlling public equity stake nuances the results from Section 3.1. For example, in Section 3.1 the politician unambiguously preferred full public ownership and control of the resource whenever the firm's opportunity cost was non-zero. Now, the politician may prefer private control of the resource over full public control in domains 2 and 3; whether she does or not depends on a combination of exogenous factors and how these combine with the value of the equity stake. In all three domains an increase in the value of the politician's equity stake will increase preferences for private control (with partial public ownership) over full public ownership and control.[32] This occurs because in addition to generating utility through taxation the politician generates additional utility by capturing rents through her equity stake that are equivalent to 'I^*b' without affecting the firm's decision to produce or not.[33,34]

Table 3.3 Summary of incremental utility by domain of private control with partial public ownership.

Domain 1	$\Delta U^* = b\left(1 - I^*\right) \geq 0$
Domain 2	$\Delta U^* = p_1\sqrt{a} \; - \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) + I^*\left(1 + \frac{4bp_2}{p_1^2 + 4ap_2^2}\right)\right) \lesseqgtr 0$
Domain 3	$\Delta U^* = \frac{p_1^2}{4\Pi p_2} + \Pi p_2 a \; - \left(\frac{p_1^2}{2p_2} + \Pi p_2\left(a - \frac{p_1^2}{4p_2^2}\right)\right)\left(\left(1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}\right) + I^*\left(1 + \frac{4bp_2}{p_1^2 + 4ap_2^2}\right)\right) \lesseqgtr 0$

32 The only exception occurs in domain 1 when the opportunity cost of firms is nil. In this case, the politician is indifferent to ownership type regardless of the level of her equity stake.

33 This can be seen by recognizing that the term on the right-hand side of the politician's utility function $U_{PRI(equity)} = p_1\tau e + \Pi p_2 \tau R(e) + I^*\left(p_1\left(1-\tau\right)e + \Pi p_2\left(1-\tau\right)R(e)\right)$ can be replaced with 'b'. This is because for a feasible solution to exist the politician will always fully-tax up to 'b', which allows the participation constraint to be rewritten as follows when equilibrium conditions are satisfied: $p_1(1-\tau^*)e^* + p_2(1-\tau^*)R\left(e^*\right) = b$.

34 Another explanation is that the introduction of a partial equity stake reduces the firm's opportunity cost by a factor 'I^*'.

Exploring the case of partial public ownership in the firm yields important insights regarding what matters for efficiency and ownership incentives. As shown above, the introduction of a non-controlling state equity share reduces the government's incentives for full public ownership and does so without affecting the efficiency of the production path. As a result, if private control is socially optimal but not incentive compatible with the politician's utility, a non-controlling equity stake in the firm is one possible solution that might allow for an efficient result while still generating maximum utility for the government. This potential 'win-win' might explain why so many countries highlighted in Table A.1, Table A.2 and Table A.3 of Appendix A have chosen a combination of taxation and equity participation in their extractive industries.

Although the case of state equity generates interesting and meaningful insights for this research effort it is not carried forward into the subsequent analysis. In the chapters that follow this research will focus on the case of $I = 0$, recognizing that $0 < I$ provides less motivation for full public ownership and control and may be an alternative mechanism by which the state obtains a larger share of rents while not affecting the efficiency of private operations. Instead, the focus in the subsequent chapters will turn to how a competitive or market access advantage of private ownership affects incentives for public ownership and control. However, before examining that new model set-up is it of benefit to consider potential policy recommendations that might follow from the preceding analysis.

3.3 Potential policy recommendations

The political economy literature highlights two types of institutions that can lead to optimal policy-making: (i) those that constrain the ruling elite; and (ii) those that incent governments to make correct decisions. As the size of the resource or the opportunity cost of firms are factors outside the control of the host country, institutional recommendations can only be influenced by these factors but cannot be anchored in them. The results show clearly that when politicians are unconstrained, they would prefer the suboptimal institutional choice of public ownership and control over the resource.

Politicians do, however, respond to costs and therefore policies or measures that increase the institutional cost (C_{inst}) of public ownership and control could lead to optimal decision making. Section 3.1.3 shows how preferences for one set of ownership and control institutions over another can be affected by institutional costs. At one extreme, countries wanting to protect against the inefficiencies manifesting through public ownership could restrict state participation in extractive industries through appropriate constitutional amendments, since the constitution is very difficult and costly to change in most countries. Another less onerous restriction with potentially broader based benefits would be for governments to require inter-ministerial representation on the board of state owned resource companies to allow for greater inter-governmental transparency and require the adoption of exacting standards for corporate governance for state owned enterprises. These would in effect limit the discretionary control of state owned enterprises and add to the institutional cost of public ownership. Once these institutional costs are considered, the incentives for ownership would be affected by commodity prices, the size of the resource, and the opportunity cost of the firms who would consider developing the resource.

One factor that might reduce incentives for full public ownership and control is a partial non-controlling equity stake in the firm. As was discussed in Section 3.2 a non-controlling public equity stake in the firm might provide an incentive-compatible and efficient response to potential inefficiencies arising from full public ownership and control. As highlighted in the tables of Appendix A, this potential 'win-win' combination of taxation, equity participation and/or production- and risk-sharing contracts has been used in many countries' extractive industries and should be considered as an option where private ownership is believed to be socially efficient. However, care must be taken to set the level of state equity low enough (or make alternative contractual arrangements) to incentivise the firm to deploy any proprietary cost or market access competitive advantages it may possess. These potential sources of competitive advantage are the focus of the following chapter.

CHAPTER 4

MODEL 2: A SIMPLE MODEL WITH DIFFERENTIAL EXTRACTION COSTS

The following chapter extends the previous model to explore the effect of adding extraction costs and a competitive cost or market access advantage of private ownership. The model is extended through the inclusion of costs for the following three reasons: (i) much of the literature assumes costless extraction, therefore developing one model with costs allows provides an opportunity to compare previous findings (albeit imperfectly) with their inclusion; (ii) developing two models, one with costs and one without, while keeping all other parameters and the structure of the model constant tests the sensitivity of results from the preceding chapter and provides an indication of the robustness; and (iii) as La Porta and López-De-Silanes (1999), Galiani et al. (2003), Hartley and Medlock (2008) and Das (2012) have well documented, state ownership and control of resource companies is often accompanied with high costs and lower production efficiencies compared with the private sector. Therefore, the incorporation of costs provides an opportunity to explore how a potential cost or market access differential between private and public ownership and control may impact incentives for choosing one form of ownership and control over another as well as aspects regarding the efficiency of extraction.

The model follows the general structure of the previous model under costless extraction and as before, in the face of reelection uncertainty the politician must choose a production path to maximise her expected two-period utility. After letting *'c_{PUB}'* denote the constant marginal cost of extraction under public ownership, the politician's utility function under public ownership and control can be expressed as:

$$U_{PUB} = \left(p_1 - c_{PUB}\right)e + \Pi\left(p_2 - c_{PUB}\right)R(e). \tag{4.1}$$

If c_{PUB} and c_{PRI} represent the cost of extraction under public and private ownership respectively, the expression in equation (4.1) can be simplified by defining net prices as $p_1' = p_1 - c_{PRI}$, $p_2' = p_2 - c_{PRI}$ and introducing a new cost term *'c'* defined as $c = c_{PUB} - c_{PRI}$.[35] The new parameter '*c*' can be interpreted as the differential cost, or the cost advantage of private ownership. Wolf (2009), Wolf and Pollitt (2008), La Porta and López-De-Silanes (1999), Galiani et al. (2003), Schmitz and Teixeira (2008) and Das (2012) all provide strong empirical evidence to support the assumption that '*c*' is statistically significant, positive and large; that is, state owned oil, gas and mining companies are on average less efficient and less profitable than their private sector counterparts. The term '*c*' can also therefore be interpreted to represent any competitive advantage of private ownership over public ownership regardless of whether this is a cost savings, or activities that allow it to realise higher revenues. This paper subsequently refers to '*c*' as the cost or market access advantage of private ownership.[36] After completing the substitutions described above, equation (4.1) can be rewritten as:

$$U_{PUB} = \left(p_1' - c\right)e + \Pi\left(p_2' - c\right)R(e). \tag{4.2}$$

Net prices are restricted to be positive and non-negative in both periods, i.e., $p_i' - c > 0 \ \forall \ i \in \{1,2\}$.[37]

4.1 Equilibrium for models of public and private ownership and control

The next subsection proceeds as before and first examines the case of public ownership and control before examining private ownership and control. The Lagrangian for the constrained optimisation is $L = \left(p_1' - c\right)e + \Pi\left(p_2' - c\right)\left(a - e^2\right) + \lambda_R\left(\sqrt{a} - e\right)$. As before, the Kuhn-Tucker technique is used to find the feasible solution set by exploring two scenarios: Scenario 1, where the production constraint binds, and Scenario 2, where the production constraint does not bind. Since much of the derivations are similar to those included in Chapter 3, for the purpose of parsimony the derivations are omitted, and the result of the derivations and equilibrium conditions

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[35] Both c_{PUB} and c_{PRI} are restricted to take on positive, non-zero values.

[36] To how 'c' also captures aspects related to a market access benefit, let the prices received by the politician and the firm be p_{PUB} and p_{PRI} respectively. If the firm receives a price premium, '*m*', due to market access advantages then $p_{PRI} = p_i + m$, $\forall \ i \in \{1,2\}$. With public price being 'p_i' the difference in public and private price received is merely, *m*. For the purpose of parsimony, this study lets the concept of '*m*' be captured within '*c*'.

[37] If there is no cost or market access advantage of private ownership the expression in equation (4.2) collapses to the one presented in equation (3.1) with the notable difference that prices have been replaced by p'_i.

are now presented. Should the reader wish to advance to the next subsection (4.2), a summary of the equilibrium conditions and constraints required to satisfy the equilibrium are contained in Table B.2 of Appendix B.

<u>Scenario 1: The production constraint binds.</u> In this scenario the entire resource is depleted in the first period and the equilibrium utility function for the politician is expressed as $U^*_{PUB} = (p_1' - c)\sqrt{a} > 0$.

<u>Scenario 2: The production constraint does not bind.</u> In this scenario the possibility for two cases: $e^*=0$ and $0 < e^* < \sqrt{a}$ are separately examined. The first case of $e^*=0$ is not a feasible solution. The second case provides a feasible solution which is characterised by: $e^* = \frac{p_1' - c}{2\Pi(p_2' - c)} < \sqrt{a}$; $R(e^*) = a - e^{*2}$; and $\lambda_R^*=0$. Production takes place in both the first and second periods and optimal utility is expressed as $U^*_{PUB} = \frac{(p_1' - c)^2}{4\Pi(p_2' - c)} + \Pi(p_2' - c)a > 0$.

Turning now to the model set-up where a profit maximising firm holds ownership and control rights over the resource subject to taxation by the politician. Here, the firm's two-period profit optimisation problem can be expressed as: $P^* = \max_{\{e\}} p_1'(1-\tau)e + p_2'(1-\tau)R(e)$ subject to the same production constraint. The politician's optimisation is the same as before and is also subject to the same participation constraint and the Lagrangian for her constrained optimisation is: $L = p_1'\tau e + \Pi p_2'\tau R(e) + \lambda_P\left(b - p_1'(1-\tau)e - p_2'(1-\tau)R(e)\right)$. The game between the politician and the firm is the same as was discussed in Section 3.1.1 and results mirror those from that section with the exception that p_1' and p_2' replace p_1 and p_2 respectively. Feasible solutions are only found when the firm's participation constraint is binding because even when production is not costless, it is optimal for the politician to tax all rents away up until the remaining rents captured by the firm equal its opportunity cost.

Scenario 1: The production constraint binds. In the case where the production constraint binds, all production occurs in the first period the politician's optimal utility is expressed as $U^*_{PRI} = p_1'\sqrt{a} - b \geq 0$ subject to the restrictions that $b \in \left[0, p_1'\sqrt{a}\right]$ and $p_1' > 2p_2'\sqrt{a}$.[38]

Scenario 2: The production constraint does not bind. In this case, production occurs in both periods and the first period production and optimal utility are characterised by: $e^* = \frac{p_1'}{2p_2'}$; and

$$U^*_{PRI} = \left(\frac{p_1'^2}{2p_2'} + \Pi p_2'\left(a - \frac{p_1'^2}{4p_2'^2}\right)\right)\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right).$$

4.2 Comparing public and private forms of ownership.

The politician's optimal utility under public and private forms of ownership and control are now compared to gain insights into which ownership structure the politician prefers when a cost or market access advantage of private ownership exists.

The constraints that define the feasible solution space are once again graphically represented in Figure 4.1, which organises the feasible solution set according to values for: (i) the stock parameter '*a*'; and, in the case of private ownership and control to, (ii) the firm's opportunity cost, '*b*'. The interpretation of the chart is identical to that in Chapter 3 with the exception that the axes are now defined in terms of net prices.[39]

For ease of reference the equilibrium utility functions are summarised and categorised by domain in Table 4.1 and again in Table B.2 of Appendix B. These utility functions will be used in the subsequent subsections where differential optimal utility over the three domains will be compared, and the differential equilibriums' response to changes in exogenous parameters are examined, this time through five propositions.

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[38] The restrictions on '*b*' are required to constrain optimal taxes to be within the feasible range. If '*b*' is at the upper limit, then the politician will not capture any rents for herself ($U^*_{PRI} = 0$), whereas if '*b*' is at the lower limit she captures all available rents ($U^*_{PRI}=p'_1$).

[39] The interpretation of this chart will not be expanded upon further except to reiterate that the definition of domains is important to ensure that the correct equilibrium utility functions and feasible expressions for '$\sqrt{a}$' and '*b*' are used in each of the domains.

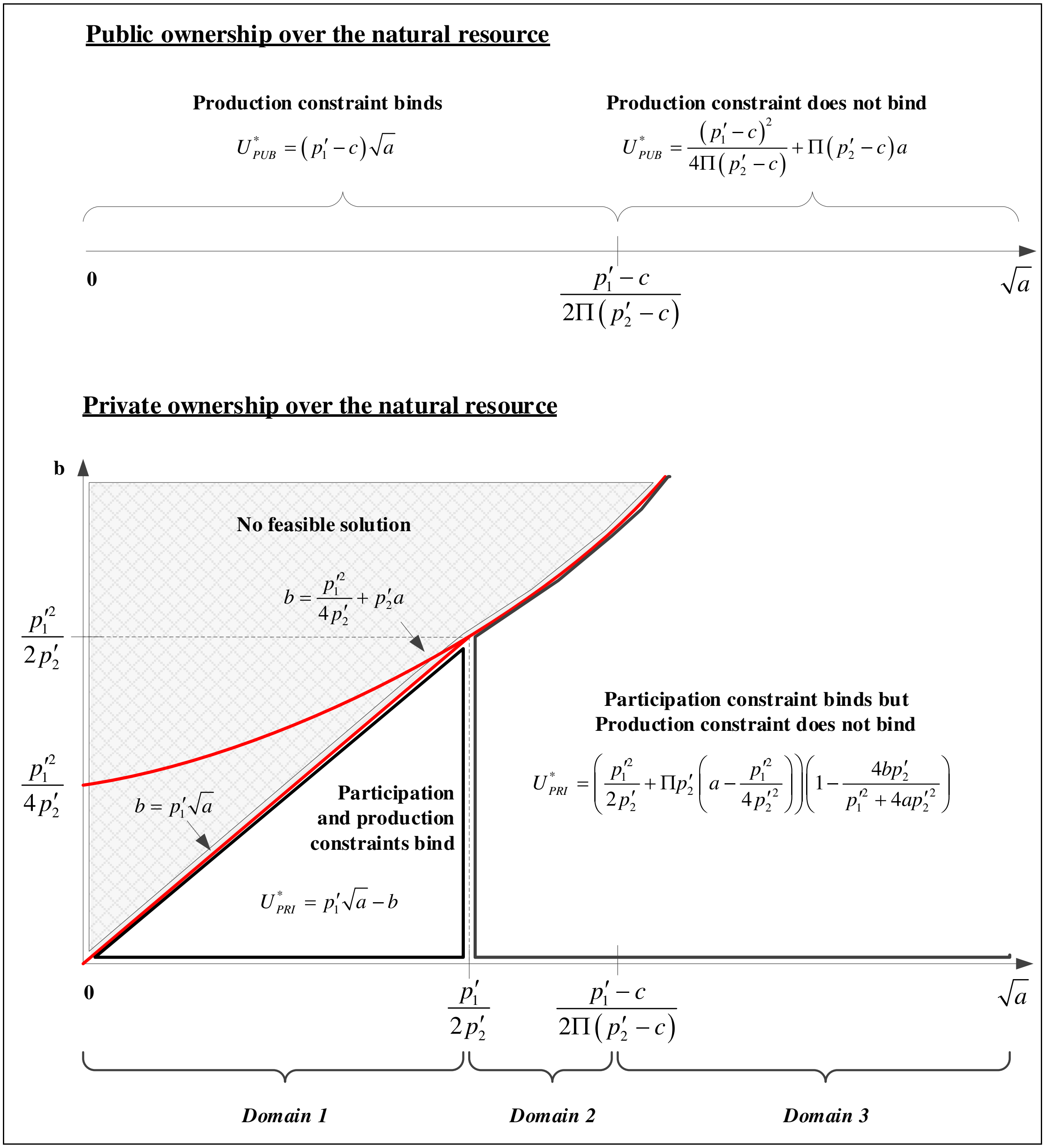

Figure 4.1 Feasible solution space as functions of '*a*' and '*b*' with differential extraction costs.

Table 4.1 Summary of optimal utility over three domains by ownership and control model with differential extraction costs.

Model / Domain	**Domain 1** $0<\sqrt{a}\le\frac{p_1'}{2p_2'}$	**Domain 2** $\frac{p_1'}{2p_2'}<\sqrt{a}<\frac{(p_1'-c)}{2\Pi(p_2'-c)}$	**Domain 3** $\frac{(p_1'-c)}{2\Pi(p_2'-c)}\le\sqrt{a}$
Public ownership and control	Production constraint binds. $U_{PUB}^{*}=(p_1'-c)\sqrt{a}$		Production constraint does not bind. $U_{PUB}^{*}=\frac{(p_1'-c)^2}{4\Pi(p_2'-c)}+\Pi(p_2'-c)a$
Private ownership and control with taxation	Production and participation constraints bind. $U_{PRI}^{*}=p_1'\sqrt{a}-b$	Production constraint does not bind but participation constraint binds. $U_{PRI}^{*}=\left(\frac{p_1'^2}{2p_2'}+\Pi p_2'\left(a-\frac{p_1'^2}{4p_2'^2}\right)\right)\left(1-\frac{4bp_2'}{p_1'^2+4ap_2'^2}\right)$	

4.2.1 Equilibrium over the first domain

Over the first domain the resource is fully depleted in the first period under both ownership models. Incremental utility of public ownership and control over its private counterpart is defined as:

$$\Delta U^{*}=b-c\sqrt{a}\gtreqless 0. \tag{4.3}$$

In Section 3.1 the politician preferred public ownership and control in all cases where the opportunity cost of the firm was greater than zero. (See Section 3.1.2.1.) Examination of equation (4.3) shows that due to the introduction of costs, the politician may now favour either public or private ownership depending on the specific parameterisation. Closely examining equation (4.3) provides the following insights: when production occurs only in the first period the politician will prefer public ownership and control over private ownership and control if the opportunity cost of the firm is greater than the total costs saved through private ownership. In other words, she will prefer public ownership and control if the rents she foregoes to induce the firm's production are not more than offset by the additional rents generated by the firm through improved efficiency. If either the cost advantage of the firm is small, or the resource stock is small relative to the firm's opportunity cost, she will choose public ownership and control. However, as the resource increases in size and as the cost or market access advantage of the firm increases, the incentives for choosing private ownership and control increase.

Five propositions will be tested over each of the three domains to better understand the effect of exogenous parameters on the equilibrium. The propositions below examine how the incentive for public or private ownership and control changes in response to the four parameters previously examined in Chapter 3, and to a change in the differential cost, *'c'*. Only the first two propositions and the last one examining the impact of a change in differential cost are relevant over domain 1 and discussion below is therefore limited to these. Although all the propositions apply over domains 2 and 3 in sub-sections 4.2.2 and 4.2.3 respectively, only those that generate results that differ from Chapter 3 are included in the text. The complete set of results with a comparison to those generated in Chapter 3 are summarised in Table B.6 of Appendix B.

Proposition 1: An increase in the firm's opportunity cost, 'b', increases incentives for public ownership. ($\partial\Delta U^*/\partial b>0$)

The partial derivative of differential optimal utility with respect to the firm's opportunity cost is:

$$\frac{\partial \Delta U^*}{\partial b} = 1 > 0. \tag{4.4}$$

An increase in the firm's opportunity cost, '*b*', will unambiguously increase preferences for public ownership. The result is unaffected by any other model parameter including prices or the probability of re-election. The interpretation of this result is the same as that under costless extraction and the reader is referred to Section 3.1.2.1 for a more detailed discussion of this proposition.

Proposition 2: A resource stock boom increases incentives for public ownership. ($\partial\Delta U^*/\partial a>0$)

The partial derivative of differential utility with respect to the stock parameter, '*a*', yields:

$$\frac{\partial \Delta U^*}{\partial a} = -\frac{c}{2\sqrt{a}} < 0. \qquad (4.5)$$

When both the firm and the politician produce the entire resource in the first period, an increase in the size of the resource unambiguously decreases preferences for public ownership. As the resource size increases, the cost advantage of the firm generates more rents that become available for taxation thereby reducing incentives for public ownership. However, if the cost or market access advantage of the firm is zero, a change in the resource stock has no effect on ownership preferences since there is no advantage to private ownership.[40]

Proposition 5: An increase in the cost or market access advantage of private ownership decreases incentives for public ownership ($\partial\Delta U^*/\partial c<0$)

The partial derivative of differential utility with respect to the cost or market access advantage of private ownership, '*c*', yields:

$$\frac{\partial \Delta U^*}{\partial c} = -\sqrt{a} < 0. \qquad (4.6)$$

Not surprisingly an increase in the competitive advantage of private ownership unambiguously increases preferences for private ownership. The interpretation of this result is similar to that for proposition 2: as the cost or market access advantage of the firm increases, the firm generates more rents that become available for taxation. This reduces incentives for public ownership.

4.2.2 Equilibrium over the second domain

Over the second domain the production constraint binds only in the case of public ownership and control, where the entire resource is depleted in the first period. Under private ownership and control production takes place in both periods. The difference in optimal utility between public and private forms of ownership is expressed as:

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[40] This result is consistent with that generated in Chapter 3 since the differential utility function in equation (4.3) collapses to equation (3.4) when there is no cost advantage of private ownership.

$$\Delta U^* = \left(p_1' - c\right)\sqrt{a} \; - \left(\frac{p_1'^2}{2p_2'} + \Pi p_2' \left(a - \frac{p_1'^2}{4p_2'^2}\right)\right)\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right) \gtreqless 0. \qquad (4.7)$$

The function above is almost identical to that under costless extraction (equation (3.6)) except for the presence of the differential cost term on the left-hand side. The presence of this additional term prevents the expression from being definitively signed over the range of domain 2.

Despite this, an examination of the lower limit where $\Delta U^* = b - c\left(p_1'/p_2'\right) \gtreqless 0$ provides the following insight: if the firm's opportunity cost is small relative to its competitive advantage over public ownership (i.e., if $b << c$), and/or net prices are in contango (i.e., when $p_1' > p_2'$) there is a greater likelihood that the politician would prefer private ownership and control. This is because when the market, or cost, advantage of the firm is large the firm generates more economic rents that can in turn be taxed and captured by the politician. Similarly, when the opportunity cost of the firm, *'b',* is small, the firm requires less rents to induce production thus leaving more to be captured by the politician. Finally, because of the politician's time preferences, the politician values rents in the first period more than in the second, therefore when prices are in contango the price path reinforces the politician's time preferences. If should be noted however that neither a small opportunity cost of the firm, nor prices in contango are necessary or sufficient for the politician to prefer public ownership – it is a combination of prices, cost or market advantage and the firm's opportunity cost that will drive this result.

In order to explore how ownership choice is affected by the opportunity cost of the firm, *ΔU** is examined at the feasible limits of *'b'* over this domain. When *'b'* takes on its lowest possible value '0', the politician may still prefer public over private ownership because of her time preference. However, when *'b'* takes on its maximum possible value, or in other words when the firm's opportunity cost is so high that it would capture all the economic rents generated, the politician will unambiguously prefer public ownership and control. Over all other values of *'b'*, *ΔU** cannot be definitively signed as positive or negative and the politician may either prefer public or private ownership and control. To better interpret the results, the model is later parameterised and results for differential utility are simulated in Chapter 5.

It is now of interest to examine how the differential utility between public and private ownership and control is affected by exogenous changes to the firm's opportunity cost, *'b'* (Proposition 1), the size of the resource stock *'a'* (Proposition 2), first and second period prices p_1 and p_2 (Proposition 3), re-election uncertainty, *'Π'* (Proposition 4), and to the cost or market access advantage of the firm, '*c*' (Proposition 5). Results and the interpretations for Propositions 1, 3 and 4 are identical to those in Chapter 3 with the exception that prices are replaced with net prices. Therefore, for brevity only Propositions 2 and 5 are included below. Results are summarised in Table B.6 of Appendix B where they are also compared with the results generated under costless extraction in Chapter 3.

Proposition 2: A resource stock boom increases incentives for public ownership. (∂ΔU*/∂a>0)

The partial derivative of differential utility with respect to the stock parameter, '*a*', yields:

$$\frac{\partial \Delta U^*}{\partial a} = \frac{p_1' - c}{2\sqrt{a}} + p_2'\Pi\left(\frac{8bp_1'^2 p_2'}{\left(p_1'^2 + 4ap_2'^2\right)^2} - 1\right) \gtreqless 0. \qquad (4.8)$$

An algebraic examination of the proposition yields an ambiguous result due to the presence of the firm's competitive advantage, *'c'*. The result is indicative of a complex 'tension' between: (i) increased rents generated by an increase in the resource stock (which will be depleted in the first period under public ownership and in two periods under private ownership); combined with (ii) the increased rents generated by the firm due to improved efficiency; and (iii) an adjustment due to the time preference of the politician. Even if the opportunity cost of the firm is zero, an increase in the resource stock still has an ambiguous effect as the politician may still favour private ownership if the firm's cost advantage is large enough. This rich interpretation of various factors was not possible with the simpler model with costless extraction.

Proposition 5: An increase in the cost or market access advantage of private ownership decreases incentives for public ownership (∂ΔU*/∂c<0)

The partial derivative of differential utility with respect to the cost or market access advantage of the firm, *'c'*, yields:

$$\frac{\partial \Delta U^*}{\partial c} = -\sqrt{a} < 0. \qquad (4.9)$$

As can be seen, an increase in the cost or market access advantage of the firm unambiguously decreases incentives for public ownership. Because a competitive advantage of private ownership generates more rents compared to public ownership, an increase in that advantage will always reduce incentives for public ownership regardless of prices, reelection uncertainty or the opportunity cost of the firm. The result is magnified when the resource is large since a unit cost advantage translates into even greater rents when there is more resource.

4.2.3 Equilibrium over the third domain

Over the third domain, production takes place in both periods under both forms of ownership.[41] The difference in optimal utility is expressed as:

$$\Delta U^* = \frac{\left(p_1' - c\right)^2}{4\Pi\left(p_2' - c\right)} + \Pi\left(p_2' - c\right)a - \left(\frac{p_1'^2}{2p_2'} + \Pi p_2'\left(a - \frac{p_1'^2}{4p_2'^2}\right)\right)\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right) \gtreqless 0. \tag{4.10}$$

Taking the limit of ΔU^* as the square root of 'a' approaches the lower boundary of the third domain yields an expression that cannot be signed definitively. However, when taking the limit of ΔU^* as the resource stock parameter approaches infinity yields $\lim_{\sqrt{a}\to\infty^+}\left(U_{PUB}^* - U_{PRI}^*\right) = -\infty$, and as a result, if the resource were to become infinitely large, the politician would prefer private over public ownership and control. This is because whenever the cost, or market access advantage of the firm is non-zero, as the resource size approaches its upper limit of infinity the firm will generate an infinite amount of rents more than the public ownership. This is contrary to the result under costless extraction where the politician preferred public ownership and control for all sizes of the resource and provides important insights into state decisions for resource ownership: where a firm may have certain proprietary technologies or access to markets that are not accessible generally, governments will be incentivised to choose models that include private ownership to access these competitive advantages. In the absence of these technological or market access advantages, governments might prefer public ownership. Furthermore, governments will be increasing incentivised to choose private ownership models when the resource is very large, or where the competitive advantage of the firm is very large.

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[41] As a result, the production constraint is non-binding in both models and the only binding constraint is the participation constraint under private ownership.

It is now of interest to examine how the incremental utility from public ownership is affected by exogenous changes to the minimum profitability requirement, '*b*' (Proposition 1), the size of the resource stock '*a*' (Proposition 2), first and second period prices p_1 and p_2 (Proposition 3), re-election uncertainty (Proposition 4) and to the cost wedge of public ownership (Proposition 5). For brevity, Proposition 1 is not repeated as the result is identical to that under costless extraction except that prices are replaced with net prices. A complete summary of results is included in Table B.6 of Appendix B.

Proposition 2: A resource stock boom increases incentives for public ownership. ($\partial\Delta U^*/\partial a>0$)

The partial derivative of differential utility with respect to the stock parameter, '*a*', yields:

$$\frac{\partial \Delta U^*}{\partial a} = \frac{8bp_1'^2 p_2'^2 \left(\Pi - 1\right)}{\left(p_1'^2 + 4ap_2'^2\right)^2} - c\Pi \le 0. \tag{4.11}$$

An examination of the proposition yields a similar result as under Chapter 3 – that an increase in the resource stock decreases incentives for public ownership. One difference is that when a competitive advantage of the firm exists an increase in the resource stock will further decrease incentives for public ownership. Conversely, if both the firm's opportunity cost is nil and it has no cost or market access advantage, then an increase in the resource stock will have no effect on ownership preferences.

Proposition 3: Temporary, anticipated and permanent increases in prices increase incentives for public ownership. ($\partial\Delta U^*/\partial p'_1>0$, $\partial\Delta U^*/\partial p'_2>0$ and where $p'_1=p'_2=p'$, $\partial\Delta U^*/\partial p'>0$)

The partial derivatives of differential utility with respect to first period prices (p_1), second period prices (p_2) and then to a permanent price shift ($p_1=p_2=p$) yields:

$$\frac{\partial \Delta U^*}{\partial p_1'} = \frac{p_1' - c}{2\Pi\left(p_2' - c\right)} + \frac{p_1'\left(\Pi - 2\right)}{2p_2'}\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right) + \frac{2bp_1'\left(p_1'^2\left(\Pi - 2\right) - 4ap_2'^2\Pi\right)}{\left(p_1'^2 + 4ap_2'^2\right)^2} \gtreqless 0;$$

$$\frac{\partial \Delta U^*}{\partial p_2'} = \frac{p_1'^2}{2p_2'^2} - \frac{\left(p_1' - c\right)^2}{4\Pi\left(p_2' - c\right)^2} - \frac{16abp_1'p_2'}{\left(p_1'^2 + 4ap_2'^2\right)^2} - \frac{p_1'^2\Pi}{4p_2'^2}\left(\frac{p_1'^4 + 8ap_1'^2p_2'^2 + 16ap_2'^3\left(p_2'a - 4b\right)}{\left(p_1'^2 + 4ap_2'^2\right)^2}\right) \gtreqless 0; \text{ and} \tag{4.12}$$

$$\left.\frac{\partial \Delta U^*}{\partial p'}\right|_{p_1'=p_2'=p'} = \frac{\left(\Pi - 1\right)^2}{4\Pi} \ge 0.$$

As can be seen from equation (4.12), both temporary and anticipated price booms have an ambiguous effect on preferences for ownership and control. Although prices do matter, the effect of temporary and anticipated price booms is a combination of factors that include the resource size, the opportunity cost of the firm and cost advantage of private ownership.[42] This result provides analytical support to the work of Guriev et al. (2011), Mahdavi (2014), Singh (2014) and Wilson (2015) who all provide either empirical or qualitative pluralistic explanations for variances in state ownership that go beyond prices.

In the event of a permanent price boom, preferences for public ownership and control are unambiguously increased when reelection is uncertain. When reelection is certain the production path of the politician becomes perfectly aligned with that of the firm and in this instance a permanent price boom has no effect on preferences for ownership and control.[43]

In contrast to the model of costless extraction where public ownership was always preferred regardless of exogenous shocks, the above result shows that distinct types of price booms and busts can have varied effects. In other words, both booms and busts can create incentives for public and private ownership, however these effects depend critically on the specific parameterisation of the model. In this respect, it is of interest to note that in their examination of mineral expropriation cycles, Cole and English (1991) find that preferences for public expropriation of resources could occur in both boom or bust periods. They define two explanations for their observations, (i) an opportunistic explanation: where the probability of an expropriation increases in years in which the real price of the output mineral is high ('boom years'); and (ii) a desperation explanation: where the probability of expropriation increases in years in which the real price of the output mineral is low ('bust years'). The results of this proposition provide a potential theoretical framework for their finding. However, as the current model does include other sectors of the economy or the potential for public debt, support for the desperation effect is limited. One would need to proxy this through a combination of decreasing first period prices and decreasing reelection probability.

[42] Recall that under costless extraction, price booms impact preferences for ownership and control, but only if the probability of reelection is uncertain. When reelection is certain, price booms had no impact on preferences for ownership and control since the production path of the politician mirrored that of the firm.

[43] As was discussed in Section 3.1.4 this result is largely driven by the assumed time preferences of the politician relative to the firm and the social optimal.

Proposition 4: An increase in the probability of reelection decreases incentives for public ownership. (∂ΔU*/∂Π<0)

The partial derivative of differential utility with respect to the probability of reelection is shown in equation (4.13). As can be seen, an increase in the probability of reelection has an ambiguous effect on ownership preferences.

$$\frac{\partial \Delta U^*}{\partial \Pi} = (b - 4ac) - \frac{2bp_1'^2}{p_1'^2 + 4ap_2'^2} + \frac{1}{4}\left(\frac{p_1'^2}{p_2'^2} + \frac{(p_1' - c)^2}{\Pi^2 (p_2' - c)}\right) \gtreqless 0. \tag{4.13}$$

As reelection becomes increasingly uncertain, the production paths of the firm and the politician deviate and the politician increasingly prefers public ownership and control over private.[44] However, when reelection is certain, the production paths of the firm and politician are perfectly aligned and preferences for ownership and control are then determined by a combination of the opportunity cost of the firm and the cost advantage of private ownership.[45] In this case, if the opportunity cost of the firm is nil, then the politician will prefer private ownership due its cost advantage (i.e. $\lim_{\Pi \to 1} \Delta U^* \Big|_{b=0} < 0$). However, if the cost advantage of private ownership is nil then she will prefer public ownership since the opportunity cost of the firm requires her to forego rents she would otherwise capture under public ownership (i.e. $\lim_{\Pi \to 1} \Delta U^* \Big|_{c=0} > 0$). (This result is the same as that generated under costless extraction in the previous chapter.) If, however, both the opportunity cost of the firm and its cost or market advantage are nil, then the politician is indifferent to the form of ownership (i.e. $\lim_{\Pi \to 1} \Delta U^* \Big|_{c=0;b=0} = 0$).

These results are useful in explaining some apparently contradictory empirical observations. Duncan (2006) finds that expropriations are more common in democracies than in dictatorships where continuity of power is more certain. Yet others have found that democratic political institutions of various kinds reduce political risk of expropriation (Jensen 2003; Li 2009; Ali et al. 2010). The "anything-can-happen" results shows how the political economy may combine with a combination of various exogenous factors to create a unique set of incentives for

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[44] This can be seen by taking the limit of ΔU^* in equation (4.10) as Π approaches zero which yields a result of $+\infty$.

[45] This can be seen by examining the limit of ΔU^* in equation (4.10) as Π approaches unity: $\lim_{\Pi \to 1} \Delta U^* = b - ac - p_1^2/(4p_2) + (p_1 - c)^2/(4(p_2 - c)) \gtreqless 0.$

adopting public or private ownership. The simulations explored later in Chapter 5 and Chapter 6 will help to further elucidate this point.

Proposition 5: An increase in the cost or market access advantage of private ownership decreases incentives for public ownership ($\partial \Delta U^*/\partial c<0$)

The partial derivative of differential utility with respect to the cost or market access advantage of the firm yields:

$$\frac{\partial \Delta U^*}{\partial c} = \frac{\left[(p_1' - c) - (p_2' - c)\right]^2 - (p_2' - c)^2}{4\Pi (p_2' - c)^2} - \Pi a < 0. \tag{4.14}$$

Examining this proposition at the limits of domain 3 allows it to unambiguously be signed as negative. Furthermore, since $\partial^2 \Delta U^* / \partial c \partial a = -\Pi$, not only does an increase in the cost or market access advantage of the firm increase the politician's preferences for private ownership, its effect is greater as the resource size increases.[46]

4.3 Institutional constraints – the cost of institutional change

Results for the preferred ownership type and the propositions over each of the three domains are respectively summarised in Table B.4 of Appendix B. Recall from Section 3.1.3, that a fixed, two-period institutional cost, C_{inst}, can be introduced to capture the concept that the politician could incur an incremental cost (or loss of utility) when pursuing public ownership. With the introduction of C_{inst}, the results can be generalised to say that the politician will choose public ownership over private ownership when the incremental utility of public ownership exceeds the institutional costs of ownership, C_{inst}, i.e., when $\Delta U^* > C_{inst}$. As a fixed cost, the introduction or this new variable does not affect any of the preceding comparative statics; its effect is limited to shifting the minimal differential utility (ΔU^*) required by the politician to prefer public over private ownership and control.

[46] Examining the effect of an increase in the cost advantage of private ownership and how this varies in relation to the politician's reelection certainty shows that if there is no chance of reelection then an increase in the cost advantage of the firm will have no effect on preferences for ownership. This is because when there is no chance to be re-elected, the game effectively becomes a one period game where the politician produces the entire resource in the first period while the firm chooses to produce over two periods. To see the impact of an increase in 'c' under these circumstances, the reader is referred to the comparative static under domains 1 and 2 where a result of $\partial \Delta U^*/\partial c<0$ was obtained.

The concept and use of institutional costs will become clearer when the model is parameterised and preferred ownership model is simulated in Chapter 5 and country case studies examined in Chapter 6.

4.4 Socially optimal extraction rate.

Economic efficiency is affected by a combination of factors. Not only do differences in time preference between the firm and politician have implications for efficiency, the cost or market advantage of the firm is a new and very important consideration.

As before, the notion of a social planner is introduced. The social planner seeks to maximise the following two period income function $\max_{\{e\}} Y = p'_1 e + p'_2 R(e)$, subject to the production constraint. The social planner has access to the latest technologies, so her costs and market access are the same as the firm, c_p. The Lagrangian for the planner's constrained optimisation and resulting Kuhn-Tucker conditions are the same as those generated in Section 3.1.4 with the exception that p_1 and p_2 are replaced with p'_1 and p'_2 respectively. Solving the optimisation shows that when the production constraint binds, the socially optimal value of e^* is the same as for the previously examined cases of private and public ownership: $e^* = \sqrt{a}$.

When the production constraint does not bind (i.e. in the second or third domains), the socially optimal first period production rate is the same as the private sector: $e^*_{SOCIAL\ PLANNER} = p'_1 / 2p'_2 = e^*_{PRI}$. Where both the firm and social planner hold a competitive advantage over public ownership and have identical time preferences (i.e. when c>0 and $\Pi_{SP} = \Pi_{PRI} = 1$ discussed in Section 3.1.4), the relationship between the socially optimal first period production rate, the private rate and that under public ownership can be expressed as $e^*_{PUB} \gtreqless e^*_{\text{SOCIAL PLANNER}} = e^*_{PRI}$. As can be seen, the politician may or may not always overproduce relative to the firm and whether she does depends on the values for the cost or market access advantage over public ownership, the probability of reelection and first and second period prices.

This can be readily seen by comparing the expressions of e^* under each case: $e^*_{PUB} = \dfrac{p'_1 - c}{2\Pi\left(p'_2 - c\right)} \gtreqless \dfrac{p'_1}{2p'_2} = e^*_{PRI} = e^*_{SOCIAL\ PLANNER}$. Upon inspection of this inequality, if reelection is uncertain and:

(i) there is no cost or market access advantage over public ownership (i.e. if $c = 0$);

(ii) first and second period net prices are the same (i.e., if $p_1' = p_2'$); or

(iii) first period net prices are greater than second period net prices (i.e., if $p_1' > p_2'$),

then, the politician will produce more in the first period than the firm. This is consistent with the results in Chapter 3. However, if second period net prices are greater than first period net prices (i.e., if $p_1' < p_2'$), the politician may, or may not, produce more in the first period than the firm. Whether she does or not is a combination of relative net prices, reelection probability, and the magnitude of the firm's cost advantage.

Although the private sector's extraction path perfectly mirrors the socially optimal path, the politician's production path can be faster, slower or the same. If there is no cost advantage of private ownership or net prices are either constant or decreasing, the politician will unambiguously over-produce in the first period relative to the socially optimal rate. However, if prices are increasing (an anticipated resource boom) the politician may sub-optimally over- or under-extract the resource in the first period relative to the social optimum. As a result, we can conclude that the politician may or may not always overproduce relative to the social optimal and therefore public ownership may not always generate a socially inefficient production path.

Examining how e^*_{PUB} changes in response to the cost advantage of private ownership gives additional insights regarding an important factor affecting the politician's first period production choice. When taking the limit of e^*_{PUB} as 'c' approaches p_1' and p_2' we can see that the impact of an increase in the firm's cost advantage on the timing of production depends critically on whether first or second period rents will be entirely eroded first, which in turn depends critically on the price path since unit costs do not change over the two periods.[47] If one believes that non-renewable resources are becoming increasingly scarce and that prices will increase per Hoteling (1931), p_1 will limit cost increases and the entire resource will be scheduled for depletion in the second period. However, if prices are decreasing in line with the Prebisch-Singer hypothesis (Prebisch

[47] For clarify, an examination of the limits shows: $\lim_{c \to p_1'^-} e^*_{PUB}\Big|_{p_2' > p_1'} = 0$; and $\lim_{c \to p_2'^-} e^*_{PUB}\Big|_{p_1' > p_2'} = \infty$. Using the substitutions defined in the introduction to Chapter 4 it can be shown that 'c' approaching p_1' and p_2', is equivalent to c_{PUB} approaching p_1 and p_2 respectively. At the limit $c_{PUB}=p_1$ and $c_{PUB}=p_2$

1950; Singer 1950; Harvey et al. 2010; Arezki et al. 2014), then p_2 will limit cost increases and the entire resource will be depleted in the first period. Finally, when c_{PUB} is substituted for first and second period prices into the equation for $e*_{PRI}$, it can be seen that: $e^*_{PRI}\big|_{p_1=c_{PUB}} > 0$ and $e^*_{PRI}\big|_{p_2=c_{PUB}} > 0$, which are not the extreme values of '*0*' or '∞' generated before, highlighting that the production path is much more sensitive to changes in price under public rather than private ownership and control. This is due to the competitive advantage of private ownership, which relative to public ownership, results in more rents and therefore less production path sensitivity in relation to changes in prices.

In summary, when the production constraint binds under both public and private ownership (i.e. in domain 1) there is no difference in production between forms of ownership and so all are socially optimal. However, when extraction is not costless and when the production constraint does not bind, the model shows that the politician can either inefficiently *over*- or *under*-extract the resource relative to the socially optimal rate. The outcome depends on a combination of the ratio of first to second period prices and on the size of the cost or market access advantage of private ownership. It is also worth highlighting that this effect is partially due to assumptions made regarding the time preferences of the politician, the firm and the social planner. As noted in Section 3.1.4, care must be taken to not draw strong conclusions regarding the efficiency of production of the firm and the politician that depend on differences in time preference alone, since it is possible for the politician to have a lower discount rate than the firm and social planner, and for the politician's time preferences to be more aligned to the social planner than the firm.

Finally, when considering the most efficient ownership model it is necessary to consider not only how time preferences affect efficiency, but also how important cost (technological) or market access advantages of the firm can increase the rents generated from the resource. This increased ability to generate rents (production efficiency) can either reinforce or offset the efficiency effects from different time preferences relative to the social planner's.

4.5 Summary of results

The signs and the expressions for the optimised incremental utility of public ownership over private ownership are summarised below in Table 4.2.[48] As can be seen, over all domains the politician's preferences for ownership and control is ambiguous; she could prefer public or private ownership and her choice will depend critically on the size of the resource, the opportunity cost of the firm, the cost or market access advantage of private ownership, her reelection probability and prices. This "anything-can-happen" result is in stark contrast to the definitive results generated under the costless extraction model and can provide important insights regarding what factors matter for politicians when making ownership decisions and potential policy responses to generate a socially optimal choice.

Table 4.2 Summary of incremental utility of public ownership by domain.

Domain 1	$\Delta U^* = b - c\sqrt{a} \gtreqless 0$
Domain 2	$\Delta U^* = \left(p_1' - c\right)\sqrt{a} - \left(\frac{p_1'^2}{2p_2'} + \Pi p_2'\left(a - \frac{p_1'^2}{4p_2'^2}\right)\right)\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right) \gtreqless 0$
Domain 3	$\Delta U^* = \frac{\left(p_1' - c\right)^2}{4\Pi\left(p_2' - c\right)} + \Pi\left(p_2' - c\right)a - \left(\frac{p_1'^2}{2p_2'} + \Pi p_2'\left(a - \frac{p_1'^2}{4p_2'^2}\right)\right)\left(1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}\right) \gtreqless 0$

When examining the results in Table 4.2 over each domain it can be seen that, in the first domain, if the resource size combined with the cost or market access advantage of the firm is very small relative to the firm's opportunity cost, the politician prefers public ownership and control over private. (This can be seen if we let '*a*' and '*c*' approach zero in the expression given for domain 1 in Table 4.2.) This is because the politician will only choose private ownership if the rents generated by private ownership (through its competitive advantage) are greater than those the politician must forego (due to the firm's opportunity cost) to incent the firm to produce.

In the second domain, the politician produces the entire resource in the first period while the firm produces over two periods, which is sub-optimally slow from the politician's perspective.

[48] Table B.4 of Appendix B summarises the form of ownership preferred over each domain.

Since the politician's utility is linear in taxation she is unable to incent the firm to skew its production profile in favour of period one and, due to the firm's opportunity cost, she is also unable to fully capture all the rents generated by the firm. However, due to its cost or market access advantage, the firm has the potential to more than compensate the politician for its opportunity cost and the negative effect of its slower than optimal depletion profile if its competitive advantage is large. If the resource size is small, the competitive advantage of the firm is small, or the politician's reelection probability is low, the firm's advantage may not amount to enough for the politician to favour private over public ownership. This was seen when exploring the five propositions over domain 2. These results are summarised in Table B.6 of Appendix B.

In the third domain, even though the firm still produces sub-optimally slow relative to the politician, both the firm and politician produce the resource over two periods. In this domain, preferences for ownership and control depend again on the combination of several factors. If the resource is very large, the politician will prefer private ownership and control when the firm has a cost advantage over the politician. This is because when the firm has a unit cost advantage, it will generate very large incremental rents that will become available to the politician through taxation and compensate her for the firm's slower depletion rate and opportunity cost. This can be seen if we let 'a' approach infinity in the expression given for domain 3 in Table 4.2. It follows that the larger the cost advantage of private ownership, the greater the politician's incentive to choose private ownership. If on the other hand, the firm has no, or a small cost advantage over the politician she will prefer public ownership over the private alternative. Similarly, if the firm's opportunity cost is large or increasing, the politician will similarly favour public ownership. Temporary and anticipated price increases have complex effects and can either increase or decrease preferences for the form of ownership depending on other model parameters. A permanent shift in both period prices, however, will increase preferences for public ownership if reelection is uncertain. When election is certain, and the production paths of the firm and politician are perfectly aligned, a permanent price shift will have no impact on the politician's preference for ownership. Finally, as was discussed in Section 4.3, if the politician faces specific institutional costs to public ownership and control, an increase in those institutional costs will decrease incentives for public ownership and control. These insights are substantiated by the comparative statics performed as part of testing propositions one through five in Section 4.2. Table B.6 in

Appendix B summarises the results of the propositions over each domain and compares them with the results generated under costless extraction.

Contrary to other models of ownership such as Chang et al. (2017), the model shows that although price does indeed have an impact on ownership choices, its effect is nuanced by several other relevant factors under consideration. Regarding which form of ownership is more efficient the analysis in Section 4.4 shows that the introduction of costs weakens the efficiency arguments of Robinson et al. (2014) and Matsen et al. (2016). When extraction is not costless, and extraction takes place over both periods (i.e in domain 3), the model shows that the politician can either inefficiently *over*- or *under*-extract the resource relative to the socially optimal rate. The outcome depends on a combination of the ratio of second to first period prices and on the size of the cost or market access advantage of private ownership. Furthermore, when considering that the time preferences between the firm, social planner and the politician can take on a range of values which potentially overlap (see discussion in Section 3.1.4), caution is warranted regarding drawing too strong a conclusion about the efficiency of private ownership relative to public ownership based on time preference differences alone. It is important to consider how time preferences affect efficiency, but also how technological or market access advantages of the firm can increase the rents generated from the resource and therefore reinforce or offset and efficiency effect of different time preferences relative to the social planner's. Finally, a cost or market advantage of private ownership creates additional economic efficiency through the generation of more rents; unlike with the timing effect which is only a consideration when production takes place over both periods, the cost efficiency benefit is present when production takes place over one period, or both periods.

4.6 Potential policy recommendations

Prescriptions for policy are more nuanced than in Chapter 3 due to the more complex interpretation regarding which form of ownership and control yields the more efficient outcome. As before, the suite of policy options can be broadly categorised as: (i) those that constrain the ruling elite; and (ii) those that incent governments to make correct decisions. As the size of the resource or the opportunity cost of firms are factors outside the control of the host country, institutional recommendations can only be influenced by these factors but cannot be anchored in them.

Governments have many potential options to remove or reduce costs which affect the cost of during business and improve overall economic efficiency. This study has shown how a cost or market access advantage can improve efficiency. To further stimulate innovation as a source of increased efficiency governments can create direct incentives to investment in research and development. One option could include the introduction of optimal subsidy that would target high priority sectors with the objective of increasing economic efficiency. The question remains however as to who, the firm or the politician would deploy the innovation more effectively.

As highlighted by La Porta and López-De-Silanes (1999) and Galiani et al. (2003), innovations and market access benefits are often better harnessed and deployed by private as opposed to public ownership models due to the incentives facing firms vis-à-vis their government counterparts. As a result, efficiency gains that materialise through a competitive advantage of the firm could reinforce the benefits of private ownership and control and create disincentives for public ownership. Firms would, however, need to ensure that the innovation, management know-how, or differential market access capability they hold are not appropriable; otherwise, the additional rents generated through the improved efficiency could make the firm a target for nationalisation. This finding is supported by Opp (2012), who concluded that differentiating technologies can create endogenous property rights and improve security of tenure. Strong intellectual property rights institutions and rule of law can provide an appropriate environment to protect the firm's competitive advantage (i.e. a high C_{inst}) however, where they may be weak or non-existent firms may need to use other strategies. As highlighted by Fang et al. (2017), with poor property rights and weak rule of law, it is not clear a priori that private firms would have strong incentive to innovate or deploy new technologies since they are ill-protected from expropriation. Therefore, although on the one hand investments in improved innovation, cost effectiveness, market access and know-how act as a potential hedge on, or insurance policy from expropriation, they can also draw attention to the firm if that capacity is not applied in a non-appropriable manner.

Turning now to the role of institutional costs, if policy-makers know *a priori* which ownership and control model is likely to yield the more efficient outcome, then, like before, they can put in place certain policies that steer the decision in that direction. Politicians respond to costs and therefore policies or measures that increase (or decrease) the institutional cost (C_{inst}) of public ownership and control could lead to optimal decision making. Section 3.1.3 showed how preferences for one set of ownership and control institutions over another can be affected by institutional costs. At one extreme, countries wanting to protect against the inefficiencies manifesting themselves through a particular form of ownership could restrict (or encourage) state participation (or private participation) through appropriate constitutional amendments. This could act as a large hurdle since the constitution is very difficult costly to change in most countries. Another less onerous restriction would be for governments to increase the requirements for the corporate governance of state owned enterprises. Once these institutional costs are considered the incentives for ownership would be affected by commodity prices, the size of the resource, the opportunity cost and cost advantage of the firms who would consider developing the resource.

CHAPTER 5

SIMULATED RESULTS

This chapter shows, through a feasible parametrisation of the model and simulation how several factors combine to affect the politician's choice of ownership. It is included to help the reader better understand how the different parameters combine to affect the politician's preferences for one ownership type over another. Due to the richer interpretation provided by the model including a cost or market access advantage of the firm, results are simulated for this model only.

In the next series of charts, the differential utility of the politician (ΔU^*) is plotted against the resource size. The plots show how differential utility is affected by: (i) the opportunity cost of the firm; (ii) the probability of reelection; (iii) prices; and (iv) the cost or market access advantage of the firm.

5.1 Variations to the opportunity cost of the firm

The case where the opportunity cost of the firm varies is examined first in Figure 5.1. Here, parameters are set such that p_1=p_2=10; Π=0.5; c_{PRI} = 0 and c = 0.2 (therefore, c_{PUB}=0.2) while b varies.[49] The results of the simulation confirm the findings from Chapter 4, and more specifically from Table 4.2: the politician may prefer either public or private ownership and control over all three domains. This is seen in Figure 5.1 since, depending on the model's parameterisation differential utility is either positive or negative over the entire domain. When holding all else constant, ΔU^* is increasing in b indicating that the higher the opportunity cost of the firm, the greater the incentive for public ownership. This is confirmed by the results of the Proposition 1 for the three domains summarised in Table B.6 of Appendix B.

[49] Many model parameters are kept fixed across different simulations to maximise comparability between the individual charts.

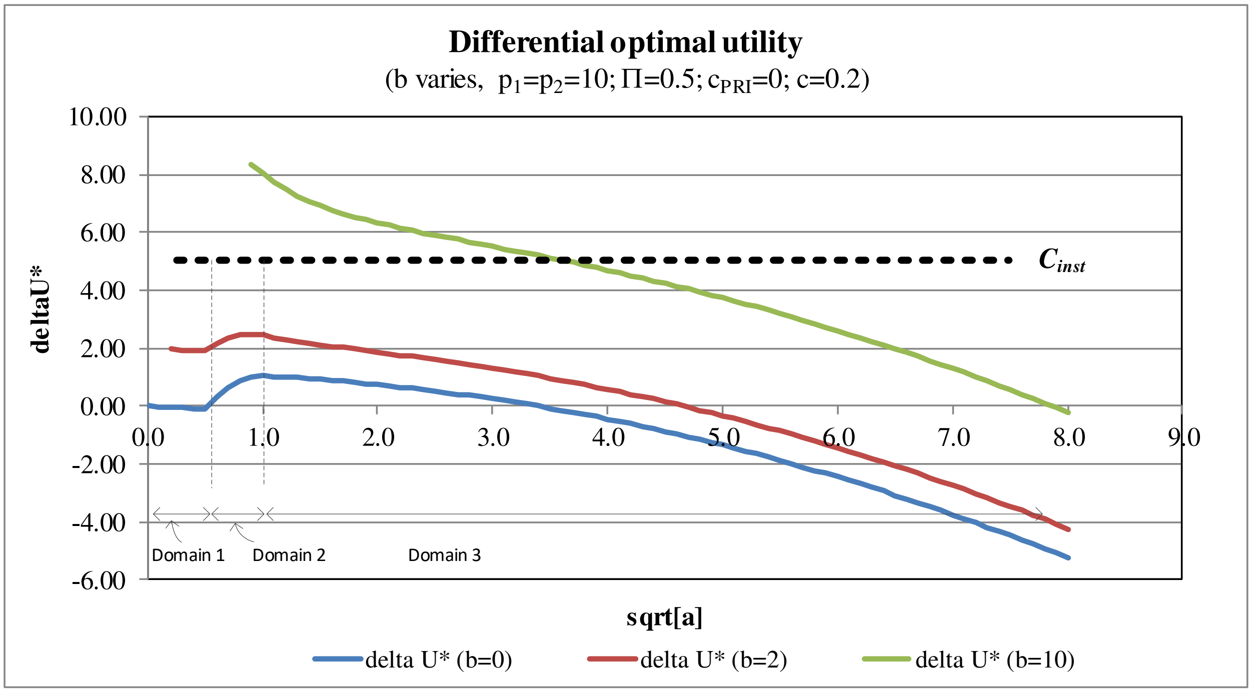

Figure 5.1 Plot of differential optimal utility over range of resource sizes and sensitivity to firm's opportunity cost, 'b'. (c=0.2)

The lines in Figure 5.1 and in those that follow in this chapter appear relatively continuous but gaps in the lines represent small discontinuities as domains change.[50] Full range of domains 1, 2 and 3 are shown for charts where *b*=0 and *b*=2. However, where *b*=10, only domain three is shown because when the resource size is small *b* is greater than the maximum allowable value for a feasible solution to exist. Examining the first domain where the firm's opportunity cost is nil (i.e. *b*=0) shows that under this specific parameterisation private ownership is unambiguously preferred due to the firm's cost advantage. This can be seen since values for ΔU^* are slightly negative along the line for "deltaU* (b=0)" over this domain and well below C_{inst}. Over the second domain, preferences for private ownership decrease in favour of public ownership as $\sqrt{a}$ increases. This is because under the current parameterisation, the firm under-extracts in the first period relative to the politician and this loss of utility is not more than offset by the cost or market access advantage of private ownership. If the competitive advantage of the firm was larger (*c*=*5*), then

[50] Gaps are due the limitations of producing charts using spreadsheets. The gaps are due to a combination of (i) the increments in which 'a' increases over the entire domain; and (ii) a switch between formulas since there are different ΔU^* formulas for domains 1, 2, and 3.

the simulation shows that preferences for private ownership would continue to increase over the second domain under all values for the firm's opportunity cost. (This is shown in Figure 5.2.) Focusing now on the third domain, both Figure 5.1 and Figure 5.2 show that as the resource size increases further, incentives for public ownership decrease. This is due to the cost advantage of the firm, which offsets the utility losses from private ownership because of slower depletion and the firm's opportunity cost. This result is supported by an examination of Proposition 2 in this domain and through the examination of the limit of ΔU^* as $\sqrt{a} \to \infty^+$ in Section 4.2.3, which concludes that an increase in the resource stock will tend to decrease, or in rare circumstances have no effect on, incentives for public ownership.

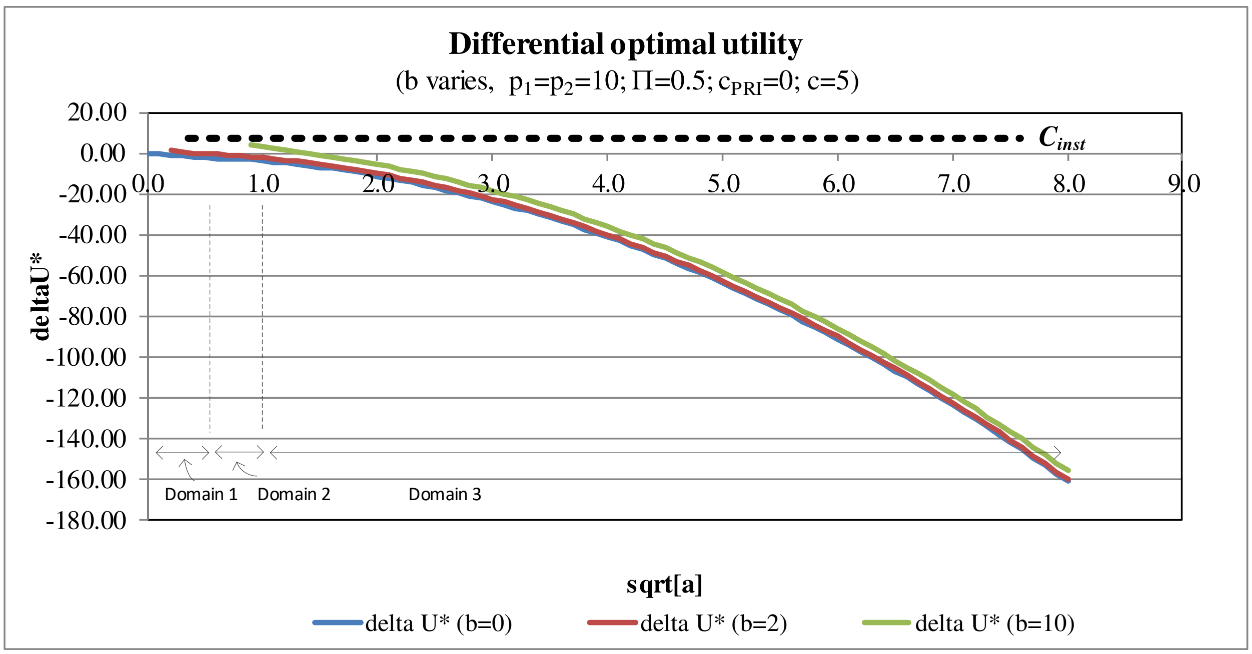

Figure 5.2 Plot of differential optimal utility over range of resource sizes and sensitivity to firm's opportunity cost, 'b'. (c=5.0)

Potential institutional costs associated with public ownership are also shown in Figure 5.1 and Figure 5.2. If differential utility is greater than C_{inst}, then it is deemed that the benefits of adopting public ownership will outweigh the institutional or political costs and the politician will choose public ownership, otherwise private ownership is optimal.

5.2 Variations to the politician's reelection uncertainty

Turning now to explore the effect of reelection uncertainty, Figure 5.3 shows how differential utility depends once again on the combination of parameters, including institutional constraints. The parameterisation used is p_1=p_2=10; b=2; c_{PRI}=0 and c=0.2 while reelection uncertainty, Π, varies. As can be seen by comparing the different lines in Figure 5.3, when holding all else constant preferences for public ownership are decreasing as reelection becomes more certain. Now examining the chart domain by domain, it can be seen that in the first domain the politician would prefer public ownership for small values of $\sqrt{a}$ (when 'b' is non-zero). However, the institutional costs are too large and so when considering these the politician will instead choose private ownership. In this domain differences in reelection probability have no impact on the choice of ownership and control because both the firm and politician deplete the entire resource in first period. In the second domain, the firm depletes the resource over two periods while the politician depletes the entire resource in the first period. Here, increased probability of reelection aligns the politician's depletion path with that of the firm resulting in decreased incentives for public ownership given the cost advantage generated by private ownership and control.[51] If reelection is highly uncertain (Π=0.1), preferences for public ownership begin to increase significantly and exceed the minimum threshold (C_{inst}) required for the politician to choose public ownership.

As the resource becomes large in domain 3 production takes place over two periods for both politician and the firm. Preferences for ownership in this domain can be either public or private depending on the specific parameterisation. However, as the resource size increases, preferences for public ownership decreases due to the cost or market advantage of private ownership. If the resource is very large, the politician will choose private ownership since the benefits of the firm's cost or market access advantage will compensate the politician for the firm's opportunity cost and slower depletion path. This is shown in Figure 5.4 where values for the resource stock parameter are increased in comparison to Figure 5.3. It is also confirmed by an examination of the limit of ΔU^* as $\sqrt{a} \to \infty^+$ performed in Section 4.2.3.

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[51] As reelection becomes certain, the politician's decision is only influenced by the opportunity cost of the firm and its cost advantage.

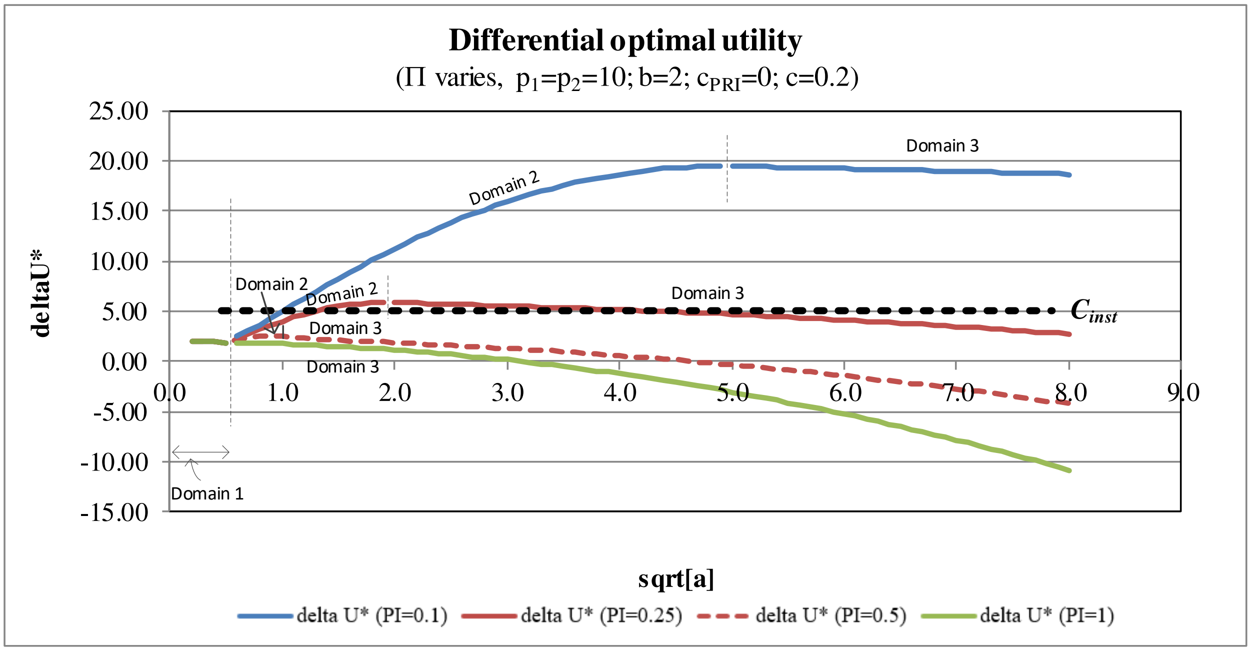

Figure 5.3 Plot of differential optimal utility over range of resource sizes and sensitivity to the politician's reelection uncertainty, *Π*. (a_{max}=9)

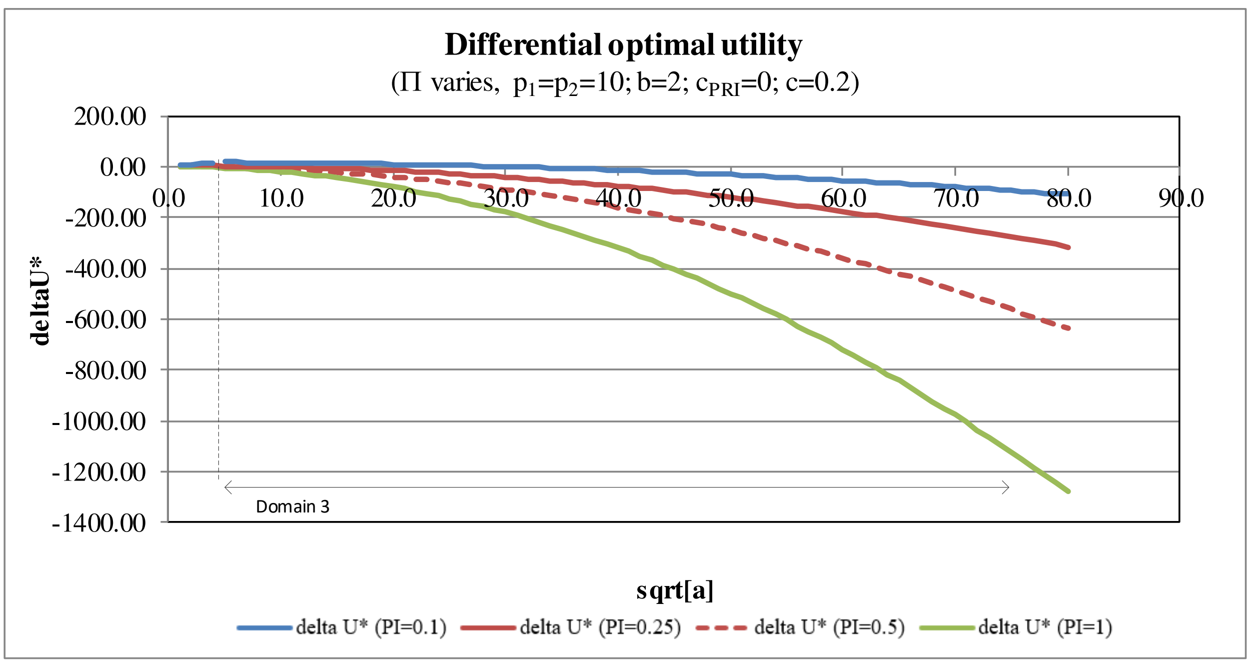

Figure 5.4 Plot of differential optimal utility over range of resource sizes and sensitivity to the politician's reelection uncertainty, *Π*. (a_{max}=90)

As before, lines appear relatively continuous but gaps in the lines represent small discontinuities as domains change. Full range of domains 1, 2 and 3 are shown where $\Pi = 0.1$, $\Pi = 0.25$ and $\Pi = 0.5$. When $\Pi=1$, only domain 1 and 3 exist as domain 2 collapses. This is more readily seen in Figure 5.3 than Figure 5.4.

5.3 Variations to the price path

To examine the effect of changes in price on the politician's choices three scenarios are examined in comparison to a base case price path. The price scenarios are defined as follows: (i) a temporary price boom: $p_1=2p_2$; (ii) an anticipated price boom: $2p_1=p_2$; (iii) a permanent price boom: $p_1=p_2=20$. Other parameter values are: p_i varies where $i=\{1,2\}$; $\Pi=0.5$; $b=2$ $c_{PRI}=0$ and $c=0.2$ The base case price path used as a reference is defined as: $p_1=p_2=10$.

Consistent with the findings of Duncan (2006), Chang et al. (2017) and Hajzler (2012) Figure 5.5 shows that price booms *can* increase incentives for public ownership when compared to the base price path. This finding lends support to the assumption in the theoretical and empirical literature that the value of the underly assets rationale for nationalisation figures prominently in the government's decision-making. Public ownership is at least in some sense therefore driven by opportunism, rather than reflecting mere shifts in political ideology. However, the simulation shows that the 'type' of price boom matters since an anticipated price boom decreases the incentives for public ownership. This is because the firm defers more production to the second period relative to the politician. This combined with booming prices and the firm's cost or market advantage increases incentives for choosing private ownership and control. Therefore, if the expectation is that commodity prices for non-renewable resources will follow the Hoteling rule (Hoteling 1931), increasing prices will increase the value of more distant production, benefiting the firm's production path more than the politician's and thereby decreasing incentives to adopt public ownership. However, if the expectation is that prices will follow the Prebisch-Singer hypothesis (the secular trend in primary commodity prices which Prebisch (1950) and Singer (1950) have conjectured should be declining in the long run), then public ownership and control will be preferred if the net benefits of public ownership exceed the institutional costs.

Once again, the simulation shows that as the resource increases in size, the politician's preferences for public ownership decrease as the competitive advantage of private ownership more than compensates the politician for the firm's opportunity cost and reduced utility from slower first period production. Only in the second domain does an increase in resource size lead to increased incentives for public ownership. This is due to the differences between the firm's and politician's production profiles over this domain, which is driven by different time preferences. However, even this result depends on the specific parameterisation; for example, as can be seen in Figure 5.5, if the politician anticipates a price boom, an increase in the resource size could decrease incentives for state ownership over the second domain.

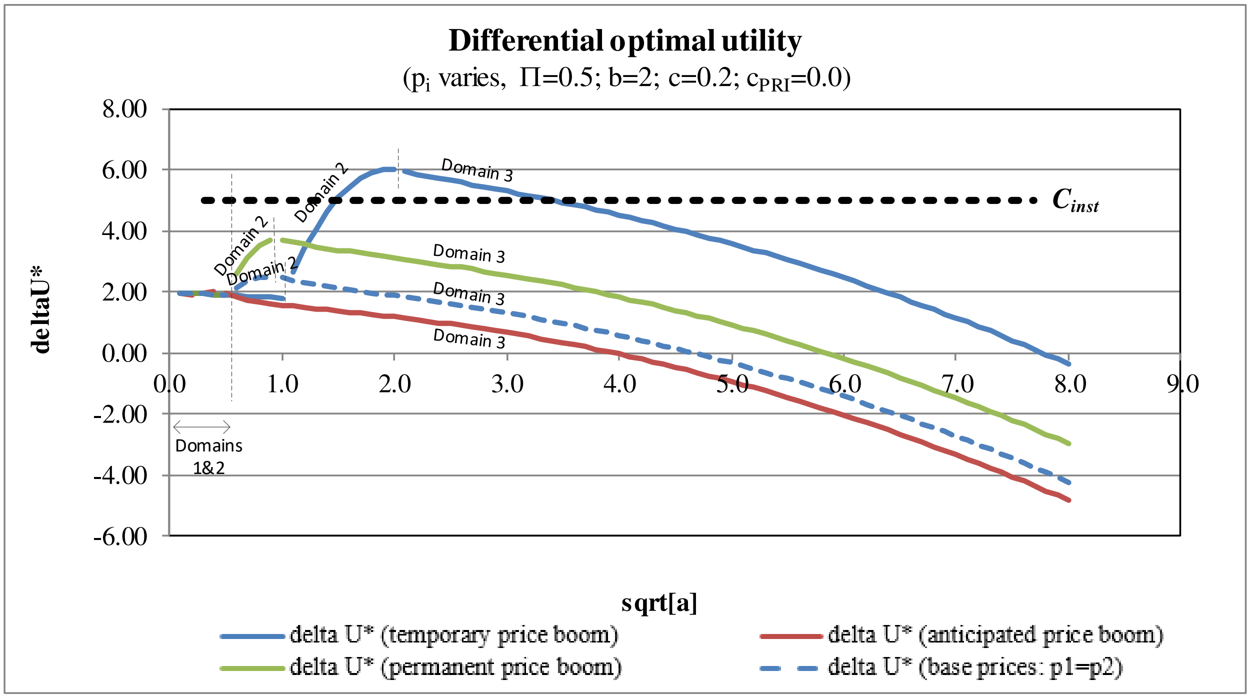

Figure 5.5 Plot of differential optimal utility over range of resource sizes and sensitivity to price assumptions.

5.4 Variations to the firm's cost or market access advantage

Now turning to examine the effect of a cost or market access advantage of the firm over the politician. The model's parameters are set so that that p_1=p_2=10; b=2; Π=0.5; c_p=0 while c varies. Simulated results are shown in Figure 5.6. As can be seen, as expected an increase in the competitive advantage of private ownership reduces preferences for public ownership. This result is supported by Proposition 5 over all three domains as detailed in Sections 4.2.1 to 4.2.3, and summarised in Table B.6 of Appendix B. Furthermore, once again Figure 5.6 shows that an increase in the resource size decreases incentives for public ownership when the firm has a competitive advantage over the politician.

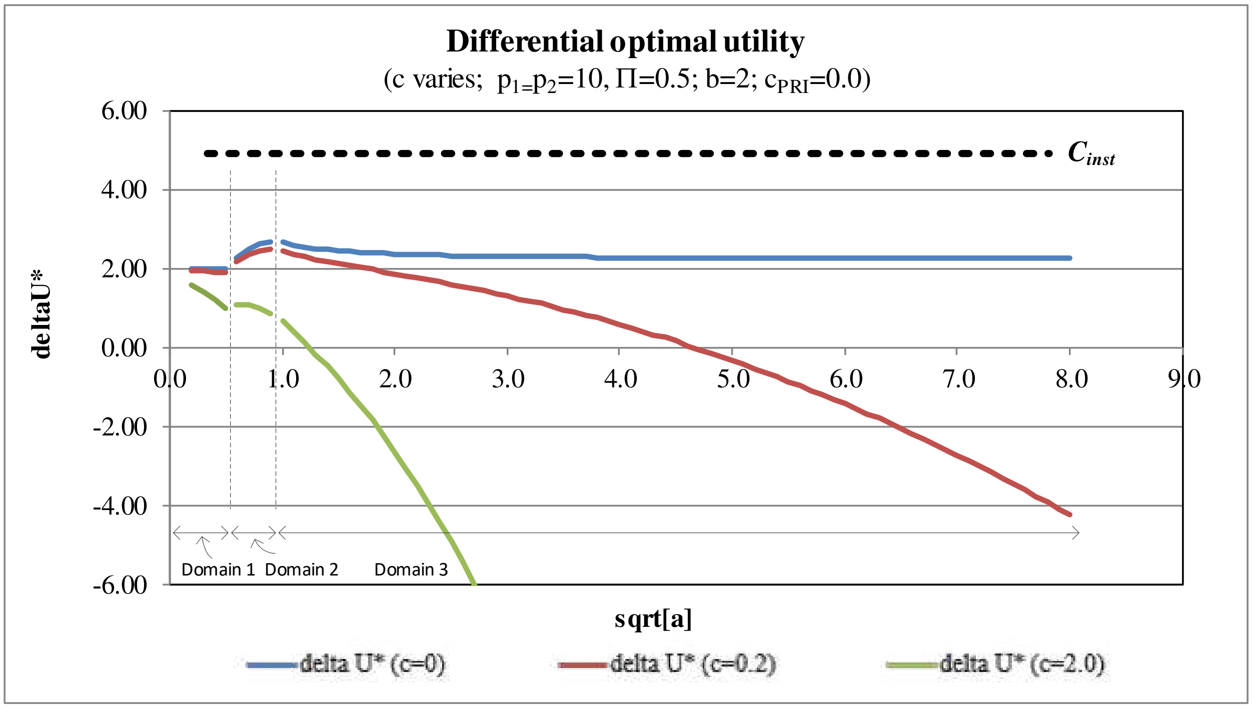

Figure 5.6 Plot of differential optimal utility over range of resource sizes and sensitivity to the differential cost assumptions.

Looking more closely now at the effect of differential costs over each domain, in the first domain where both the politician and the firm extract the entire resource over the first period preferences for public ownership decrease as the resource size increases due to the cost advantage of private ownership. In the second domain, results are more nuanced since the benefits to the politician due to the competitive advantage of private ownership are offset by the loss of utility due to the firm's slower depletion path. If the competitive advantage of the firm is high enough though (when $c=2.0$), increased resource size over the second domain would lead to reduced incentives for public ownership. However, where the competitive advantage of the firm is not sufficiently high ($c=0$; and $c=0.2$), then an increase in the resource size reinforces preferences for public ownership. Finally, in the third domain where a competitive advantage of private ownership exists (i.e. when $c\neq 0$), an increase in the resource size decreases incentives for public ownership in favour of the more profitable extraction under private ownership. When no cost advantage exists, an increase in the resource size has no impact on ownership preferences in the first or third domains (see Proposition 2 in Sections 4.2.1 and 4.2.3) and, under the current parameterisation, it is associated with increased preferences for public ownership in the second domain. To view support for this, see proposition 2 in Section 4.2.2.

The introduction of institutional costs once again nuances the interpretation. Under the above parameterisation, in all scenarios examined the differential utility is not greater than the institutional costs of transitioning to public ownership. In these cases, the politician would optimally choose private ownership and control for all resource sizes.

5.5 Summary of results

The simulations above generate results consistent with the analytical results from Chapter 4. Over all domains the simulation shows that depending on the specific parameterisation, the politician may prefer public or private ownership and control. This "anything-can-happen" result is again in contrast to the definitive results generated under the costless extraction model and provides important insights regarding what factors matter for politicians when making ownership decisions and potential policy responses that generate a socially optimal choice. In the following chapter the focus now turns to further contextualizing the model and checking its explanatory power by examining specific country case studies.

CHAPTER 6

A CHECK ON MODEL ROBUSTNESS: A QUALITATIVE ANALYSIS

The theoretical and simulated results above yield interesting insights regarding the political economy of resource ownership. If relying solely on previous literature one would expect to find that where rents are large (either through prices or the size of the resource) strong incentives would exist for politicians to operate and control the resource to capture all the rents. However, this research finds that if a non-appropriable differentiating capability exists within the private sector that can lead to increased efficiency (through lower costs or equivalently to improved revenue through, for example, better market access), a tension exists between private and public ownership and control. Decisions regarding ownership and control are now much more nuanced and consideration must not only be made regarding the size of the rents and cost differential, but also of the reelection uncertainty, the opportunity cost of firms and the institutional costs (or constraints) facing the politician.[52]

This chapter contextualises the theoretical and simulated results discussed earlier by exploring the case of four resource producing countries that have adopted different models: Botswana, Mexico, Bhutan and Morocco. Finally, a fifth generalisable case is examined which is applicable to many countries – the general lack of state involvement in the industrial minerals sector.

It is important to note that state ownership over the natural resource need not automatically lead to control. Many countries including Botswana and Saudi Arabia may hold the underlying ownership rights to the resource and share an interest in a company that depletes the resource. In these models the government has relinquished "control" over the development and depletion of that resource to a private partner. In relinquishing control, the state joint venture company can access technologies or markets through the private partner. Thus, in this hybrid model, the state

[52] It is of interest to note that this tension does not exist in the costless extraction model. Although the costless extraction model contains the firm's opportunity cost, it's effect reinforces the effect created by different time preferences between the politician and the firm and serves to strengthen preferences for public ownership.

gives up an equity interest and share of resource rents in return for improved rent generation through technology or market access. The state still has the rights to tax the joint venture entity through its statutory fiscal regime, or, as is commonly the case in the oil sector, through production sharing agreements.

6.1 Diamond mining: Botswana

Botswana's mining industry (particularly diamonds) dominates the economy and accounts for ~39% of GDP, more than 70% of exports and almost 50% of government revenues. (Faye et al. 2009). With its reliance on diamonds, the elevated level of mineral rents and the fact that the world's richest mine, the Jwaneng mine, is located in Botswana, nationalisation would have been tempting. (See Figure C.1 in Appendix C.)

Instead, following the discovery of kimberlites by De Beers in the 1960s and 1970s the Government of the Republic of Botswana, together with De Beers created a jointly controlled mining company called Debswana.[53] Even though De Beers provides a number of specialist technical functions for Debswana, De Beers' market power as opposed to extraction technology was likely the deterrent to nationalisation. As a luxury product, (and not a commodity) diamonds require significant marketing expertise, product preparation and access to distribution networks that rely heavily on long standing relationships.

In the 1970s De Beers controlled approximately 80% of the diamond market through its own mines and a marketing agreement with the Russian state diamond miner, Alrosa. This degree of market control would have made it difficult for the Government of Botswana to compete in this environment or enter the market without fear of retaliation. Furthermore, the valuation and preparation of diamonds into parcels tailored for specific diamantaires required skills, insight into the diamond market, and diversity of production. As a scale player with approximately 100 years of experience De Beers was able to provide the mix and stability of diamonds to its customers while also guaranteeing to buy rough diamonds from the Debswana joint venture: financial security that was, and still is, attractive to the government.

[53] Kimberlite is a type of volcanic rock best known for (sometimes) containing diamonds. It is named after the town of Kimberley in South Africa, where the first major diamonds mines were found.

Although the government shares control of Debswana with De Beers, it took measures to secure the bulk of the mineral rents. As part of its Debswana joint venture, "over 80% of all gross profits realised by Debswana go into government revenues, making it the single most important source of financing for national development" (De Beers 2009, 29). In addition to this, the government holds a 15% equity state at the De Beers holding company level and can appoint two directors, giving it direct insights and influence over the company's global strategy.

When considering how to parameterise the model for Botswana it is useful to think about the following: the government has experienced majority victories for many consecutive elections, and although history is not always a predictor of the future, a relatively high expectation for reelection is assumed. (As a result, $\Pi=0.9$ is used. See Table C.1 in Appendix C for additional information regarding Botswana election results.) Diamonds are not found in great abundance across the globe, and deposits of the quality found in Botswana are extremely rare. "There are few known major underdeveloped diamond sites, and no major discoveries have been made over the past two decades" (Linde et al. 2014, 11). On this basis, the opportunity cost of the firm, De Beers in this case, is very low ($b=0$). The cost or market access advantage of the firm is modelled to be high – in this case, not only did the government's mining partner, De Beers, contain proprietary technology for recovery of diamonds, but access to global markets for the diamonds was restricted. (This simulation uses $c=2$.) Prices are modelled as relatively constant since the long-term price of diamonds has steadily matched U.S. GDP growth and diamonds are seen by many such as Linde et al. (2014) as a store of wealth. With $c=2$, to simulate the high rent nature of Botswana's diamond deposits the simulation uses $p_1=p_2=10$.[54] The simulation results for this parameterisation are shown in Figure 6.1.

The results of the simulation correspond with practice in Botswana: private control of the resource is preferred over pure public control. With the presence of a large resource, high expectation of reelection, a large cost and market access advantage of the firm and steady prices, one would expect to see private ownership and in particular, control, over the resource. The model reflects this.

[54] The Jwaneng and Orapa mines that form part of Debswana are two of the world's largest and most profitable diamond producers. (See Figure C.1of Appendix B.)

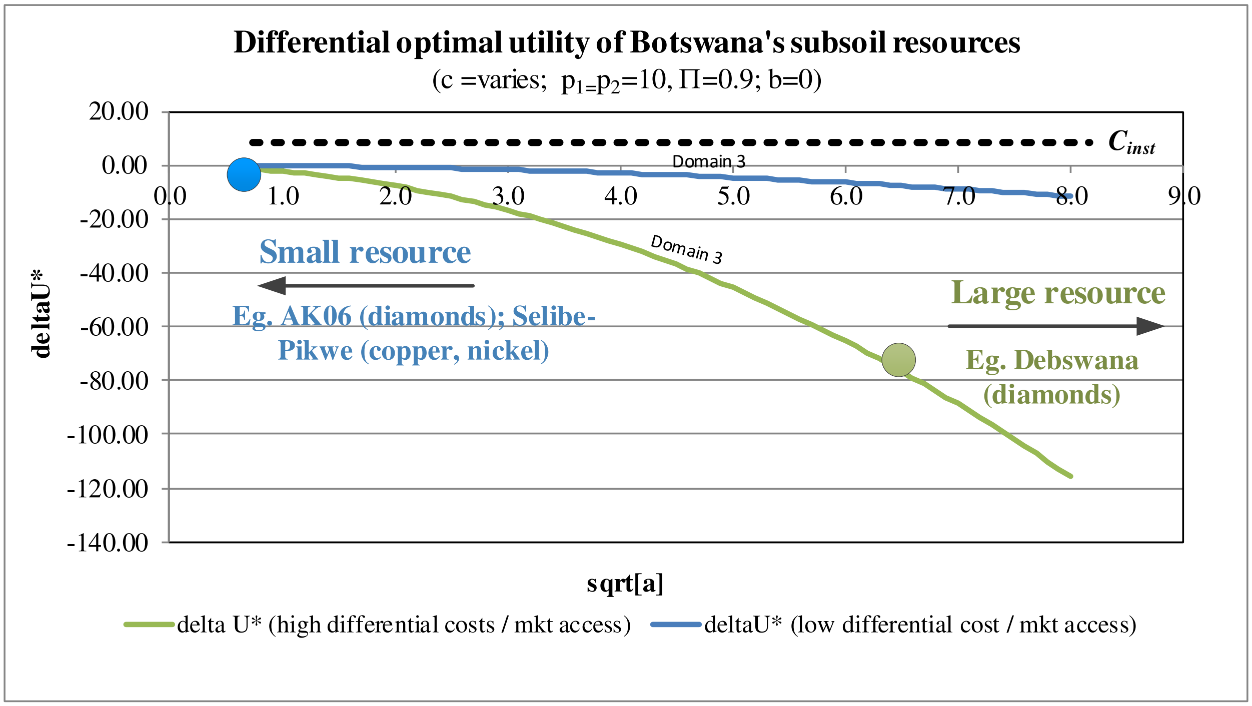

Figure 6.1 Differential optimal utility of Botswana's subsoil resources.

Outside of diamonds, Botswana is a significant producer of copper/nickel (which has long been the second largest mineral export), and recent finds of natural gas, uranium, and potentially iron ore have potential to contribute substantially to export earnings. However, the biggest opportunity may lie in coal, where Botswana is estimated to have more than 200 billion tons of coal reserves (around two-thirds of Africa's total), although it is not yet proven to be commercially viable due to the large investments in rail and port facilities required to get the coal to market . In all these instances the state has not sought to adopt the same model as it did with De Beers on the large diamond deposits. Even with the smaller diamond discoveries the government did not enter arrangements similar to those of Debswana. This decision by government indicates that the complex arrangements with De Beers were perhaps not justified with the smaller deposits due to the high institutional costs associated with jointly running a state-owned enterprise.

In order to explore the consistency of government decision making in Botswana and applicability of the model ownership preferences for the smaller non-diamond and diamond resources are simulated. In these simulations, small resource sizes are examined. For the specific case of non-diamond production (Selibe-Pikwe copper / nickel mine), a scenario where the cost and market access advantage of the firm is low (*c=0.1)* is examined. As can be seen from the results in Figure 6.1, in both these cases the incentives for state ownership and control are low and lie below the institutional costs limit.

As a result, the model predicts that the government of Botswana would prefer private ownership and control over state ownership and control. The results indicate that in Botswana state decisions are a combination of: (i) a high expectation of reelection; (ii) a high and non-appropriable cost advantage of the firm (through technology and market access); (iii) a low opportunity cost of the firm; as well as (iv) the ability to capture a large degree the rents through a joint ownership model. These combine to create incentives for Government to let the private sector maintain control over production decisions.

6.2 Oil and gas: Mexico

State ownership of energy assets has been a historic characteristic of Mexico's energy sector and had a significant impact on the evolution of Mexico's economy. The nationalisation of Mexico's petroleum sector in 1938 provoked a deep resentment of foreign domination; it was dramatic and confrontational (McPherson 2011). It marked the first ever overall blanket nationalisation within the petroleum sector. Foreign assets were taken over by the national oil company, Petróleos Mexicanos ("PEMEX"), which became and remains an important national symbol (Tordo 2011). PEMEX's monopoly position was enshrined in Mexico's constitution, which restricted all private (foreign and domestic) participation in the petroleum sector.

Over the years PEMEX became highly politicised and political interference in its operations was common. Corruption, inefficiency, and waste were believed to be rife. At the same time draconian taxes made PEMEX highly dependent on non-transparent negotiations with government for funding of its operations and investment budgets (McPherson 2011). In recent years, it has become evident that a crisis was looming in the sector, with significant implications for the overall economy given that oil accounts for approximately 30% of budget revenues and 20% of GDP (O'Neil 2014). Reserves and production have begun to decline rapidly and without new investment in productive capacity Mexico would cease to be a net exporter of oil within the next five years (McPherson 2011). (See Figure C.2 in Appendix C.)

The capital investments in new production required to reverse this trend are very large, as are the technical challenges since new reserves will have to come mostly from deep-water areas in the Gulf of Mexico. Due to these financial and technological barriers offshore oil prospects were expected to bring a number of positive governance changes to attract the technical and financial resources required. Mexico's government committed to a major reform of the country's energy sector, which was expected to include a package of fiscal, governance, and budgetary reforms for PEMEX designed to enhance performance, its ability to raise finance and ultimately grant greater operational and budgetary independence within existing constitutional constraints.

Ultimately, on December 20, 2013, Mexican President Enrique Peña Nieto signed historic constitutional reforms aimed at reversing oil and gas production declines. On August 11, 2014, secondary laws to implement those reforms officially opened Mexico's oil, natural gas, and power sectors to private investment. Because of these reforms, PEMEX can now partner with international companies that have the experience and capital required for exploring Mexico's vast deep water and shale resources.

Mexico's reasons for pursuing institutional change are not unique. In examining cycles of nationalisation and privatisation, Chang et al. (2017) note that there is a large diversity of trends within natural resources, and only a special set of natural resources (eg. oil, gas and mining) have been subject to privatisation and nationalisation cycles. Kobrin (1984), Chua (1995), and Duncan (2006) also single out the energy, mineral and fuel sectors as being highly prone. Chang et al. (2017) believe that what makes some of these sectors different and prone to nationalisation is in part due to their production technology, which in some cases can be easily appropriated by national oil companies. This leads to a key insight raised earlier in this thesis: for technology to create incentives for a transition to privately held property rights (and control) or to maintain those property rights, (a.) the technology must be non-appropriable and the firm must have the ability to withdraw the technology, or (b.) the firm must be able to continually develop new proprietary technologies which generate rents that the state would not be able to generate on its own. As shown by Opp (2012) in a game theoretic set up of property rights, differentiating technology in the form of management expertise or patents can create endogenous property rights and improve security of tenure.

When considering how to parameterise the case of Mexico, it is useful to think about the following: the presidential elections in Mexico have seldom resulted in the same candidate or party remained in power for two terms and often the party with most voters lacks a majority and has had to from a coalition to secure the votes it has. As a result, certainty for reelection is low in Mexico and for the purpose of parameterizing the model $\Pi=0.2$ is used. (See Table C.2 of Appendix C for additional information regarding Mexican presidential election results.) Oil is found and produced in many countries and companies have options of where to invest (more than in the case of diamonds), thus there is an opportunity cost for oil and gas companies wishing to invest in Mexican oil development ($b=3$). When considering the development of conventional on-shore resources the cost advantage of the private sector over PEMEX is low ($c=0$). Conversely, when considering the development of deep, off-shore resources in the Gulf of Mexico, PEMEX does not yet have this technological capability and the cost advantage of the private sector is higher. Should the government decide to access these deep offshore resources without a strategic partner it would face the risk of significant cost overruns, poor recoveries and significant environmental degradation. (A value of $c=2$ is used to represent the advantage of the firm for offshore resources.) Because it is beyond the scope of this research to make predictions regarding the future price path of oil, three possible price paths are modelled: constant prices ($p_1=p_2=10$), increasing prices ($2p_1=p_2$; $p_2=20$); and decreasing prices ($p_1=2p_2$; $p_1=20$). The simulation results for this parameterisation are shown in Figure 6.2 (constant prices only) and in Figure 6.3 (all three price paths).

As can be seen in Figure 6.2 and Figure 6.3 in the case of large on-shore resources, the politician is incentivised to own and control the resource provided that the incremental utility is greater than the institutional costs of running a national oil company. In the case of a large off-shore resource where the state oil company lacks the technology to efficiently and safely extract the resource, incentives for state ownership and control deteriorate significantly as the resource increases in size. In this case, it is optimal for the government to allow private ownership and control and tax the company to the point where foregone rents cover the firm's opportunity cost; this will allow the state to generate and capture a greater share of rents than if it chooses to deplete the resource on its own.

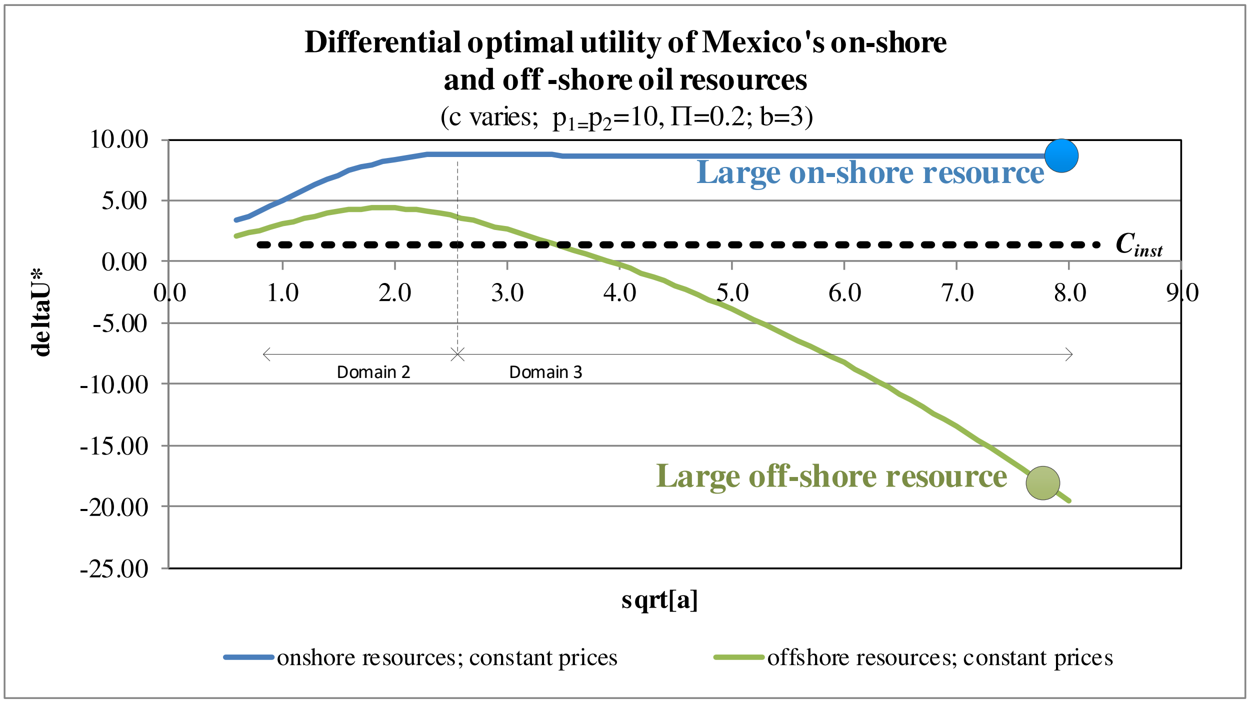

Figure 6.2 Differential optimal utility of Mexico’s on- and off-shore oil resources (constant prices).

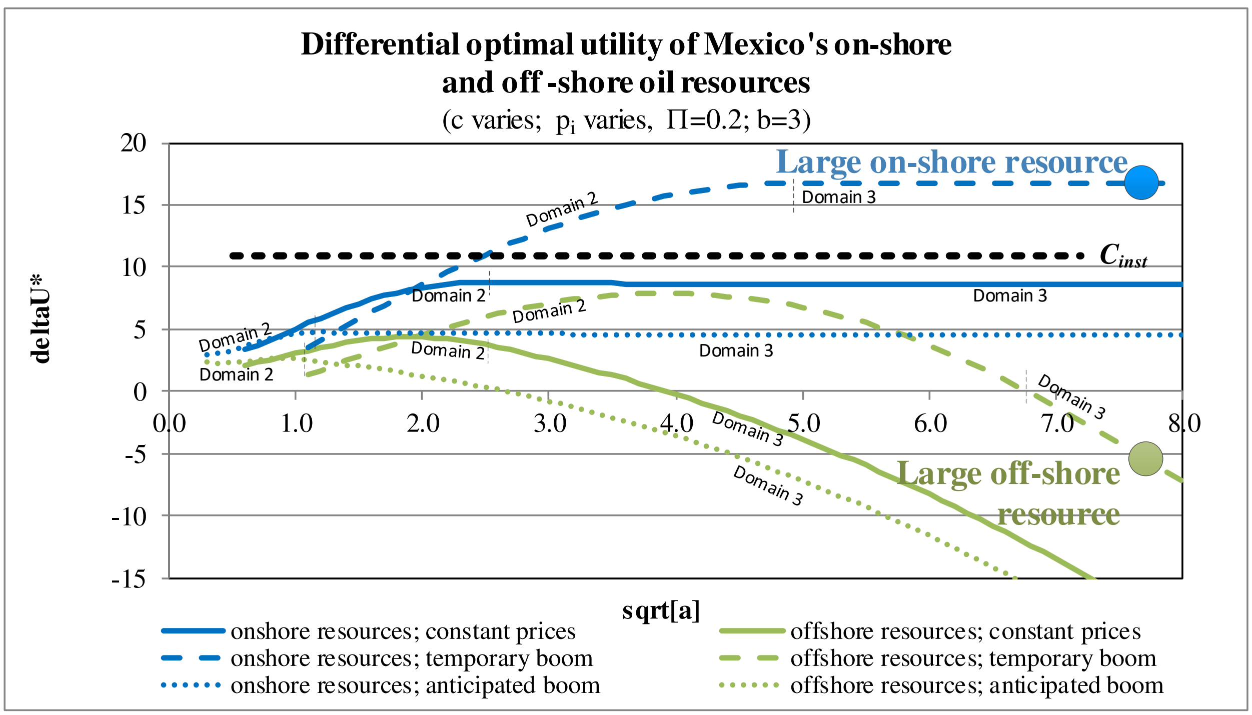

Figure 6.3 Differential optimal utility of Mexico’s on- and off-shore oil resources (with three price scenarios).

The simulated model results correspond well with the history of Mexico's energy sector where onshore production is largely dominated by PEMEX, and where recent changes to the governance of the sector have enabled private sector participation in the offshore resources through bidding rounds (Dos Santos et al. 2015).

6.3 Industrial minerals: the generalised case and the cases of Morocco and Bhutan

It is now of interest to turn away from the cases of the high rent and world class deposits of Botswana and Mexico and consider cases where state ownership is less common, or mixed, such as in industrial minerals.

Industrial minerals are minerals that are mined for their commercial value; they are not fuels and are not sources of metals. They are used in their natural state or after beneficiation, either as raw materials or as additives in a wide range of applications.[55] Typical examples of industrial minerals include limestone, clays, sand, gravel, diatomite, kaolin, bentonite, silica, barite, gypsum, phosphate rock and talc.

As they find their use in agricultural, construction or manufacturing processes, the markets for industrial minerals are often local. In many countries, deposits are low rent since supply is abundant and the price of the mineral is less a factor of scarcity or quality but often a function of the distance from the deposit to the market and thus reflect transportation costs more than a supply constraint. In other cases, markets can be global where large high-quality deposits exist such as with Morocco's phosphate rock mines. In other cases, minerals can take on a strategic value as is the case with Bhutan's aggregate minerals. With the objective to further test the model's explanatory power focus will now turn to exploring these two different cases.

In all cases the model is parameterised such that the differential cost of production between the government and the private sector is low – this is because most industrial minerals are located close to surface, are relatively easy to mine and do not require sophisticated metallurgical processes or other technologies, ($c=0.01$ is used). Since deposits are normally abundant, firms are generally local and small scale due to the generally low rents the opportunity cost of the firm is

[55] Mineral beneficiation is a process by which valuable constituents of an ore are concentrated by means of a physical separation process.

therefore assumed to be low (*b=0.1*). Prices are modelled to be constant in the long term ($p_1=p_2=10$). See IndexMundi (2017) for a 30-year history of the price for phosphate rock which shows a relatively stable price except for a short-lived spike in 2007-2008.[56,57] The probability of reelection is varied to cater for different local circumstances and this is discussed briefly in the next two subsections before examining the simulation results in Section 6.3.3.

6.3.1 Phosphate rock in Morocco

The manufacturing of fertilisers and the production of animal feed supplements account for more than 95% of phosphate rock consumption and continued global population growth and the need for dependable food supplies underscore the need for phosphate fertilisers (Norman 2015). The remainder of the production is used to produce elemental phosphorus, with the balance used in a variety of household products, such as vitamins, pharmaceuticals, soft drinks, toothpaste, flame retardants, glass, photographic film, and other consumer goods.

In 2008, the State of Morocco mined 24.9 million tonnes of phosphate rock, equivalent to approximately 15% of global production (World Bank 2011). This increased to 30 million tonnes or 13% of global supply by 2015 (Jasinski 2015, 2016). Unsurprisingly, due to this share of global phosphate production the mining sector holds an important place in the Moroccan economy. Managed by the state-owned Office Cherifien des Phosphates ("OCP"), Morocco is the world's second largest phosphate rock producer and the world's largest phosphate rock exporter with phosphate representing 29% of exports. The state-owned company employs over 20,000 workers (Government of Morocco 2015).

Maintaining political power in Morocco is unpredictable and complex. The country is governed as a parliamentary constitutional monarchy, whereby the Prime Minister of Morocco is the head of government, and of a multi-party system. However, the constitution grants the king extensive powers; he is both the secular political leader and the "Commander of the Faithful" as a

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[56] No standard domestic or world price for phosphate rock exists. Average ranges of world prices were published in various industry trade journals based on a sample of transactions.

[57] Prices were driven up by an imbalance between supply and rapidly expanding demand, especially in Asia. Demand was particularly strong in China and India, but a contributing factor was increased demand for fertilisers to produce biofuels in the United States, Brazil, and Europe. Increased livestock production created still more demand for grain and thus for fertilisers. Grain reserves became historically low and prices rose sharply. However, prices fell rapidly in late 2008 because the high fertiliser prices caused 'demand destruction.' Farmers were unable or unwilling to pay two or three times the prices of early 2007. Collapse of the global credit market, a trade recession, and slowdown in world economic growth worsened the situation. Demand for fertilisers fell and stocks accumulated. Fertiliser manufacturers cut back on production (IFDC 2008).

direct descendant of the Prophet Mohammed. He presides over the Council of Ministers; appoints the Prime Minister following legislative elections, and on recommendations from the Prime Minister, appoints the members of the government. Following elections on January 3, 2012 King Mohamed VI appointed the new members of the government to be led by the Justice and Development Party ("PJD"). A coalition party between the PJD, the Independence Party (Istiqlal), Popular Movement ("PM") and Party of Progress and Socialism ("PPS") held power. However, on October 10th, 2013 there was a government reshuffle. The new government ended after the conservative Istiqlal party pulled out. The centre-right National Rally of Independents ("RNI"), which is close to the King, replaced ministers from the conservative Istiqlal party while in the background Morocco's King appointed several new ministers.[58] In the October 7, 2016 legislative elections, the PJD won a plurality of 125 seats. Abdelilah Benkirane was appointed to form a new government three days later (Lansford 2017). However, on March 17, 2017, King Mohammed VI replaced Benkirane with a new prime minister, also from the PJD, to end a political deadlock that left the country without a government for five months as Benkirane had failed to form a government (The National 2017). With respect to model parameterisation, $\Pi=0.1$ is used. Results are discussed later together with the case of Bhutan in Section 6.3.3.

6.3.2 Aggregate minerals in Bhutan

The Kingdom of Bhutan is located on the Himalayan mountains' eastern edge. The Kingdom is known for its monasteries and dramatic landscapes that range from subtropical plains to steep mountains with peaks as high as 7,326m above sea level. With such drastic relief, hydropower has become one of the most important economic sectors in Bhutan, both as the main supplier of electricity and as a major contributor to GDP. In 2012, the electricity & water supply sector contributed 17.1% of total GDP. The sector is also an important foreign exchange earner for the country. Largely energy secure and independent, in 2012 Bhutan exported 4924 GWhr of electricity to India and imported only 36.75 GWhr.

In 2012, the installed hydropower capacity in the country was 1,488 MW, about 5% of the total potential of 23,760 MW. Backed by Indian financing, Bhutan plans to increase hydropower

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[58] Morocco's king has appointed 19 new ministers after the prime minister reached a deal to form a new coalition that weakened the ruling Islamists who are trying to push through unpopular reforms to subsidies and the pensions system. The king increased the number of ministers to 39 from 30 and put the RNI in key ministries such as interior, finance and foreign affairs.

capacity to 4,546 MW and small hydropower plant capacity from 8,000 kw to 20,000 kw to reach more than 10,000 MW hydropower capacity by 2020 (World Bank 2014). Approximately 80% of the envisaged power will be sold to India. GDP growth is projected to average 10 percent over the course of 2013-2018, powered initially by construction of hydropower plants followed by electricity sales in the later years (ibid).

To achieve this expansion in hydropower generation capacity Bhutan envisages harnessing its vast water resources and rugged mountainous terrain and will build approximately 74 dams in cascades across the country. The massive expansion in construction will require many industrial minerals, most notably those suitable to produce cement and concrete.

Bhutan has large deposits of many industrial minerals. The main types of mineral currently being developed in the country include dolomite, limestone, gypsum, coal, quartzite, and marble. Despite the mining and quarrying sector contributing only 1.9% to Bhutan's GDP in 2013, it was the second largest foreign exchange earner (second only to energy) and the sector thus plays an important role in the balance of payments. Dolomite, gypsum, coal, cement, copper wire, ferrosilicon, and manganese are the main exports (Fong-Sam 2016).

Bhutan's deposits of mineral resources are not world class by any measure and the rugged geographic terrain of the mountainous kingdom makes access to resources costly. Deposits therefore have value due to their proximity to construction sites and existing transport infrastructure. The massive expansion of the hydropower sector has significantly bid up the value of previously uneconomic deposits and created the potential to realise significant rents.

As a result of the government's hydropower expansion plans and related concerns about the potential inequitable distribution of resource wealth, the Government of Bhutan created the State Mining Corporation ("SMC"), and on December 31, 2014, it handed control over to the state investment holding company, Druk Holding and Investments ("DHI").[59] It is envisaged that the state mining company will pay 75 percent of its after-tax profit to the government as dividends

[59] DHI is the only government-owned holding company in Bhutan. It holds shares in 18 different companies operating in the manufacturing, energy, natural resources, financial, communication, aviation, trading and real estate sectors. Its vision is to be "the leading wealth management and creation organization that helps transform Bhutan into a globally competitive economy guided by the principles of [Gross National Happiness (GNH)]." (DHI 2014)

(Palden 2014). As part of the handover event licences for five quarry sites were allocated to the SMC to supply materials to the 600MW Khologchhu hydropower project.

With respect to political economy considerations Bhutan has a national bicameral parliamentary legislature and there have been significant swings in political control in recent years. The National Assembly of Bhutan is the lower house of Parliament and had 47 members as of 2013. Between 2008 and 2011, 45 seats were won by the ruling Bhutan Peace and Prosperity Party ("DPT") and 2 were taken by the opposition, the People's Democratic Party ("PDP"). However, in the 2013 National Assembly elections, the PDP, won 32 of the 47 seats with the DPT holding the remaining. With respect to model parameterisation, $\Pi=0.50$ is used.

6.3.3 Simulation results

Simulated results for the cases of Bhutan and Morocco can be found in Figure 6.4. As can be seen, in the case of small, low rent resources, the benefits to public ownership lie below the institutional costs of public ownership, which creates incentives to leave small aggregate mineral deposits to the private sector. Conversely, when potential rents increase with the resource size, as in the case of Morocco with its large phosphate rock deposits, public ownership over the resource is preferred. This is especially true when where reelection certainty is low as Figure 6.4 shows that incentives for public ownership increase as Π decreases.

The case of the State Mining Company in Bhutan is more nuanced and provides for an interesting narrative. Bhutan is representative of a mixed ownership economy. In some cases, pre-existing mining and quarrying licences are held by the private sector. However, many of the new and potentially lucrative quarrying licenses that will provide much of the material needed for the government's hydropower expansion programmes have been awarded to the State Mining Company. In this sense, the increased economic and strategic value (and corresponding increased volume of economically feasible minerals) has made government's differential utility of public ownership exceed the institutional costs of ownership and tipped the decision in favour of public ownership. This is shown in Figure 6.4 where the value of Bhutan's aggregate minerals shifts right along the horizontal axis and upward along the differential utility line.

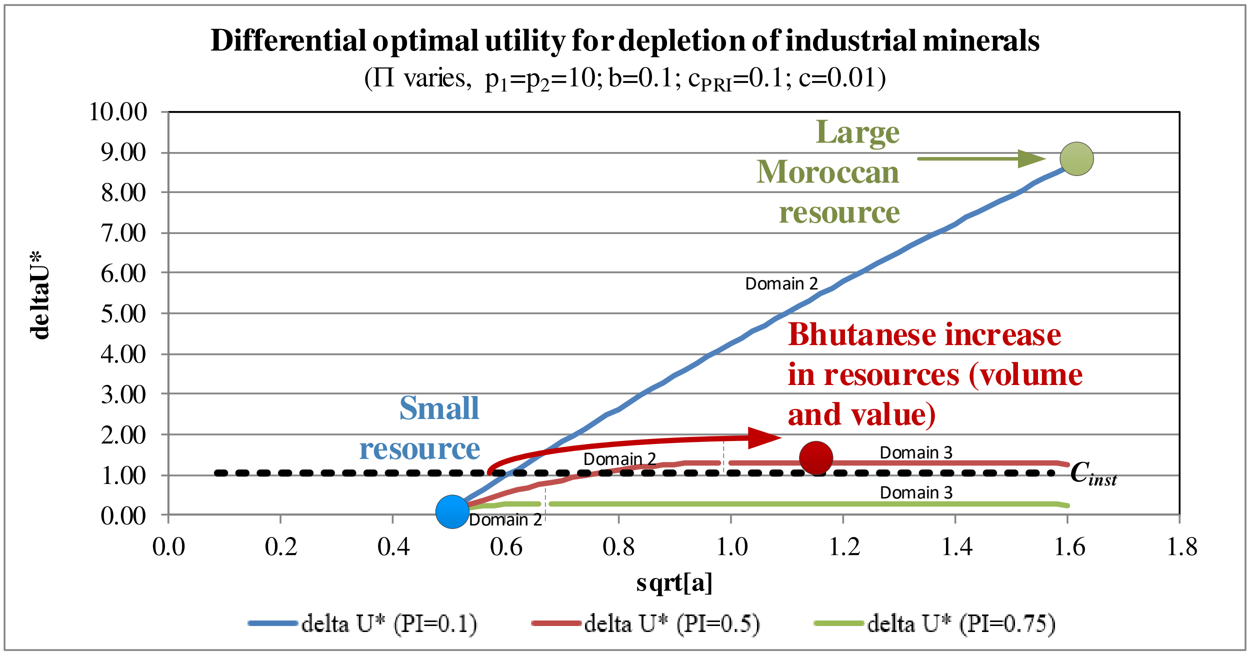

Figure 6.4 Differential optimal utility industrial minerals under the generalised case and the cases of Morocco and Bhutan.

Finally, another observation from Figure 6.4 is that under the current parameterisation of the model increased preferences for public ownership and control can be seen to be associated with increased reelection uncertainty. This would suggest that if all else holds, as reelection becomes more certain in Morocco and time preferences of politicians become more long term, one could expect a privatisation of OCP, the state phosphate mining company.

When performing a sensitivity analysis of the simulation with respect to the price path (not shown here), the simulation found that preferences for public ownership tend to increase in anticipation of a price increase (anticipated price boom) and decrease when prices are decreasing (temporary price boom). This result corresponds well with the case of Bhutan where the government created the state mining company in anticipation of a price boom.

6.4 Summary of results

In the above subsections the cases of Botswana, Mexico, a generalised case of industrial minerals and the specialised cases of industrial minerals in Morocco and Bhutan were examined. In all cases, the model has demonstrated a high degree of explanatory power. The country cases show how decisions regarding public ownership vary from country to country and from resource to resource. It is not one parameter alone that determines the ownership and control structure over non-renewable resources, but rather it is the combination of the resource size (and rents), political economy, the opportunity costs of firms, cost advantages or market barriers between the private sector and the state and of course, institutional costs or political constraints. The results of the five cases are summarised in Table 6.1.

Table 6.1 Summary of country case studies.

Country	**Resource size (degree of rents), $\sqrt{a}$.**	**Opportunity cost of firms, 'b'.**	**Differential costs or barriers, 'c'.**	**Political economy, Π.**	**Ownership and control model**
Botswana	Very high (Debswana) and Small (AK06, Copper, Nickel)	Low – companies do not have access to deposits of the same quality.	Very high for the large diamond deposits. Low for other deposits.	Very high reelection probability	For the large Debswana diamond deposits: joint state and private ownership, private control and private technology and market access co-opted For smaller deposits: Private ownership and control.
Mexico – on shore	Very high	High – companies have other options	Low	Low reelection probability.	Public ownership and control
Mexico – off shore	Very high	High – companies have other options	High		Mix of public and private ownership, private control.
Generalised industrial minerals	Low	Low	Low	Varies	Private ownership
Morocco	High (relatively to economy)	Low	Low	Low reelection probability.	Public ownership

Table 6.1 Continued.

Country	**Resource size (degree of rents), $\sqrt{a}$.**	**Opportunity cost of firms, '*b*'.**	**Differential costs or barriers, '*c*'.**	**Political economy, *Π*.**	**Ownership and control model**
Bhutan	Transitioning from low to high resource value (rents and strategic value)	Low	Low	Neither low nor high reelection probability	Historically private ownership but transitioning to public ownership and control.

The discussion in the preceding section relies on select qualitative evidence to contextualise the model and test its explanatory power. Unfortunately, the history of the world and range of mineral ownership and control is diverse enough to support a wide variety of possible models. Qualitative evidence is not in itself a conclusive test of a model's robustness; econometric techniques should be used to rigorously test the model. Unfortunately, due to a lack of readily available data sets data regarding the ownership and control of mineral resources on a global scale, the econometric analysis of the model's robustness must be left to future research.

CHAPTER 7

SUMMARY AND CONCLUSIONS

This research effort set out to develop a political-economic model that filled a gap in the existing literature by explaining choices of ownership and control of non-renewable resources through opportunistic responses to price changes and politico-economic reasons while also capturing aspects related to institutional constraints – a model that only examines one of these in isolation oversimplifies the issue and limits real insights and appropriate policy response. The model described in the above chapters fills this gap; it provides a rich and nuanced interpretation of the incentives governments face in making ownership decisions over non-renewable resources. It also provides important insights regarding the potential policy responses that generate a socially optimal outcome.

Results are corroborated by observations in empirical literature and the model's explanatory power is highlighted through a range of country case studies. As a detailed discussion of the individual model results are contained and summarised within the individual chapters and their summary sub-sections (Sections 3.1.5, 4.5, 5.5 and 6.4) that discussion will not be repeated here. However, some key results are highlighted, and comparisons drawn, between the two models in the text that follows.

First, it is striking how a slight modification to the model through the incorporation of costs or a partial non-controlling state equity interest significantly weakens the deterministic outcomes presented in Section 3.1 and raises questions regarding much of the literature on the subject, particularly Robinson et al. (2014). To borrow a phrase from Manski (2011), this anything-can-happen result through the addition of costs, together with the other model parameters provides insights regarding the strength and "incredible certitude" of some of the highly cited literature regarding the political economy and the resource curse. Importantly, though attractive for its simplicity and tractability, this incredible certitude can be harmful to governments who adopt policies based on those incorrect recommendations.

Two distinct issues are discussed throughout this thesis: institutional (ownership) choice and economic efficiency. These are discussed separately below since this study finds that not only is there: (i) an "anything-can-happen" preference for ownership type that depends on a combination of exogenous parameters; but, (ii) these combinations of exogenous parameters also generate an "either-ownership-model-can-be-efficient" result.

As has been documented through this analysis, this research shows that governments could prefer public or private ownership and that choice depends critically on the size of the resource, the opportunity cost of the firm, the cost or market access advantage of private ownership, reelection probability, prices, institutional costs and the degree to which government holds a non-controlling partial equity stake in the firm. In some instances, the model lends support to the conclusions in the theoretical and empirical literature that public ownership is in some sense driven by opportunism in response to price cycles. This was seen through an examination of Proposition 3 over the second and third domains, and then verified in the simulation that explored responses to price booms (Figure 5.5). This result showed that rather than reflecting mere shifts in political ideology, politicians can act opportunistically in response to price booms in line with Chang et al. (2017), Duncan (2006) and Hajzler (2012). However, this study also finds that the opposite can be true and that in some instances price booms can lead to increased preferences for private ownership, thereby reinforcing property rights, and that conversely price decreases can lead to increased preferences for public ownership. This is consistent with Cole and English (1991) who describe how expropriations in boom and bust periods can be explained through decisions motivated by either opportunism (in booming periods) or desperation (in bust periods) by governments.

Further examination of the effect of price booms show that the 'type' of price boom matters. An anticipated price boom decreases the incentives for public ownership because the firm defers more production to the second period relative to the politician. This combined with booming prices and the firm's cost advantage increases incentives for private ownership and control. Therefore, if the expectation is that commodity prices for non-renewable resources are in contango or will follow the Hoteling rule (Hoteling 1931), increasing prices will increase the value of more distant production, benefiting the firm's slower production path more than the politician's and thereby decreasing incentives to adopt public ownership. However, if the price boom is temporary and the expectation is that prices are in normal backwardation or follow the Prebisch-Singer hypothesis then public ownership and control will be preferred.[60]

The probability of reelection also provides for a rich interpretation since increased probability of reelection can either increase or decrease preferences for public ownership. This can be seen from a comparison of Proposition 4 (see Table B.6 in Appendix B), which shows that results differ across domains; though it is worth recalling that it is only in the model with costs where the politician might select private over public ownership.[61] The generalised simulations in Chapter 5 (Figure 5.3) show that preferences for public ownership decrease as reelection becomes more certain. This is further supported by the specific parameterisation of the model for the cases of Bhutan and Morocco (Figure 6.4). Political stability therefore appears to be an important first step for the private ownership and control of natural resource wealth in those countries. This is partly due to the specific parametrisation of the models; an analysis of the propositions over the third domain shows that an increase in the probability of reelection can either increase or decrease preferences for public ownership and control (Proposition 4, see Table B.6 in Appendix B). These results provide insights that might be useful in explaining the contradiction between the well-established link between democratic political institutions and reduced political risk and risk of expropriation (Jensen 2003; Li 2009; Ali et al. 2010), with the finding that expropriations of energy and mineral resources are more common in democracies than in dictatorships; where continuity of power is less certain leading to possible short-termism in government decision-making (Duncan 2006).

One of the few variables that has a clear, unambiguous effect is the cost advantage, or market access advantage, of private ownership. From the results of Proposition 5 (summarised in Table B.6 of Appendix B) it can be seen that under all three domains an increase in the cost advantage or market access advantage of the firm results in an increased preference for private ownership. This is because when the firm has a competitive advantage over the politician it is able to generate more rents per unit of production in each period than the politician can. The degree to which these incremental rents offset its opportunity cost and slower production profile (resulting

[60] The Prebisch-Singer hypothesis refers to the secular trend in primary commodity prices that Prebisch (1950) and Singer (1950) have conjectured should be declining in the long run.
[61] Recall that under costless extraction the politician is either indifferent or chooses public ownership over all domains. See Table B.3 in Appendix B.

from a different time preference from the politician) determines whether the politician will prefer private ownership over public. Furthermore, the magnitude of incremental rents generated are a function of the resource size. And the degree to which they are valued by the politician is a function of the politician's reelection probability which also exacerbates differences between production profiles as reelection become increasingly uncertain. The simulations in Chapter 5 (Figure 5.3) show the effect for a generic parameterisation, while the cases of Botswana and Mexico illustrated in Chapter 6 (Figure 6.1 and Figure 6.2 respectively) further contextualise how the competitive advantage of the firm has manifested itself in the evolution of ownership structures in those countries.[62]

Similarly, as was shown in Section 3.2, an increase in the government's non-controlling equity stake in the firm will increase preferences for private control (with partial public ownership) over full public ownership and control. This occurs because the equity stake allows the politician to capture additional rents without affecting the firm's decision to produce or not, or the efficiency of its production path. Furthermore, since production decisions are not negatively affected by the partial equity stake, policies that support state equity offer a potential incentive-compatible 'win-win' solution where private control over the resource is socially efficient.

Regarding efficiency considerations, much of the literature has focused on the inefficiency of public ownership and control. Robinson et al. (2014) and Matsen et al. (2016) show how the politician's myopic time decision-making (due to the uncertainty of reelection) cause her to make inefficient choices regarding rates of extraction and use of public funds. Wolf (2009), Wolf and Pollitt (2008), La Porta and López-De-Silanes (1999), Galiani et al. (2003), Schmitz and Teixeira (2008) and Das (2012) all provide strong empirical evidence to support that state-owned oil, gas and mining companies are on average less efficient and less profitable than their private sector counterparts. In line with the previous literature, this research also finds that the cost or market access advantage of the firm improves the efficiency of private ownership and control over public ownership and control. However, it is important to caveat its positive contribution to efficiency by emphasizing that a technological or market access advantage of the firm is not enough. It is necessary that the firm's competitive advantage be non-appropriable by the government - either

[62] In Botswana this was characterised as nearly full taxation with private control to gain market access. In Mexico this has manifested itself through the relaxation of the constitution to allow entry of the private sector to develop Mexico's technologically complex offshore oil and gas assets.

through strong intellectual property protection laws or through the manner through which the firm deploys this competitive advantage. If the competitive advantage is appropriable by the government, the improved efficiencies of the firm could render it a target for nationalisation (at an extreme) or be adopted by government under public ownership. Once the technologies are owned by government under some form of sole or joint ownership, the benefits or efficiencies accrue to the new owners and the advantage of the firm is nullified. This is an important insight since Dalgaard and Olsson (2008) find that the degree to which resource rents have a negative impact on a country's income and manifest in a "resource curse" depends critically on institutional quality and the ease of appropriation of the rents.

Regarding the efficiency of the production path, whereas others such as Robinson et al. (2014), Matsen et al. (2016) and Hartley and Medlock (2008) have found that public ownership always leads to an inefficient result, this study finds that this result is largely dependent on assumptions about the relative time preferences of the politician, the private sector firm, and the social planner. If the politician's time preferences are assumed to be more short-term than the social planner or the firm's (as the literature often does), then public ownership yields a sub-optimally fast depletion path compared to private ownership as decisions are more short-termed in nature. Conversely, if the politician's time preferences are more long term in nature, she will sub-optimally deplete the resource slower in comparison to private ownership. However, as discussed in Section 3.1.4, if the politician's discount rate is more in line with the social discount rate than the firm's, her production path will be more socially optimal than the firm's. Furthermore, as was then subsequently discussed in Section 4.4, even without consideration of the differences in time preference the introduction of costs alone allows for the possibility that the firm has a faster extraction path than the politician.[63] In these instances, only the firm's potential non-appropriable competitive cost or market access advantage can make private ownership the more efficient choice.

When both the efficiency of the production path and cost of extraction are considered this study finds that either ownership model can be efficient. This departs from the position of Luong and Weinthal (2010) whose qualitative analysis concluded that private ownership is preferable to state ownership for the attainment of development. This study concludes that the determination

[63] Recall that the outcome depends on a combination the ratio of second to first period prices and on the size of the cost or market access advantage of private ownership.

of whether one form of ownership is more efficient than the other depends critically on: (i) whose time preferences are more aligned with the social time preference; and (ii) any non-appropriable cost or market access advantages the firm may have over the politician.

The quality of institutions of course also matter and the literature highlights two types of institutions that can lead to optimal policy-making: (i) those that constrain the ruling elite; and (ii) those that enable governments to make correct decisions. As the size of the resource or the opportunity cost of firms are factors outside the control of the host country, institutional recommendations can only be influenced by these factors but cannot be anchored in them. In terms of enablers and constraints, the model does not contain any particular constraints on the politician other than the limitations to the choice of ownership and the introduction of institutional costs. At one extreme, countries wanting to protect against the inefficiencies manifesting through ownership could restrict state participation through appropriate constitutional amendments. Another less onerous restriction with potentially broader based benefits would be for governments to require inter-ministerial representation and require the adoption of exacting standards for corporate governance for state owned enterprises. Kendall-Taylor (2009) suggests that the establishment of party-based electoral democracies will extend the time preferences of leaders and therefore better align time preferences with the socially optimal where the politician's time preference is sub-optimally short termed. This would in effect restrict discretionary control of state owned enterprises, better align public ownership with the socially optimal and add to the institutional cost of public ownership. Once these institutional costs are considered, the preferences for ownership model will be a factor of the state of commodity markets, the size of the resource, the opportunity cost of the firms that are likely to invest in such a resource and their differential cost advantage (if any). In all cases the political economy considerations of the politician will need to be considered together with the potential efficiency gains of private ownership.

A qualitative analysis through country case studies confirms the model's explanatory power. Specific country examples of Botswana (diamonds and nickel), Mexico (on- and off-shore oil and gas), Morocco (phosphate) and Bhutan (industrial minerals) were examined. In all the cases examined, the model was shown to have high explanatory and potential predictive abilities. Unfortunately, the history and variety of petroleum and mineral ownership and control is diverse enough to support a wide range of conclusions. Although helpful to show the model's performance, the simulations married with qualitative evidence are not in themselves a definitive test of a model's robustness; econometric techniques should be used to rigorously test the model if suitable datasets can be collected. This is left for future research programs.

In summary, large non-renewable resources with high rents can 'optimally' both be private or publicly held depending on a host of factors. Importantly, these factors include costs or other competitive and non-appropriable advantages the firm may have over the politician, the political economy (as reflected through election uncertainty and differential time preferences), price expectations (and specifically whether we are in a Hoteling (contango) or Prebisch-Singer (normal backwardation) environment), the opportunity cost of the private sector and institutional costs of state ownership and control. Thus, as with the research efforts of others this study find that prices do matter, however, prices alone are not enough to explain the diversity of ownership and control choice across countries and commodities.

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APPENDIX A

FISCAL REGIMES AND STATE PARTICIPATION

Table A.1 Summary of petroleum fiscal regimes and state equity participation in selected countries. (Daniel et al. 2010)

	Royalties	**Cost recovery**	**Profit share**	**Corporate income tax**	**Comments**
Angola offshore	n/a	50-65% W/U	30%-90% on return	50%	State equity participation
Angola onshore	n/a	50-65% W/U	35%-90% on cum. prod.	50%	State equity participation
Cameroon	n/a	60%	20%-70% on R-factor	40%	State equity participation
Equatorial Guinea	13%-16% on daily prod.	70%	10%-60% on cum. prod.	35%	State equity participation
Ghana	12.5% flat		12%-28% on return	30%	State equity participation
Madagascar (onshore)	8%-20% on daily prod.	60%	20%-70% on daily prod.	n/a	n/a
Madagascar (offshore)	8%-20% on daily prod.	65%	20%-70% on daily prod.	n/a	n/a
Mauritania		70%	20%-50% on daily prod.	30%	State equity participation
Mozambique	10% flat	65%	10-50% on R-factor	32%	State equity participation
Namibia	5% flat	n/a	n/a	35%	n/a
Nigeria (onshore)	10% flat	100% W/U	52%-60% on daily prod.	50%	tax allowance on dev. costs, NOC
Nigeria (offshore)	10% flat	100% W/U	60%-65% on daily prod.	50%	tax allowance on dev. costs, NOC
Nigeria (deepwater)	10% flat	100% W/U	20-50% on cum. prod.	50%	tax allowance on dev. costs, NOC

Table A.1 Continued.

	Royalties	Cost recovery	Profit share	Corporate income tax	Comments
Sierra Leone	10% flat	n/a	n/a	37.5%	n/a
Australia	n/a	n/a	n/a	30%	n/a
Timor-Leste	5% flat	100% W/U	40% fixed	30%	State equity participation
Colombia	8%-25% on daily prod.	n/a	n/a	33%	NOC
Peru	5%-20% on daily prod.	n/a	n/a	30%	NOC
Norway	n/a	n/a	n/a	28% w/ 50%ST	NOC
UK	n/a	n/a	n/a	30% w/ 20%ST	n/a

Notes: W/U: with uplift; NOC: National Oil Company participates.

Table A.2 Summary of mineral taxation in selected countries highlighting state ownership interests. (Otto et al. 2006; Hogan and Goldsworthy 2010.)

	Royalties	Corporate income tax	Comments
Angola	2% (other minerals), 3% (iron and base metals), 4% (semiprecious stones) 5% (diamonds)	40%	WHT/I:10-15%, WHT/D:10%, Surface Tax. NMC: Endiama (diamonds)
Argentina	Most minerals 0%-3%	35%	WHT/I: 35%, WHT/D:15.05%-35% (varies with residency)
Bolivia	Gold: 4-7% or 3-5% (if marginal) Silver: 3-6%, Lead, tin & copper: 1-5% all price based.	25%	WHT/I&D:12.5% (non-residents only)

Table A.2 Continued.

	Royalties	**Corporate income tax**	**Comments**
Botswana	Most mineral 3%, Metals 5%, Precious stones 10%	Variable rate formula w/ 25% min. De Beers JV subject to ~80:20 profit split in favour of Govt	WHT/I&D: 15% , 50% ownership of diamond JV with De Beers
Brazil[1]	Aluminium and phosphate: 3%, Copper, iron, zinc: 2%, Industrial metals: 2%.	34% (effective)	Royalties allocation[2]. WHT/I: 15% (non-residents only)
Chile	Copper: 0.5-5% (sales based)	35%	WHT/I:4%(foreign) 35% (domestic), WHT/D: 35%
China	Al, Fe, Zn: ad valorem + per unit charge Cu: 2%+0.4-30, Gold:4%+0.4-30, Industrial Min. 2%+0.5-20.	25%	WHT/I.:10%
Ghana	3-6% varies by operating profit	25%	Royalties allocation[3]. WHT/I&D: 8%
Guinea[7]	Bauxite 10%, Alumina 5%, Iron 7%, Base metals 7%, Gold 5%, Diamonds and gems 5-10%	35%	WHT.I&D: 15%, Additional profit tax of 50% when ROE > 20%, 35% free interest.
India	Aluminium 0.35%, Copper 3.2%, Gold, 1.5%-2.5%, industrial minerals on a per tonne basis, Zinc 6.6%,	30% (residents) 40% (foreign)	WHT/I:20% WHT/D:17%
Indonesia	Aluminium, copper, iron, phosphate: unit based. Gold: 7.5% (placer) 2.5% (other) Industrial minerals: 0.14-0.16 $/t	10% to 30% (sliding scale)	WHT/I : 20%(foreign) WHT/D: 15%(residents) 20% (foreign)
Malawi	Most minerals 3%	30%	10% RRT when post-tax cum. cash flows > 20% WHT/I:15% , WHT/D:10%
Mexico	none[4].	28%	none

Table A.2 Continued.

	Royalties	Corporate income tax	Comments
Mongolia	Most minerals 5%, coal and other: 2.5%	10% first MNT 3bn, 25% excess	68% tax when copper price > $2600/t and gold > $500/oz. WHT/I&D: 20%
Mozambique	Coal and other minerals 3%, basic minerals 5%, precious metals 10%, diamonds 10%-12%.	32%	WHT/I&D:20%
Namibia	Most minerals 5% max, Uncut precious stones 10%	37.5% (other mining) 55% (diamond mining)	50% ownership of diamond JV with De Beers
Peru	Min of 1% of sales or 1% to 12% of income	30%+0.5% on assets above DEN 1 million	Canon Minero[5], PMSP[6], Royalties distributed to sub-nat'l Gov. WHT/I: 30%, WHT/D:4.1%
Philippines	Most minerals 2%	30%	WHT/I:10%-20% (varies with residency),WHT/D: 20%
South Africa	Refine minerals 5% (max) unrefined 7% (max).	28% (normal) Gold mining subject to variable rate.	WHT/D:15%, 15% HDSA[8] ownership 26% by 2014.
Venezuela	Most minerals 3-4%	34%	WHT/I: 3-5%
Zambia	Base metals, energy & industrial minerals, 3% Precious stones, 5%	30% (min)	WHT/I:15%

RRT: Resource rent tax, WHT/I: withholding tax on interest WHT/D: withholding tax on dividends

Notes:

1. 34% represents Brazil's effective tax rate: 15% CIT, 9% social security, 10% surtax on income greater than BRL 240,000
2. Pursuant to Law n.8.001/91, 65% of royalties are distributed to municipalities, 23% to individual states, leaving the federal government with 12%. Of the federal government's 12%, 2% goes to the national fund of scientific and technological development and 10% to the ministry of mining and energy. The Ministry of Mines and Energy will in turn allocate 2% to a fund for the environmental protection of the mining regions
3. 20% of the royalties are paid into the minerals development fund (MDF) while the remaining 80% are integrated with the national budget. Since 1993, 10% percent of mineral royalties (or 50% of the MDF) is set aside to finance mining sector institutions: at the national and local levels in areas where mining takes place. (World Bank, 2010) The remaining 10% (or other 50% of the MDF) flow to the Office of the Administrator of Stools and Lands ("OASL"). The OASL in turn retains 10% (1% effective) for administrative purposes and, pursuant to Article 267.(6) of the Constitution, distributes the remaining 90% (9% effective) to the producing regions as follows: 25% (2.25% effective) to the Stools, 20% (1.8% effective) to the Traditional Authorities and 55% (4.85% effective) to the District Assemblies.

4. Mexico is in the process of considering levying a royalty due to tax leakage in income tax.
5. The Canon Minero is a legislated system of distributing mineral revenues to sub-national governments. Through the Canon municipalities and regional governments of mineral producing regions are entitled to receive 50% of the income taxes collected from mining activities for the purpose of investment in education and social programs.
6. The PMSP, or Mining Program of Solidarity with the People it a "voluntary" contribution in excess of fiscal contributions required by law. It was negotiated with the mining industry following the Peruvian elections of 2006 to combat issues with the exemption of many mining companies from having to pay the royalty due to existing stabilisation contracts.
7. Guinea may contain approximately 25% of the world's bauxite reserves according to the USGS. Bauxite production accounts for 90% of Guinea's exports and 20% of its GDP.

Table A.3 State participation in petroleum-rich and mineral-rich countries. (World Bank 2011; McPherson 2010; Hogan and Goldsworthy 2010; Allibritton 2012.)

Country	Mining participation	Oil & gas participation
Algeria		51% CI, NOC: Sonatrach
Angola	NMC: Endiama (diamonds)	20%/variable CI, NOC: Sonangol
Azerbijan		20%/variable CI
Bahrain		None
Bolivia[1*]		100%, NOC: YPFB
Botswana	50% WI diamonds, negotiable WI in other minerals	
Brazil*		Variable, NOC: Petrobras
Brunei Darussalam		50%
Cameroon		50% CI
Chad*		10%, NOC: SHT.
Chile	NMC: Codelco (copper)	
Colombia	NMC: liquidated in 2004.	NOC: Ecopetrol
Democratic Republic of the Congo[2]	5% F/Negotiated equity shares 15-51%. SOE: Gecamines (copper)	
Ecuador	NMC: Empresa Nacional Minera	NOC: PetroEcuador
Equatorial Guinea		15% CI, NOC: GEPetrol
Gabon		15% CI
Ghana*	10% F/20% WI	10%F/variable CI
Guinea[3]	35% F	
India	75% production state owned.	
Indonesia[4]	+51% domestic interests	10%, NOC: Pertamina
Iran		100%, NOC: National Iranian Oil Company

Table A.3 Continued.

Country	Mining participation	Oil & gas participation
Iraq		100%, NOC: Iraq National Oil Company
Kazakhstan		50%/variable CI
Kuwait		100%, NOC: Kuwait Petroleum Corporation
Kyrgyz Republic	Variable WI 15%-66%	NOC: KazMunayGas
Lesotho	25%-30% WI diamonds only[6].	
Liberia	15% F/Mittal only. Law specifies 10%	
Libya		NOC: National Oil Corporation
Mauritania*	NMC: Société Nationale Industrielle et Minière[5] (iron)	10%/variable CI
Mexico		NOC: PEMEX, variable CI/WI
Mongolia	10% Local / 50% Govt	
Namibia	Diamonds, 50%. None otherwise	
Nigeria		+50%, NOC: Nigerian National Petroleum Company
Norway		20%-56% WI, NOC: Statoil
Oman		65%
Papua New Guinea	30% WI/ Not all mines	
Pakistan	25% CI in Reqo Dik	
Peru	8% pre-tax profits share to workers.	NOC: Petroperú
Qatar		65%, NOC: Qatar Petroleum
Russia		Minority to 100%, NOC: Gazprom Neft, Rosneft
Sao Tome and Principe*		None
Saudi Arabia	NMC: Ma'aden (diversified)[7]	100%, NOC: Aramco
Sierra Leone	10% F/30% WI	
South Africa	15% HDSA[8] ownership 26% by 2014	
Sudan		
Syria		
Tanzania	25% WI diamonds only.	
Timor-Leste*		20% CI
Trinidad and Tobago		None
Turkmenistan		NOCs: Turkmenneft and Türkmengaz

Table A.3 Continued.

Country	Mining participation	Oil & gas participation
Uganda*		20% CI
United Arab Emirates		60%-100%, NOC: Emirates National Oil Company
Uzbekistan	NMCs: Navoi Metallurgical Kombinat (gold, uranium), Almalyk Metallurgical Kombinat (copper, gold)	50%, NOC: Uzbekneftegaz
Venezuala		60%-100% WI
Vietnam		15%CI, NOC: Petro Vietnam
Yemen		None
Zambia	Minority interests	
Zimbabwe	51% domestic ownership.	

*Represents potentially large medium- and long-term petroleum revenue. CI: carried interest, WI: working or paying interest, F: "free" equity, NMN: National Mining Company, NOC: National Oil Company.

Notes:

1. Mines privatised in 1996. Talk of nationalisation in 2006. Glencore smelter nationalised in 2007.
2. Renegotiated mining rights over 40 of 60 contracts between 2005-2008. Remaining terminated. In 2011, new model contract states State should have F/35% WI
3. Recently changes from 15% in 2011.
4. Indonesia changes its mining law in 2012 to limit foreign participation in mining from 80% to less than 49% interests
5. A partnership between the Mauritanian state (78.35%) and other Arab and Islamic institutions.
6. WI varies by project.
7. 50% equity traded on Saudi stock exchange.
8. HDSA refers to historically disadvantaged South Africans which includes Blacks, Coloureds and Indians.

APPENDIX B

SUMMARY OF EQUILIBRIUM CONDITIONS, OPTIMAL OWNERSHIP, AND PROPOSITIONS

Table B.1 Summary of equilibrium conditions under costless extraction.

	e^*; $R(e^*)$	λ_R^* (Shadow price of production constraint that second period production must be non-negative)	τ^*	λ_P^* (Shadow price of participation constraint requiring positive two period profits of the firm.)	Comments / constraints on equilibrium	Feasible (Y/N)
Public Ownership						
Scenario 1 (production constraint binds)	$e^* = \sqrt{a}$ $R(e^*) = 0$	$p_1 - 2\Pi p_2 \sqrt{a} > 0$	*not applicable*	*not applicable*	$p_1 > 2\Pi p_2 \sqrt{a}$; or equally $\sqrt{a} < \frac{p_1}{2\Pi p_2}$	Y
Scenario 2 (production constraint does not bind)	$e^* = \frac{p_1}{2\Pi p_2}$ $R(e^*) = a - \left(\frac{p_1}{2\Pi p_2}\right)^2$	$\lambda_R^* = 0$	*not applicable*	*not applicable*	$0 < p_1 \leq 2\Pi p_2 \sqrt{a}$; or equally $\frac{p_1}{2\Pi p_2} \leq \sqrt{a}$	Y
Private Ownership						
Scenario 1a (participation and production constraints binds)	$e^* = \sqrt{a}$ $R(e^*) = 0$	$\frac{b\left(p_1 - 2p_2\sqrt{a}\right)}{p_1\sqrt{a}}$	$\tau^* = 1 - \frac{b}{p_1\sqrt{a}}$	$\lambda_P^* = -1$	$b \in \left[0, p_1\sqrt{a}\right]$; and $p_1 > 2p_2\sqrt{a}$; or equally $\sqrt{a} < \frac{p_1}{2p_2}$	Y
Scenario 1b (participation constraint binds, production constraint does not bind)	$e^* = \frac{p_1}{2p_2}$ $R(e^*) = a - \left(\frac{p_1}{2p_2}\right)^2$	$\lambda_R^* = 0$	$\tau^* = 1 - \frac{4bp_2}{p_1^2 + 4ap_2^2}$	$\lambda_P^* = -\left(\frac{p_1^2(2-\Pi) + 4p_2^2\Pi a}{p_1^2 + 4p_2^2 a}\right)$	$b \leq p_1^2/4p_2 + ap_2$	Y

Table B.1 Continued.

	e*; R(e*)	***λ_R**** ***(Shadow price of production constraint that second period production must be non-negative)***	***τ****	***λ_P**** ***(Shadow price of participation constraint requiring positive two period profits of the firm.)***	**Comments / constraints on equilibrium**	**Feasible (Y/N)**
Private Ownership						
Scenario 2a (participation does not bind, production constraint binds)	$e^* = \sqrt{a} = 0$ $R(e^*) = 0$	∞	$\tau^* > 1 - b/p_1\sqrt{a} > -\infty$	0	*not a feasible solution*	N
Scenario 2b (participation and production constraints do not bind)	$e^* = \frac{p_1}{2p_2}$; $R(e^*) = a - \frac{p_1^2}{4p_2^2}$	$\lambda_R^* = 0$	$\tau^* > -\infty$	0	*not a feasible solution*	N

Table B.2 Summary of equilibrium conditions with differential extraction costs.

	e*; R(e*)	***λ_R**** *(Shadow price of resource constraint that second period production must be non-negative)*	***τ****	***λ_P**** *(Shadow price of participation constraint requiring positive two period profits of the firm.)*	**Comments / constraints on equilibrium**	**Feasible (Y/N)**
Public Ownership						
Scenario 1 (production constraint binds)	$e^* = \sqrt{a}$ $R(e^*) = 0$	$\lambda_R = (p_1' - c) - 2\Pi(p_2' - c)$	*not applicable*	*not applicable*	$\sqrt{a} < \frac{p_1' - c}{2\Pi(p_2' - c)}$	Y
Scenario 2 (production constraint does not bind)	$e^* = \frac{p_1' - c}{2\Pi(p_2' - c)}$ $R(e^*) = a - \left(\frac{p_1' - c}{2\Pi(p_2' - c)}\right)^2$	$\lambda_R^* = 0$	*not applicable*	*not applicable*	$\frac{p_1' - c}{2\Pi(p_2' - c)} \le \sqrt{a}$	Y
Private Ownership						
Scenario 1a (participation and production constraints bind)	$e^* = \sqrt{a}$ $R(e^*) = 0$	$\frac{b\left(p_1' - 2p_2'\sqrt{a}\right)}{p_1'\sqrt{a}}$	$\tau^* = 1 - \frac{b}{p_1'\sqrt{a}}$	$\lambda_P^* = -1$	$b \in \left[0, p_1'\sqrt{a}\right]$; and $p_1' > 2p_2'\sqrt{a}$; or equally $\sqrt{a} < \frac{p_1'}{2p_2'}$	Y
Scenario 1b (participation constraint binds, production constraint does not bind)	$e^* = \frac{p_1'}{2p_2'}$ $R(e^*) = a - \frac{p_1'^2}{4p_2'^2}$	$\lambda_R^* = 0$	$\tau^* = 1 - \frac{4bp_2'}{p_1'^2 + 4ap_2'^2}$;	$\lambda_P^* = -\left(\frac{p_1'^2(2 - \Pi) + 4p_2'^2\Pi a}{p_1'^2 + 4p_2'^2 a}\right)$	$b \le p_1'^2/4p'_2 + ap_2'$	Y

Table B.2 Continued.

	e*; R(e*)	***λ_R**** (*Shadow price of resource constraint that second period production must be non-negative*)	***τ****	***λ_P**** (*Shadow price of participation constraint requiring positive two period profits of the firm.*)	**Comments / constraints on equilibrium**	**Feasible (Y/N)**
Private Ownership						
Scenario 2a (participation does not bind, production constraint binds)	$e^* = \sqrt{a} = 0$ $R(e^*) = 0$	∞	$\tau^* > 1 - \frac{b}{p_1'\sqrt{a}} > -\infty$	0	*not a feasible solution*	N
Scenario 2b (participation and production constraint does not bind)	$e^* = \frac{p_1'}{2p_2'}$; $R(e^*) = a - \frac{p_1'^2}{4p_2'^2}$	$\lambda_R^* = 0$	$\tau^* > -\infty$	0	*not a feasible solution*	N

Table B.3 Summary of preferred form of ownership and control, conditions and constraints under costless extraction.

Domain	**Production constraint binds?**[1]	**Preferred ownership**	**Conditions**
Domain 1: $0 < \sqrt{a} \leq \frac{p_1}{2p_2}$	Yes	Model result: $\Delta U^* \geq 0$ Public where $b = \Delta U^* > C_{inst}$	$\sqrt{a} < \frac{p_1}{2p_2}$; and $b \in \left[0, p_1\sqrt{a}\right]$
Domain 2: $\frac{p_1}{2p_2} < \sqrt{a} < \frac{p_1}{2\Pi p_2}$	Varies: Binds under public ownership but not under private ownership	Model result: $\Delta U^* > 0$ Public when $\Delta U^* > C_{inst}$	$0 \leq b \leq \frac{p_1^2}{4p_2} + ap_2$
Domain 3: $\frac{p_1}{2\Pi p_2} \leq \sqrt{a}$	No.	Model result: $\Delta U^* > 0$ Public when $\Delta U^* > C_{inst}$	$0 \leq b \leq \frac{p_1^2}{4p_2} + ap_2$

Notes:
1. Participation constraint binds in all domains.

Table B.4 Summary of preferred form of ownership and control, conditions and constraints under differential extraction costs.

Domain	**Production constraint binds?**[1]	**Preferred ownership**	**Conditions**
Domain 1: $0 < \sqrt{a} \leq \frac{p_1'}{2p_2'}$	Yes	Model result: $\Delta U^* \gtreqless 0$ Public ownership where: $\Delta U^* = b - c\sqrt{a} > C_{inst}$	$\sqrt{a} < \frac{p_1'}{2p_2'}$; and $b \in \left[0, p_1'\sqrt{a}\right]$
Domain 2: $\frac{p_1'}{2p_2'} < \sqrt{a} < \frac{(p_1' - c)}{2\Pi(p_2' - c)}$	Varies: Binds under public ownership but not under private ownership	Model result: $\Delta U^* \gtreqless 0$ Public when $\Delta U^* > C_{inst}$	$0 \leq b \leq \frac{p_1'^2}{4p_2'} + ap_2'$
Domain 3: $\frac{(p_1' - c)}{2\Pi(p_2' - c)} \leq \sqrt{a}$	No	Model result $\Delta U^* \gtreqless 0$ Public when $\Delta U^* > C_{inst}$	$0 \leq b \leq \frac{p_1'^2}{4p_2'} + ap_2'$

Notes:
1. Participation constraint binds in all domains.

Table B.5 Summary of propositions under costless extraction.

Domain	Proposition		Result
Domain 1 $0 < \sqrt{a} \leq p_1/2p_2$	1	$\partial\Delta U^*/\partial b > 0$	$\partial\Delta U^*/\partial b > 0$
	2	$\partial\Delta U^*/\partial a > 0$	$\partial\Delta U^*/\partial a = 0$
	3	$\partial\Delta U^*/\partial p_1 > 0$ $\partial\Delta U^*/\partial p_2 > 0$ $\partial\Delta U^*/\partial p > 0$	$\partial\Delta U^*/\partial p_1 = 0$; $\partial\Delta U^*/\partial p_2 = 0$; and $\partial\Delta U^*/\partial p = 0$
	4	$\partial\Delta U^*/\partial\Pi < 0$	$\partial\Delta U^*/\partial\Pi = 0$
Domain 2 $p_1/2p_2 < \sqrt{a} < p_1/2\Pi p_2$	1	$\partial\Delta U^*/\partial b > 0$	$\partial\Delta U^*/\partial b > 0$
	2	$\partial\Delta U^*/\partial a > 0$	$\partial\Delta U^*/\partial a > 0$
	3	$\partial\Delta U^*/\partial p_1 > 0$ $\partial\Delta U^*/\partial p_2 > 0$ $\partial\Delta U^*/\partial p > 0$	$\partial\Delta U^*/\partial p_1 < 0$ $\partial\Delta U^*/\partial p_2 \gtreqless 0$ $\partial\Delta U^*/\partial p \gtreqless 0$
	4	$\partial\Delta U^*/\partial\Pi < 0$	$\partial\Delta U^*/\partial\Pi \gtreqless 0$
Domain 3 $p_1/2\Pi p_2 \leq \sqrt{a} < \infty$	1	$\partial\Delta U^*/\partial b > 0$	$\partial\Delta U^*/\partial b > 0$
	2	$\partial\Delta U^*/\partial a > 0$	$\partial\Delta U^*/\partial a \leq 0$
	3	$\partial\Delta U^*/\partial p_1 > 0$ $\partial\Delta U^*/\partial p_2 > 0$ $\partial\Delta U^*/\partial p > 0$	$\partial\Delta U^*/\partial p_1 \geq 0$; $\partial\Delta U^*/\partial p_2 \leq 0$; and $\partial\Delta U^*/\partial p \geq 0$.
	4	$\partial\Delta U^*/\partial\Pi < 0$	$\partial\Delta U^*/\partial\Pi \gtreqless 0$.

Table B.6 Summary of propositions with differential extraction costs and comparison with costless extraction

Domain	**Proposition**		**Results**	
			(with differential extraction costs)	(with costless extraction)
Domain 1 $0<\sqrt{a}\le\frac{p'_1}{2p'_2}$	1	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$
	2	$\partial\Delta U^*/\partial a>0$	$\partial\Delta U^*/\partial a<0$	$\partial\Delta U^*/\partial a=0$
	3	$\partial\Delta U^*/\partial p_1>0$ $\partial\Delta U^*/\partial p_2>0$ $\partial\Delta U^*/\partial p>0$	$\partial\Delta U^*/\partial p_1=0$; $\partial\Delta U^*/\partial p_2=0$; and $\partial\Delta U^*/\partial p=0$.	$\partial\Delta U^*/\partial p_1=0$; $\partial\Delta U^*/\partial p_2=0$; and $\partial\Delta U^*/\partial p=0$.
	4	$\partial\Delta U^*/\partial\Pi<0$	$\partial\Delta U^*/\partial\Pi=0$	$\partial\Delta U^*/\partial\Pi=0$
	5	$\partial\Delta U^*/\partial c<0$	$\partial\Delta U^*/\partial c<0$	Not applicable.
Domain 2 $\frac{p'_1}{2p'_2}<\sqrt{a}<\frac{p'_1}{2\Pi p'_2}$	1	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$
	2	$\partial\Delta U^*/\partial a>0$	$\partial\Delta U^*/\partial a\gtreqless0$	$\partial\Delta U^*/\partial a>0$
	3	$\partial\Delta U^*/\partial p_1>0$ $\partial\Delta U^*/\partial p_2>0$ $\partial\Delta U^*/\partial p>0$	$\partial\Delta U^*/\partial p_1<0$ $\partial\Delta U^*/\partial p_2\gtreqless0$ $\partial\Delta U^*/\partial p\gtreqless0$	$\partial\Delta U^*/\partial p_1<0$ $\partial\Delta U^*/\partial p_2\gtreqless0$ $\partial\Delta U^*/\partial p\gtreqless0$
	4	$\partial\Delta U^*/\partial\Pi<0$	$\partial\Delta U^*/\partial\Pi\le0$	$\partial\Delta U^*/\partial\Pi\le0$
	5	$\partial\Delta U^*/\partial c<0$	$\partial\Delta U^*/\partial c<0$	Not applicable.
Domain 3 $\frac{p'_1}{2\Pi p'_2}\le\sqrt{a}<\infty$	1	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$	$\partial\Delta U^*/\partial b>0$
	2	$\partial\Delta U^*/\partial a>0$	$\partial\Delta U^*/\partial a\le0$	$\partial\Delta U^*/\partial a\le0$
	3	$\partial\Delta U^*/\partial p_1>0$ $\partial\Delta U^*/\partial p_2>0$ $\partial\Delta U^*/\partial p>0$	$\partial\Delta U^*/\partial p_1\gtreqless0$; $\partial\Delta U^*/\partial p_2\gtreqless0$; and $\partial\Delta U^*/\partial p\ge0$.	$\partial\Delta U^*/\partial p_1\ge0$; $\partial\Delta U^*/\partial p_2\le0$; and $\partial\Delta U^*/\partial p\ge0$.
	4	$\partial\Delta U^*/\partial\Pi<0$	$\partial\Delta U^*/\partial\Pi\gtreqless0$	$\partial\Delta U^*/\partial\Pi\gtreqless0$
	5	$\partial\Delta U^*/\partial c<0$	$\partial\Delta U^*/\partial c<0$	Not applicable.

APPENDIX C

CASE STUDY DATA

Table C.1 Botswana election results over 1965 to 2009. (African Elections Database 2012)

Summary of Botswana National Assembly election results (1965-2009)

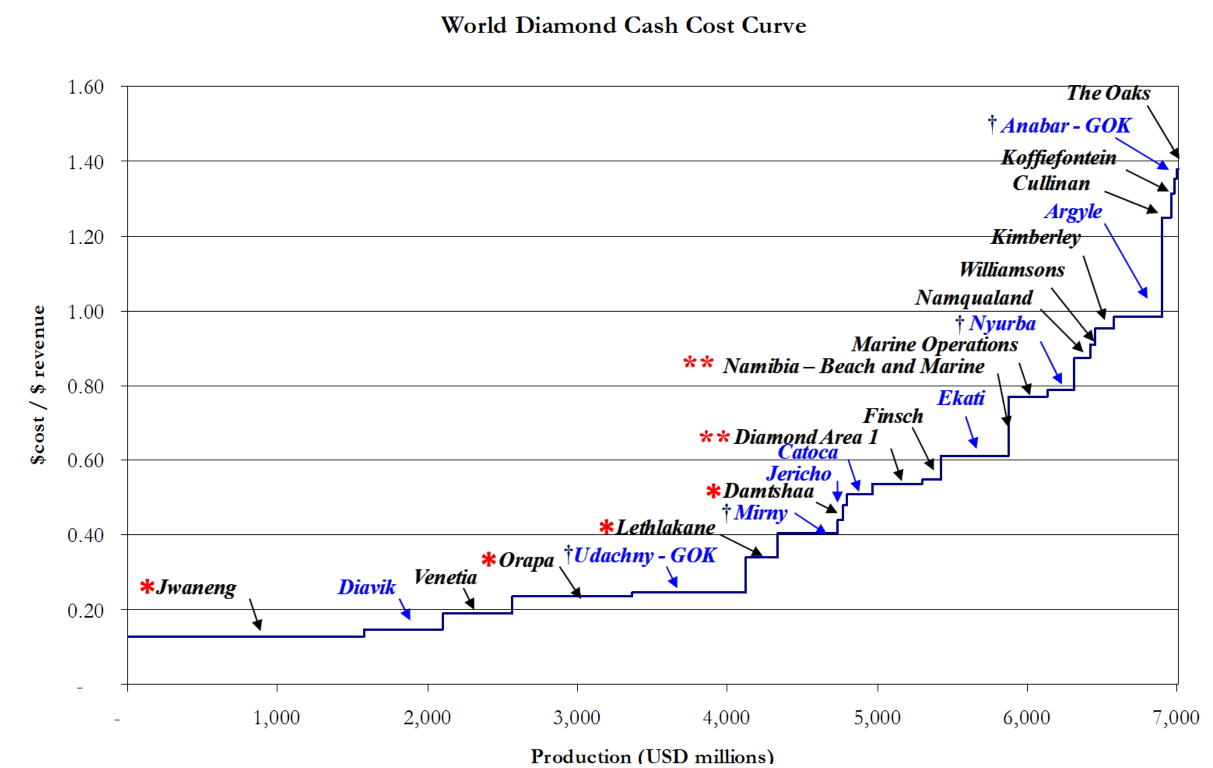
Percent of popular votes by party

	1965	1969	1974	1979	1984	1989	1994	1999	2004	2009
BDP	80.4%	68.4%	no data	75.4%	68.0%	64.8%	53.1%	57.2%	51.7%	53.3%
BNF	n/a	13.5%	no data	13.1%	20.4%	26.9%	37.7%	26.0%	26.1%	21.9%
BPP	14.2%	12.1%	no data	7.5%	6.6%	4.4%	4.6%	n/a	1.9%	1.4%
BIP/IFP	4.6%	0.8%	no data	3.8%	3.2%	2.5%	2.9%	n/a	n/a	n/a
BCP	n/a	n/a	no data	n/a	n/a	n/a	n/a	11.9%	16.6%	19.2%
Others	0.8%	5.2%	no data	0.2%	1.8%	1.4%	1.7%	5.0%	3.7%	4.3%
Total	100%	100%	no data	100%	100%	100%	100%	100%	100%	100%

Number of parliamentary seats won by party

	1965	1969	1974	1979	1984	1989	1994	1999	2004	2009
BDP	28	24	27	29	29	31	27	33	44	45
BNF	n/a	3	2	2	4	3	13	6	12	6
BPP	3	3	2	1	1	0	0	n/a	0	0
BIP/IFP	0	1	1	0	0	0	0	0	0	
BCP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	1	4
Others	0	0	0	0	0	0	0	0	0	2
Total	31	31	32	32	34	34	40	40	57	57
Share BDP	*90%*	*77%*	*84%*	*91%*	*85%*	*91%*	*68%*	*83%*	*77%*	*79%*

Notes: BCP - Botswana Congress Party, BDP - Botswana Democratic Party/Bechuanaland Democratic Party (right-wing, conservative), BIP - Botswana Independence Party, BNF - Botswana National Front (left-wing, social-democratic), BPP - Botswana People's Party/Bechuanaland People's Party (centrist), IFP - Independence Freedom Party.



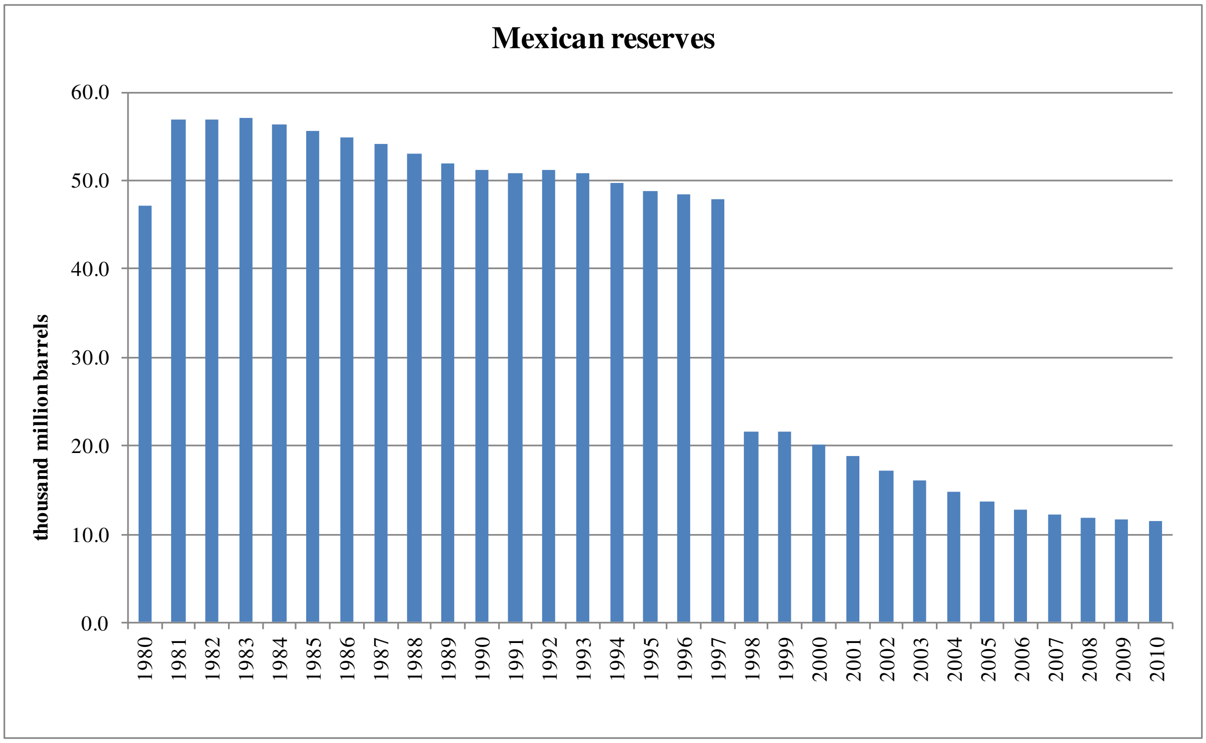
Notes:

* Represents a mine in Botswana owned by Debswana

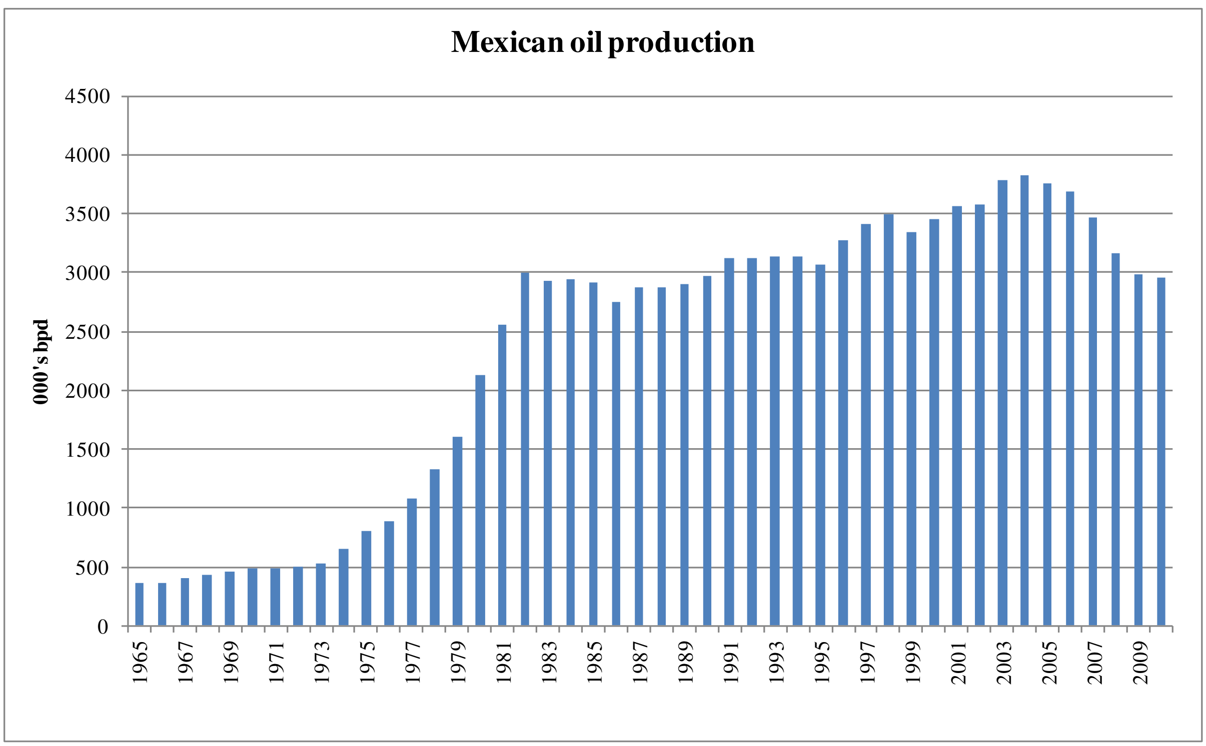
** Represents a mine in Namibia owned by Namdeb.

† Represents a group of mines in Russia owed by Alrosa but controlled by the Russian State Treasury.

Figure C.1 Global diamond industry cash cost curve. (Lokanc 2005)



Panel A – Mexican proved oil reserves. (thousand million barrels)



Panel B – Mexican daily oil production (000's bpd)

Figure C.2 Mexican reserves (1980-2010) and oil production (1971-2010). (BP 2012)

Table C.2 Mexican presidential election results from 2000 to 2012. (Alvarez-Rivera 2015)

2000 - Election information	**2000**	
Voters	37,601,618	
Invalid Ballots	788,157	2.1%
Valid Votes	36,813,461	97.9%
Candidate (Party)		
Alianza por el Cambio (PAN, PVEM)	15,989,636	42.5%
Partido Revolucionaroi Institucional	13,579,718	36.1%
Alianza por Mexico (PRD, PT, PAS,C, PSN)	6,256,780	16.6%
Democracia Social, Partido Politico Nacional	592,381	1.6%
Partido de Centro Democratico	206,589	0.5%
Partido Autentico de la Revolucion Mexicana	156,896	0.4%
Others	31,461	0.1%

2006 - Election information	**2006**	
Voters	41,557,430	
Invalid Ballots	900,373	2.2%
Valid Votes	40,657,057	97.8%
Candidate (Party)		
Partido Accion Nacional (PAN)	14,916,927	35.9%
Coalicion por el Bien de Todos (PRD, PT, C)	14,683,096	35.3%
Alanza por Mexico (PRI, PVEM)	9,237,000	22.2%
Partido Alternativa Socialdemocrata Campesina (PASC)	1,124,280	2.7%
Partido Nueva Alianza (PANAL)	397,550	1.0%
Others	298,204	0.7%

Table C.2 Continued.

2012 - Election information	2012	
Voters	50,323,153	
Invalid Ballots	1,241,154	2.5%
Valid Votes	49,081,999	97.5%
Candidate (Party)		
Compromiso port Mexico (PRI, PVEM)	19,226,784	38.2%
Movimiento Progresista (PRD, PT, MC)	15,896,999	31.6%
Partido Accion Nacional (PAN)	12,786,647	25.4%
Partido Nueva Alianza (PANAL)	1,150,662	2.3%
Others	20,907	0.0%

APPENDIX D

SUMMARY OF LUONG AND WEINTHAL (2010) ANALYSIS

Table D.1 Summary analysis of natural resource ownership structures and resulting institutional development. (Luong and Weinthal 2010)

Ownership Structure[1]	**State ownership with control (S_1)**	**Private domestic ownership (P_1)**	**State ownership without control (S_2)**		**Private foreign ownership (P_2)**		
Countries adopting ownership structure following independence	Turkmenistan and Uzbekistan	Russia	Azerbaijan		Kazakhstan		
Direct claimants	Governing elites and bureaucrats of SOEs	Domestic private owners	Foreign investors and governing elites		Foreign investors		
Indirect claimants	Domestic population	Governing elites and domestic population					
General trends over time and by ownership structure							
Time period	**1900-2005**	**1900-2005**	**1900-1960**	**1960-1990**	**1900-1960**	**1960-1990**	**1990-2005**
Transaction costs[2]	Low	High	Negligible[10]		Negligible[10]		
Societal expectations[3]	High	Low	Low (State & FI)	High (State & FI)	Low (State & FI)	High (FI) Low (State)	High (FI)
Power relations (favoured)	Governing elites and bureaucrats of SOEs	DPO, governing elites and domestic population	FI	State	FI	State	UKN
Fiscal regimes	Weak[4]	Strong[5]	Fixed royalty	Fixed royalty and PSA	Fixed royalty	Fixed royalty and PSA	Fixed royalty, PSA and CSR
Effect of resource booms[11]	*Curse*[6]	*Blessing*[6]	UKN [6,7]	*Curse*[6,8]	UKN [6,7]	*Curse*[6,8]	varies[6,9]

Notes:

FI - Foreign Investors, **DPO** - Domestic Private Owners, **CSR** - Corporate Social Responsibility, **SOE** - State Owned Enterprise, **FSU** - Former Soviet Union, **PSA** – Production / Profit Sharing Agreement, **UKN** – Unknown

1. Ownership structure relates to control in the following manner: under S_1, the state has >50% voting power while under S_2 the state has >50% of voting power yet operational control is granted to foreign investors. Under P_1, >50% of the voting shares are held and controlled by domestic private owners while under P_2 >50% of the voting shares are held and controlled by foreign investors.
2. Transaction costs relate in particular to the presence of information asymmetries between the state and the developer of the natural resource. High information asymmetries, yields high transaction costs and vice versa. Under P_1, transaction costs are high due to the highly transparent nature of the fiscal regime despite information asymmetries that may exist regarding the quality of the natural resource and efficiency of operations. Thus a new equilibrium ownership structure may require some form of "shock" (such as a price boom or bust) to justify a change in the equilibrium.
3. Societal expectations refer to the expectations for widespread dissemination of resource benefits. Amongst other things, these transfers may include subsidised energy or local investments in infrastructure.
4. Due to low transaction costs and high societal expectations, politicians and bureaucrats of SOEs have mutual incentives to hide information from the public, which encourages implicit bargaining. As a result, unstable, indirect and implicit taxation occurs across sectors while government expenditure undermines budgetary stability and transparency. Government expenditure may take the form of broad and visible transfers such as fuel subsidies or "white elephant" projects described in Robinson and Torvik (2005).
5. Strong fiscal regimes refer to stable, broad-based, direct and explicit taxation. Government expenditure is characterised by budgetary stability (partly through the use of stabilisation funds) and transparency.
6. In mineral rich states adopting S_1, weak fiscal regimes are both more likely to emerge and be reinforced by booms and busts. Conversely, mineral rich states that adopt P_1 are more likely to have strong fiscal regimes emerge and be reinforced by booms and busts. Due to the divergence in societal expectations under S_1 and P_1, a boom would increase pressure under S_1 for increased government spending since society would expect spending to be commensurate with income. This may in turn exacerbate the budgetary reliance on petroleum rents in countries adopting S_1 while facilitating broad based tax reform in countries adopting P_1. Furthermore, firms under P_1 and P_2 are more likely to undergo restructuring in bust periods than S_1, who may face pressure to maintain employment levels.
7. Despite power relations favouring the FI due to the structure of the oil and gas industry in the period of 1900-1960, oil-producing states were relatively sheltered from booms and busts. As a result, cyclicity did not aggravate expenditure; however, due to the low share of revenues received it is difficult to comment on whether booms would result in a "blessing" or "curse".
8. Because of the power relations favouring the state under S_2 and P_2 in the period of 1960-1990 as well as the high societal expectations under S_2, FIs became a source of unfettered taxation and state spending resulting in budgetary instability. This hampers the creation of strong fiscal institutions and contributes towards a resource curse.

9. A mix of power relations can result in either a stable or unstable government budget. As a result, whether a boom contributes to a resource curse or blessing varies by case.
10. Transaction costs under S_2 and P_2 have been rendered negligible due to the model contract, which was viewed by both FIs and government elites as the appropriate template for negotiations. This is the case despite the terms of the model contract evolving significantly over time and is reinforced by the fact that FIs could unilaterally enforce the contact in the first half of the 20th century.
11. Luong and Weinthal (2010) do not go as far as to classify the effect of booms as being a "curse" or "blessing". Instead, they limit their commentary to whether the effect of a boom or bust would weaken or strengthen fiscal institutions.