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Essays in Political Economy and Resource Economics
(A Macroeconomic Perspective)

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"We must always tell what we see.
Above all, and this is more difficult,
we must always see what we see."
—Charles Péguy

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Mauricio Rodríguez A.
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Chapter 1

INTRODUCTION

Market and non-market exchanges between economic agents are framed within a system of institutions, i.e., rules. These rules, which for instance delimit the set of choices of individuals, constitute a fundamental determinant of the potential efficiency of economic exchanges. As opposed to other constraints, for example those deriving from the laws of nature, institutions are humanly devised (North, 1991) and therefore, are endogenous to the economic system. In other words, being a human construct, institutions must have a traceable origin, they ought to evolve over time, and their adequacy should depend on the specific characteristics of the economic environment. For example, while a set of informal rules may be sufficient to regulate interactions in close-knit communities, the same set may be far less effective in large societies were formal rules and enforcement are likely to be necessary.

Given their importance in determining the efficiency of exchanges, from a long run perspective, institutions play a—well-established—fundamental role in the economic progress of societies. Nevertheless, it is not uncommon that the institutions that emerge and persist over time are not the most efficiency-promoting ones. Considering the prevalence of imperfect institutions, together with their endogenous nature and fundamental role for economic development, the four chapters composing this dissertation revolve around two central questions: 1. Why do inefficient institutions emerge and persist over time? And, 2. What are the dynamic consequences of inefficient institutions?

Chapters 2 and 3 investigate these two central questions using political economy models in which economic agents are endowed with unequal access to economic resources and political power and therefore, have unequal influence in the shaping of institutions. The first of these two chapters, focuses on the role of public law enforcement in the protection of property rights. Chapter 3 concentrates on the cohesiveness of institutions, and its effect on the the inter-temporal redistribution of economic rents. Chapters 3 and 4 direct their attention to the dynamic consequences of inefficient institutions. Specifically, these chapters study the role of imperfectly protected, yet evolving, property rights in the dynamic management of non-renewable natural resources.

The protection of property rights is a recurrent theme throughout this dissertation. At a fundamental level, the strength of these rights shapes the incentives of individuals to engage in economic activities such as producing, investing, preserving natural resources, and rent-seeking. For instance, when property rights are weak—i.e., weakly protected—individuals face higher uncertainty about the return of their productive activities and investments. As a consequence, under weak property rights, economic agents have stronger incentives to divert otherwise productive resources into unproductive activities, such as protection or appropriation. From a static perspective, this means that well-defined and protected property rights enhance economic efficiency. From a dynamic point of view, strong property rights, through the enhanced incentives to produce and invest, are fundamental for industrial takeoff and economic development in the long run.[1]

Chapter 2 investigates the endogenous evolution of the public provision of law enforcement during the process of economic development. The public provision of law enforcement is a key determinant of the effective protection of property rights. If the provision of law enforcement is insufficient, the expected return of an investment will be lower because of the higher risk that the returns to the investment cannot be accrued. Moreover, with private protective efforts acting as a substitute for public enforcement, the inadequate provision of public enforcement may lead to the diversion of productive resources into protecting activities, reducing the net return of the investment.[2] Chapter 2 is motivated by novel evidence on the pace of emergence of the first civil police forces, in 19th century England. This historical evidence establishes that higher inequality in the access to agricultural land is negatively associated to the emergence of the police forces. Moreover, the emergence of these police forces is positively associated to the surge of a class of wealthy landless individuals. In this chapter I put forward a theory that explains these empirical findings. This theory shows that the potential conflict of interests emerging during the process of structural transformation may hamper the provision of law enforcement. Specifically, the traditional landed elite may lose from the provision of law enforcement, and oppose to it, because it enhances the efficiency of the competing urban sector. Thus,

[1] Acemoglu, Johnson, and Robinson (2002, 2005a); Demsetz (1967); Libecap (1986); North (1991); A. Smith and Wight (2007).

[2] Auerbach and Azariadis (2015); Besley and Ghatak (2010); Clotfelter (1977); Demsetz (1966); Polinsky and Shavell (2007); Shavell (1991).

by blocking the emergence of law enforcement, the landed agents can hinder the development of the urban economy. Constraining the provision of law enforcement may be optimal from the individual perspective of a landed individual, however, an insufficient provision of law enforcement is detrimental for the aggregate economic activity both in the short and the long run, when the economy may end up trapped in an institutional trap with low provision of law enforcement and low aggregate output.

Chapter 3 studies the under-provision of growth-promoting public services—e.g., law enforcement, education, and health—and the persistence of non-cohesive institutions in the presence of high fiscal revenues. This chapter empirically establishes that in economies with weak institutions, a higher availability of public revenues (e.g., rents from natural resources) does not translate into an improved provision of public services. In fact, when public revenues are sufficiently high, an increase in revenues reduces the provision of public services. This finding is underpinned with a political economy model with two asymmetric groups: incumbent and opposition. According to the theory developed in this chapter, in the absence of a democratic contest, ousting the incumbent, whom is in control of the public apparatus, is costly for the opposition. Given that the opposition's income increases with the availability of productive public services, under-providing these services makes it harder for the opposition to organize a successful challenge. Therefore, in economies with weak (i.e., non-cohesive) institutions the under-provision of productive public services, in combination with expenditure in repression, can be used by the incumbent as part of the defense strategy to retain political power. When institutions are non-cohesive, higher public revenues translate into higher incentives to control political power. Consequently, the need for under-providing public services is exacerbated, and a negative relationship between public revenues and provision of public services arises. Furthermore, when institutions are treated as an endogenous variable, the model shows that an increase in public revenues may lead to an institutional improvement. Instead of following an under-provision and repression strategy, the incumbent can resort to higher cohesiveness, that is, credibly committing to a better redistribution of rents in the future, as a strategy to avert the political challenge by the opposition. The results show that at intermediate levels of public revenues the incumbent prefers the cohesiveness strategy over the under-provision and repression one. However, when revenues increase above a certain threshold, institutions remain non-cohesive, and the under-provision and repression strategy prevails in equilibrium.

The last two chapters completing the dissertation investigate the effect of weak institutions on the optimal dynamic management of non-renewable natural resources.

Specifically, these two chapters study how the imperfect protection of property rights affects the pace at which non-renewable resources are depleted. A key element in both chapters is the endogeneity of the strength of property rights protection. When the protection of property rights is endogenous, the legitimate owner of the resource can undertake actions to mitigate the weak property rights problem. In other words, in these two chapters the (endogenously) insecure property rights shape the strategic interactions between the legitimate resource owner and the illegitimate users.

Chapter 4 is motivated by the observation that the strength of property rights protection tends to be positively correlated across different types of property. In the standard resource extraction setting there are two types of property: wealth in the ground (i.e., the remaining stock of the resource) and income above the ground (i.e., the flow of revenues from exploiting the resource). The theory developed in this chapter assumes that the rights over these two types of property may be weakly protected and that the level of protection evolves over time, along the two dimensions. That is, wealth in the ground and income above it are imperfectly protected because of the presence of trespassing and theft respectively, and these imperfections may vanish over time. On the one hand, trespassing generates incentives to accelerate the pace of depletion of the resource. On the other hand, theft creates incentives to slow it down. The results of this chapter indicate that when theft only affects the legitimate owner (and not the trespassers), in the presence of the two imperfections the resource is over-extracted relative to the social optimum. However, when theft affects both the legitimate owner and the trespasser, the intensity of theft determines whether there is over- or under-extraction in equilibrium. Specifically, if the intensity of theft is low the resource is over-extracted, while if the theft intensity is high the resource is under-extracted. On top of this, the evolution of institutions affects the inter-temporal trade-off faced by the agents: they will exhibit a more conservative behavior when they expect a favorable institutional change. That is, they prefer to delay extraction for periods with stronger protection of their individual property rights.

Chapter 5 investigates the effect of endogenous expropriations on the management of a non-renewable resource. This chapter focuses on the interaction between the legitimate owner of a non-renewable resource and a potential expropriator, particularly on how this interaction is affected by changes in the strength of property rights protection. The key argument in this chapter is that expropriations follow from a cost benefit analysis by the expropriator. Consequently, the legitimate owner can strategically mitigate the risk of expropriation by reducing the value of the asset(s) at risk (i.e., the non-renewable resource). The legitimate owner has two tools at hand to reduce the value of the resource: run down the stock of the resource or under-invest in complementary capital (i.e., install a low extraction capacity). When property rights are weak, i.e., when the cost of expropriation is low, the resource owner over-invests in extraction capacity and the resource is depleted too fast relative to the social optimum. On the contrary, when property rights are strong, i.e., the cost of expropriation is high, there is under-investment in extraction capacity, and the risk of expropriation actually entails under-extraction of the resource.

The results of this dissertation highlight the importance of institutions for economic growth, the provision of development-promoting public services, and the efficient use of non-renewable natural resources. Furthermore, the results emphasize the relevance of the feedback between the dynamic evolution of institutions and the process of economic development. The remainder of this dissertation is organized in four stand-alone chapters, each with its own introduction, conclusions, figures, tables, and appendices.

Chapter 2

LAND, CAPITAL, AND THE EMERGENCE OF PUBLIC PROTECTION OF PROPERTY RIGHTS

Abstract

Up to the 18th century, law enforcement in England, the birthplace of modern policing, was largely based on private efforts. The emergence of public law enforcement coincided with the process of industrialization. This chapter provides a theory of this joint development. In the early stages of modern economic development, large landowners control the political process, and the economy is trapped in a regime with no public law enforcement. In the absence of public enforcement, the protection of property rights is fully determined by private efforts. Later in the development process, when the urban classes gain access to political rights, a regime with public provision of law enforcement is implemented. As public law enforcement is more effective in preventing crime, the allocative efficiency of the economy is enhanced. Public law enforcement emerges sooner in communities with a lower land inequality and a larger fraction of wealthy landless individuals (capitalists). This result matches two empirical regularities that emerge from 19th century data on occupations and local police forces in England. First, local police forces emerged earlier in boroughs where access to agricultural land was more equal. Second, police forces emerged earlier and were larger in boroughs with a larger capitalist class.

2.1 Introduction

The adequate protection of property rights plays a central role in shaping the incentives of economic agents to accumulate and invest. Precisely because of this, well protected property rights have been deemed as a necessary condition for industrial takeoff and development in the long run.[1] A key determinant of the effective protection of these rights is the public provision of law enforcement. If the provision of law enforcement is insufficient, the expected return of an investment will be lower because of the higher risk that this return cannot be fully accrued. Moreover, with private protective efforts acting as a substitute for public enforcement, the inadequate provision of enforcement may lead to the diversion of otherwise productive private resources into protection, reducing the net return of the investment.[2]

But how does the public provision of law enforcement originate? Rather than being exogenous to the development process, the need and support for the provision of public enforcement of property rights has evolved over the course of it. This was particularly the case with the rapid transformation of society during the process of industrialization in the 18th and 19th centuries. This process supported the transition from an agricultural and largely rural society to a manufacturing-oriented urbanized one. It also implied the emergence of a new industrialist class, with the capacity to contest the political clout of the traditional landowning elite.

The new organization of society and production brought about unprecedented needs. Due to the complementarity between human and physical capital in the industrial processes, the eve of industrialization witnessed an increasing need for public education (Galor & Moav, 2006). While, the rapid pace of urbanization during the 19th century had a significant impact on urban mortality, which called for an improved sanitation infrastructure (Lizzeri & Persico, 2004). Moreover, the largely urban nature of the crimes against property and the expansion of the urban centers increased the need for the public provision of law enforcement (Shelley, 1981; Allen & Barzel, 2009). This last aspect, the public provision of law enforcement, is the focus of this chapter. "After the onset of industrialization in England, violent offenses ceded permanently their once preeminent position to the increasingly common property crimes . . . the mature years of industrialization were characterized by fewer violent offenses and more frequent though less threatening crimes against property" (Shelley, 1981, p. 33).

The rapid process of urbanization lead to the demise of the traditional system of

[1] Acemoglu et al. (2002, 2005a); Demsetz (1967); Libecap (1986); North (1991); A. Smith and Wight (2007).

[2] Auerbach and Azariadis (2015); Besley and Ghatak (2010); Clotfelter (1977); Demsetz (1966); Polinsky and Shavell (2007); Shavell (1991).

watches based on communal liability and private efforts, devised to keep law and order in close-knit communities. As a consequence, the 19th century witnessed the creation of civilian police forces devoted to the *prevention* of crime, the quintessential element of public law enforcement, in Western Europe and the United States (Archbold, 2012; Emsley, 1999; Monkkonen, 1992).[3] In England, for instance, the first major metropolitan force was established in London in 1829, by means of the Metropolitan Police Act sponsored by Sir Robert Peel.[4,5] "The London Metropolitan Police Department . . . would become a model for future police departments in Great Britain, the British Commonwealth, and the United States".[6] Further reforms would follow in 1835 requiring the municipal boroughs to establish a police force based on the metropolitan model, in 1839 regulating the policing of the rural areas, and finally in 1856 requiring the presence of police forces in all the jurisdictions.

This chapter contributes to the political economy of development by explaining the emergence of the public provision of law enforcement, during the process of economic development. From the empirical perspective, this chapter contributes to the existent literature by documenting the evolution of a specific aspect of public law enforcement: the police forces. In particular, the empirical evidence documents the relationship between the emergence and size of early municipal police forces in England and the occupational profile of the local population. Using occupational data from the 1831 census and records of the existence of municipal police forces, the evidence shows that there is a negative relationship between the emergence and size of municipal police forces and the local inequality in access to agricultural land. The evidence also unveils a positive relationship between the emergence of a class of wealthy landless (non-rural) individuals, and the existence and size of the early municipal police forces.

The theory presented here features a model of structural transformation with two sectors, rural and urban, and agents with heterogeneous land endowments. Property rights in the urban sector are imperfectly protected; that is, output is exposed to theft. The effective level of protection against theft depends both on publicly provided law enforcement and private protective efforts, and both are endogenously determined. During the development process, the evolution of the provision of public law enforcement is determined by the aggregation of individual preferences through a voting mechanism. In order to protect their property against theft, firms in the ur-

[3]Military police forces, like the French Gendarmerie, date back to pre-industrial times. Yet, because of their military origin, these forces had more of an influence on maintaining order than on preventing crimes against property.

[4]Home Secretary at the time and after whom the police officers are nicknamed "bobbies".

[5]The first professional police force established in London was the Thames River Police, dating from 1798 (Police, 2015).

[6]Police (2015).

ban sector need to spend resources on private protection. This protective effort is complemented by the public provision of law enforcement. While the urban sector benefits from a better provision of law enforcement, the rural sector does not directly gain from it. Better protection of property rights raises the marginal productivity of all the factors involved in the production by the urban sector. In turn, this implies that an improvement in the protection of property in the urban sector increases the cost of producing in the rural sector. Accordingly, the provision of law enforcement goes through two distinct phases during the development process. Initially, when the majority of the enfranchised population consists of individuals that mainly derive their income from the return to land (i.e., large landowners), a low provision of law enforcement prevails. As a consequence, the productivity of the urban sector is low and capital accumulation is hampered. Later in the development process, once the individuals with small or no landholdings gain access to political rights, a higher level of law enforcement emerges.

This chapter is organized in 2.7 sections including this introduction. Section 2.2 reviews the literature on property rights protection and its endogenous evolution. Section 2.3 is devoted to the empirical evidence exploring the relationship between the local occupational profile and the emergence of the municipal police forces in 19th century England. Section 2.4 presents the theoretical setup: an economy with two sectors (rural and urban) and imperfect protection of property rights. In this section the static features of the equilibrium are characterized. Section 2.5 is devoted to the dynamic analysis of the model. Section 2.6 shows how during the process of development the economy can transition from a regime with no public provision of law enforcement to a regime where law enforcement is publicly provided. In this section the main theoretical results are discussed in light of the empirical evidence. Finally, section 2.7 presents some concluding remarks.

2.2 Background

From a broad perspective this chapter belongs to the literature on the importance of institutions in general, and property rights protection in particular, as determinants of accumulation (Besley, 1995; Johnson, McMillan, & Woodruff, 2002) and development in the long run (e.g. Acemoglu, Johnson, & Robinson, 2001; Acemoglu et al., 2002, 2005a; Acemoglu, Johnson, & Robinson, 2005b; Engerman & Sokoloff, 2002; Hall & Jones, 1999; Rodrik, Subramanian, & Trebbi, 2004). From a closer point of view, this chapter is part of the literature dealing with the evolution of institutions of property rights protection. In this branch, the competition for the appropriation of resources by force, on top of the market mechanisms, is at the core of the discussion.[7] Grossman and Kim (1996) provide a pioneering theoretical contribution on the interaction between property protection and economic growth through capital accumulation. Further contributions have explored the effects of rent-seeking when property is imperfectly protected in dynamic models. Specifically, when final output (Gradstein, 2004) or productive inputs (Gradstein, 2008; Leonard & Long, 2012) are subject to rent-seeking, and better property protection (financed through taxation) reduces the incentives to engage in rent-seeking, path-dependencies may arise in the form of traps with low protection of property rights and low levels of aggregate capital. Gonzalez (2007) exploits the second-best nature of an environment in which final output is imperfectly protected to show that, a priori welfare enhancing policies may actually have a detrimental impact on welfare; he finds that this is the case with piecemeal improvements in protection, as well as with increments in capital productivity. Gonzalez (2005) uses the presence of rent-seeking as a potential explanation for slower technology adoption and technological backwardness, while Lloyd-Ellis and Marceau (2003) show that rent-seeking and credit constraints can exacerbate each others' negative impact on efficiency and accumulation. However, none of these papers studies the role of unprotected property and the emergence of publicly provided property protection in an economy undergoing structural change.

The common element in this literature, is that property rights protection is a tool to reduce rent-seeking activities. When looking at the specific problem of law enforcement (i.e., public provision of property protection), the enforceability of contracts has received particular attention (Aboal, Noya, & Rius, 2014; Haggard & Tiede, 2011). For instance, Besley and Persson (2009), Besley (2011), and Besley and Persson (2011a) study the endogenous evolution of the public capacity to enforce contracts. These papers examine the incentives of incumbent governments to invest in the state's fiscal and legal capacity; the former determines the ability to raise revenues and finance public goods, while the latter determines the capacity to enforce contracts. Better contract enforcement, which may for example improve the efficiency of credit markets (Besley & Ghatak, 2010), fosters private productivity. But building up enforcement capacity is costly, and may not always be in the best interest of the group in control of policy making.

This chapter focuses on a different role of law enforcement, namely protection against theft.[8] As such, law enforcement and private protective efforts are substi-

[7]See Levine (2005) for an overview on whether the current differences in the levels of property rights protection observed across countries originate in their legal tradition or their factor endowments.

[8]This view on the role of law enforcement as an element of protection against theft is also taken by Roland and Verdier (2003). However, their study revolves around the coordination problems that may arise in the provision of law enforcement, but it does not examine the interaction of this provision, as a policy choice, with the accumulation of wealth and the transformation of economic activity during the process of development.

tutes in the fight against theft. However, publicly provided law enforcement can endogenously improve the efficiency of the system by acting as a true crime deterrent.

Finally, given the dual (rural and urban) structure of the economy studied here, this chapter also relates to a long tradition of contributions on the role of land and agriculture in the process of economic development and structural transformation (e.g. Bertocchi, 2006; Caselli & Coleman II, 2001; Drazen & Eckstein, 1988; Fergusson, 2013; Galor, Moav, & Vollrath, 2009; Laitner, 2000; W. A. Lewis, 1954). Against the background of history, the economic interests of the groups with the power (i.e., political rights) to determine institutions, such as those of property rights protection, are pivotal for the path that these institutions follow over time (e.g. Galor et al., 2009; Falkinger & Grossmann, 2005). Moreover, the preferred institutions of these groups evolve during the process of development. It is precisely because of these dynamics that the emergence of public law enforcement, understood here as a fundamental element in the protection of property rights, is determined within the development process as the economy transforms from a rural to an urban based one.

2.3 Evidence

The first half of the 19th century witnessed the emergence of the public police forces in England. This supposed the demise of a centuries old law enforcement system based on private efforts and focused on crime detection, by a publicly organized one focused on the prevention of crime. The public police became a quintessential element in the maintenance of law and order and the protection of property. This section documents the relationship between the emergence of publicly paid police forces in the municipal boroughs of England and the occupational profile of the local populations. More specifically, this section explores the relationship between the inequality in land tenancy, as measured by the number of landless agricultural workers relative to the number of agricultural tenants, and the emergence and size of the public police forces. It also looks at the relationship between the size and existence of these early forces and the relative number of "Capitalists" in a municipality, where the latter can be interpreted as evidence of the existence of a wealthy landless class.

2.3.1 Historical context - England in the 19th century: from private to public protection of property rights

England in the early 19th century constitutes an indisputable benchmark for a society in the process of structural transformation. On the one hand, economic activity was shifting away from rural areas to the urban centers. In 1801 the rural population in England and Wales accounted for 66% of the total, by 1901 it had declined to 22% (Crouzet, 2013). This transformation came along with the emergence of a new industrialist class with the economic means, and motives, to challenge the traditional landed elite. On the other hand, at the beginning of the century law enforcement in England transitioned from being privately provided into the system of public provision that we know today.[9]

For over five centuries the Statute of Winchester (1285) regulated the provision of law enforcement in England (Allen & Barzel, 2009). The main principle behind the Statute was that of the communal liability, by which private citizens were in charge of keeping the law and order in their own local communities. The embodiment of this principle was the system the wards and watches, under which "all men of the town were on the roster to volunteer their turn and all were privately armed" (Allen & Barzel, 2009, p. 558). The watches were not so much an instrument of crime prevention as one of detection. Upon spotting a crime, the alarm ("hue and cry") would be raised, and all the male adults of the town were expected to join the pursuit of a fleeing criminal (Fisher & Lab, 2010; Sklansky, 1998). Overseeing the watchmen were the parish constables, a sort of "police chief" in the sense that he was the ultimate responsible for the watch and the apprehension of criminals (Langeluddecke, 2007). Because this was an unpaid position and kept individuals away from their trades, the constable post is often times portrayed as a rather unpopular one. It was not uncommon for affluent individuals designated to the post to, at their own expense, hire deputies to execute the constable's tasks.

With towns growing in size, and the sense of a "local" community getting diluted, the system of unpaid watchmen and constables came under pressure. By the 18th century, different private enforcement services emerged to make up for the absence of public provision of law enforcement, and the insufficiency of the unpaid system (Emsley, 2014).[10] As the traditional system crumbled, rewards for the recovery of stolen property became widespread and with them the phenomenon of the thief-takers sprawled. These were individuals and organizations in the business of recovering stolen goods or collecting information that would facilitate the recovery of property (Mcmullan, 1995). Simultaneously there was a "private commercialization" of the constable's tasks. For instance, the constables and their deputies would

[9] As seen in Hart (1956) the transition from private to public provision occurred over the course of two and a half decades.

[10] Next to the proliferation of crimes against property the rapid societal change, that England underwent during the 18th and 19th century, created room for clashes between the traditional elite and the emerging classes. Often times this materialized in the form of large-scale public disorder as, for instance, the so-called Swing riots that preceded the Great Reform Act of 1832 (Aidt & Franck, 2015).

act as thief-takers and charge for the devolution of stolen goods to their legitimate owners. Moreover, "a victim of crime who wanted a constable to undertake any substantial effort to apprehend the perpetrator was expected to pay the expenses of doing so" (Friedman, 1995, pp. 575-576), and so the constables were often times closer to a private detective than to a public servant (Sklansky, 1998).

Another manifestation of the private nature of law enforcement were the associations for the prosecution of felons (Koyama, 2012, 2014) that emerged in the last decades of the 18th century.[11] In exchange for a subscription fee, the members of these associations were insured against the costs of prosecution, which were borne by the victims of crime. By reducing the probability of a crime going unpunished, these associations served as crime deterrents. Yet, the historical accounts indicate that these associations had little participation in preemptive policing activities (Koyama, 2012). Due to the public good nature of crime deterrence, the prosecution associations naturally faced free riding problems, and so they were a better fit for smaller close-knit communities. With the rapid increase in the British population, specially in the urban centers, the associations became a less effective solution to the provision of law enforcement, putting into evidence the need for establishing publicly organized police forces (Fisher & Lab, 2010).[12]

A first major step in this direction was the Metropolitan Police Act of 1829, sponsored by the Home Secretary Robert Peel. The Act provided for the creation of a professional police in the metropolis, upon which years later the municipal police forces of the rest of England were to be modeled. This Act has the historical weight of being considered the birth of modern policing in England. Following the creation of the London metropolitan force, the necessity for extending the model to the municipal boroughs became palpable. In this regard, a new major piece of legislation was introduced by the 1835 Municipal Corporations Act. The Corporations Act supposed an encompassing re-organization of the municipal corporations, defining among other things the administrative structure, election process, and terms in office of the borough councils in the incorporated boroughs. This Act also provided for the creation of a watch committee responsible of assembling and overseeing the municipal police forces. Originally the Act incorporated and reformed 178 Boroughs in 1835, and between 1836 and 1881 62 additional boroughs were incorporated and reformed under it.

Both the Act's intended purpose in terms of policing and the challenges that it

[11] More than 500 of these associations reportedly existed between the 1780s and the 1850s.

[12] Prüfer (2015) provides a theoretical explanation for the decreasing scope for private cooperation (i.e., private enforcement) as economies grow in size and the heterogeneity among agents increases. Following this argument, as an economy develops, the need (efficiency gain) from public provision of enforcement should increase.

was supposed to meet become patent from one of Peel's interventions in the parliamentary debate on the Corporations Act: "Our interest being concurrent with the maintenance of order, of laws, and of the established rights of property, will induce us to support whatever may be proved to be conducive to such objects . . . I cannot contemplate the condition of some of the great towns of this country, and witness the frequent necessity of calling in the military in order to maintain tranquility, without feeling desirous that the inhabitants of such towns should be habituated to obedience and order through the instrumentality of an efficient civil power, and a regular and systematic enforcement of the law. I believe that you could not establish a system of good government in the populous towns and cities of this country, retaining at the same time every existing privilege and practice of the corporate bodies as at present constituted."[13]

The Act was of central importance in the overall transition from a private protection system to a system with publicly provided law enforcement. Yet, the transition was not immediate and it took further reforms to be fully deployed.[14] Interestingly, before the 1835 Act some boroughs, by means of Local Improvement Acts, did in fact establish publicly paid police forces. In many of those cases, the 1835 Act mostly entailed a change in name of the police force rather than a fundamental restructuring, and the members of the early forces were re-appointed as members of the new borough polices (Hart, 1955, 1956; Ogborn, 1993; Styles, 1987). This suggests that the police forces before 1835 were determined at the local level, and so the characteristics of the local polity played a role in the existence and size of these forces, and this role persisted for some years after the enactment of the Corporations Act.

Importantly before the Corporations Act, municipal governments were formed by undemocratic self-perpetuating bodies (Finlayson, 1966). Therefore local policy decisions, as whether to establish publicly paid policing, were captured by the local aristocracies (Lizzeri & Persico, 2004). Given the influence of the corporations in shaping parliamentary elections, primarily through its direct support of candidates, the incentives to control the municipal corporations extended beyond the city limits. As a consequence, the "local aristocracy" in control of the municipal politics was not only composed of members of the urban elite but also of the "powerful men from outside the city" (Goodman, 1965, p. 160). The democratization of local politics established by the Corporations Act somewhat curtailed the external influence in local politics after 1835 (Lizzeri & Persico, 2004; Wollmann, 2000).

[13]HC Deb 15 June 1835 vol 28 c 831: http://goo.gl/zKOKS3

[14]In this regard, the 1839 Rural Constabulary Act, regulating the formation of the rural police forces at the county level, and the 1856 Country and Borough Police Act which finally made it mandatory for all the jurisdictions in the country to have a police force were the main follow up regulations (Hart, 1955).

2.3.2 Data and Results

2.3.2.1 Data

The empirical analysis in this section looks at the emergence and size of the municipal police forces in England. As dependent variables I use an indicator of whether there was a police force and its size, as well as the first year with a publicly paid police force. The municipal boroughs constitute then the units of observation, while 1835 is the reference year to assess the existence and size of early police forces. The reference year is chosen such that the Corporations Act was not in effect yet, meaning that local polities were still largely undemocratic, political representation was to a large extent dependent on wealth, and men from outside the boroughs had an influence in the decisions of the municipal corporations.

The analysis focuses only on the boroughs that were reformed by the Municipal Corporations Act of 1835, either immediately (the original 178 boroughs) or at some moment between 1835 and 1881. Therefore, the so-called "rotten boroughs" which were never incorporated are not part of the analysis. London is excluded from the analysis, because of its unique metropolitan status and because its policing was separately regulated by the Metropolitan Police Act of 1829.

The number of officers and year of establishment of the police is collected from the outline of the police forces in England and Wales in Clark (2014). This outline, which is meant to serve as a police insignia and badges collector's guide, provides the first year for which there are local records of existence of a publicly paid police force. This guide also contains information about the number of officers within the force for specific years. When exploring the size of the police forces, 1835 is used as a reference year because it is the latest before the enactment of the Corporations Act. The existence and size of the police forces before the Act serve to capture the variation in the public provision of law enforcement across municipal boroughs, without the potentially confounding effect of a centrally imposed intervention. Given that the information on the number of officers in Clark (2014) is not recorded systematically on a yearly basis, in some cases the specific number of officers in 1835 is not reported; however, whenever the police forces were already in place before 1835, and it is clear that the change under the Corporations Act "was probably mostly in name and form only as most of the "new" appointed police were members of the existing local police of the town" (Clark, 2014), the reported number of officers for 1836 or 1837 (when available) is used. Whenever Clark claims that there is no evidence of a paid police force before the Act's enactment, the number of officers in 1835 is set to 0.

As mentioned in the introduction the characteristics of the local population, could have an impact on the development of local institutions in general, and in this particular case on the emergence of public law enforcement. Following this line of reasoning, the set of right hand side variables is mainly composed by the occupational profile of the local population. These occupational data come from the enumeration abstracts of the 1831 census, which was the first to record relatively detailed information about the occupational profile of the (male) population.[15] The occupational breakdown is only available for the male population over 20 years old (henceforth adult male population). The adult male population is classified into 9 categories: 3 agricultural occupations, 4 urban occupations, servants, and "others". The records exist at three different levels of geographical disaggregation, which from the lowest to the highest level of aggregation are: *i)* the borough, township, or parish (which may aggregate various towns for which the information was not separately collected); *ii)* then the hundred (or wapentake); and finally, *iii)* the ancient county.[16] As explained below, with exception of the variable capturing the agricultural structure, all variables are used at the lowest level of disaggregation (i.e., borough or parish).

A first element that could impact the emergence of local public law enforcement, is the composition of the local agricultural population, particularly regarding the access to land. The main hypothesis in this regard is that, by affecting the local institutions local elites can manipulate urban wages, limiting the incentives of agricultural laborers to migrate to the (local) urban areas. For this mechanism to be meaningful the migration of laborers should be possible, responsive to market forces, and mostly local. If one of these three conditions fails to hold there is no apparent gain in distorting the local institutions to manipulate the labor market. Interestingly, all three characterized the internal migration of workers in 19th century England and Wales: migration was indeed a large scale phenomenon (Crouzet, 2013), it responded to the anticipation of better conditions in the urban areas (J. Long, 2005), and it was mostly short-distance (Redford, 1976). Taking into account this last characteristic, and in order to obtain a more accurate picture of the agricultural population, which cannot be captured at the municipal level, access to agricultural land is measured at the level of the hundred. That is, it measures inequality in the access to agricultural land in the borough and its surrounding area. To operationalize the access to land, and due to the landownership data limitations, I rely on a measure of inequality in the access to agricultural land ($Land\ Ineq$). Specifically, I calculate the size of the landless agricultural male population relative to the size of the agricultural tenant

[15]The census data are obtained from the Great Britain Historical GIS Project (GBHG, 2004).

[16]When needed the location of parishes and towns within a hundred (or wapentake) were completed using S. Lewis (1848) and GENUKI (2014)

male population (see Appendix 2.C). The higher this measure, the larger the fraction of the agricultural population with no access to land. On top of overcoming the limitations on landownership data, using tenancy as a measure of inequality in the agricultural sector comes with the advantage of having a more accurate profile of the landed/landless productive structure. This is the case because owner-occupancy of agricultural land was relatively uncommon in 19th century England, and tenants were the residual claimants of the agricultural production (Stead, 2004). Furthermore, as portrayed in the motivation and further shown in the theory, the hypothesis is that what matters for the development of local institutions are the preferences of the local elites, and it was the large tenants the ones that represented the local agricultural elite (Mingay, 2000).

Arguably, the relevance of the agricultural structure for the determination of the local institutions depends on the importance of rural activities for the local economy. That is, if the agricultural sector is relatively small, the influence of the "agricultural elite" maybe less pronounced. To incorporate this notion, the level of inequality is interacted with a dummy (*Rural*) which takes the value of 1 if at least 40% of the families in the borough or parish are "chiefly employed in agriculture", allowing then for a differential relationship between the agricultural structure and the emergence of public law enforcement depending on the size of the agricultural sector.[17]

Lastly, the arguments set in the introduction establish that the views of those controlling the agricultural activity could have been effectively contested by an emerging "industrialist elite". One of the 4 urban occupations is particularly well suited to account for the emergence of a landless wealthy class; specifically, this category accounts for the number of capitalists, bankers, and other educated men (*Capitalists*). This occupation is included in absolute levels transformed by the inverse hyperbolic sine (*asinh*).[18]

Following this, the equation of reference for the estimations is

$$\begin{aligned} y_j = \beta_0 + \beta_1 LandIneq_j * Rural_j + \beta_2 LandIneq_j \\ + \beta_3 Rural_j + \beta_4 Capitalists_j + \Gamma X_j + \varepsilon_j \end{aligned} \tag{2.3.1}$$

When the existence of a police force is the variable of interest, y_j can be interpreted as a latent variable such that a police force is observed in borough j if $y_j > 0$. When turning to the size of the police force in 1835 as variable of interest, y_j can be interpreted as a latent variable such that the observed size of the police force is y_j if $y_j > 0$ and 0 otherwise. Finally, when the timing of emergence of the police force

[17] This variable is constructed by using the census' questions on the number of families "*chiefly employed in and maintained by Agriculture; or by Trade, Manufacture, or Handicraft*".

[18] This transformation (as the logarithmic) compresses the distribution and is well defined for 0 values.

is the variable of interest, y_j is the first year on record with a publicly paid force in borough j.

Turning to the right hand side of (2.3.1), X_j is a vector of control variables and ε_j is a normally distributed disturbance. Regarding X_j, the specifications that include the size of the capitalist class and look at the emergence of the police, always include the size of the total population. This is to make sure that the coefficient corresponding to the capitalist class is not merely capturing the scale of the economy.[19] Other controls include: population density (i.e., the number of inhabitants per acre), which is meant to control for the potential effect that density has on the incidence of crime; regional dummies (South, Midlands, and North); other geographic controls (distance to London, suitability for cultivation, elevation, area of the borough); and, a dummy for whether the borough was originally reformed by the 1835 Act.[20] Finally, in some specifications I control for the size of other urban occupations, that is those "employed in manufacturing or trade", and the non-agricultural laborers, both in *asinh* transformations.

Table 1 presents the summary statistics of all the variables in the analysis. As it can be seen from this table, about half of the boroughs in the sample had a publicly paid police before the enactment of the Corporations Act.[21]

Table 2.3.1: Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
Police force by 1835 (dummy)	0.514	0.501	0	1	181
First year police	1825	28.207	1744	1910	179
Police force size (per 1000 inhab.)	0.388	0.647	0	3.862	145
Land Ineq.	3.744	2.312	0.576	10.943	181
Rural (dummy)	0.099	0.3	0	1	181
Capitalists (asinh)	5.502	1.256	0.881	9.089	181
Empl. Manuf or Trade (asinh)	7.631	1.418	0.881	10.799	181
Non-agricultural Laborers (asinh)	6.594	1.488	0	10.218	181
Population density (Pop/area in acres)	7.399	18.043	0.022	142.167	181

2.3.2.2 Results

The estimations on the existence of a police force by 1835 follow from a probit specification, and are presented in table 2.3.2. Model (1) includes only the variables corresponding to the agricultural profile; model (2) adds the *Capitalists* variable; model

[19]The size of the police force is already scaled by the size of the population.

[20]The land suitability data comes from Ramankutty, Foley, Norman, and McSweeney (2002). Results are robust to the inclusion of further land suitability controls at the parish level provided by L. P. Smith (1976).

[21]For further information on the sample see Appendix 2.C.

Table 2.3.2: Emergence police forces (police by 1835) [Probit]

	(1)	(2)	(3)	(4)
Land Ineq.	0.084*	0.189***	0.096	0.110
	(0.049)	(0.052)	(0.091)	(0.090)
Land Ineq.*Rural	-0.778**	-0.691***	-0.990**	-1.135**
	(0.317)	(0.257)	(0.477)	(0.456)
Rural (dummy)	0.584	1.482*	2.575**	3.024**
	(0.717)	(0.866)	(1.211)	(1.340)
Capitalists (asinh)		0.288*	0.372**	0.421***
		(0.170)	(0.150)	(0.149)
Pop. Density			0.018***	0.021***
			(0.007)	(0.008)
Originally Reformed (dummy)			0.081	0.034
			(0.425)	(0.424)
Empl. Manuf or Trade (asinh)				0.471
				(0.545)
Non-agric Laborers (asinh)				-0.207
				(0.208)
Geo. controls	No	No	Yes	Yes
Regional dummies	No	No	Yes	Yes
N	181	181	181	181
pseudo R^2	0.084	0.194	0.284	0.295

Robust standard errors in parentheses (clustered by hundreds)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

(3) includes the additional controls, except for the other urban occupations; which are then added in model (4). Table 2.3.3 presents the average marginal effects of the two main variables of interest, *Land Ineq* and *Capitalists*, evaluated at the two values of the *Rural* dummy.

Two patterns consistently emerge from these estimations. First, there appears to be a negative and significant relationship between the measure of inequality in the access to agricultural land and the emergence of police forces by 1835, but only in boroughs with a sufficiently rural population, as suggested by models 3 and 4. This means that in those boroughs or parishes with a sufficiently large agricultural population, higher inequality in the access to land was associated with a lower probability of having a police force before the enactment of the Corporations Act. This could be interpreted as inequality in the access to land having an effect in blocking

Table 2.3.3: Average marginal effects on Pr[police by 1835]

	(1)	(2)	(3)	(4)
Land Ineq.				
Urban	0.033*	0.063***	0.028	0.031
	(0.018)	(0.016)	(0.026)	(0.025)
Rural	-0.094**	-0.103**	-0.140***	-0.147***
	(0.047)	(0.040)	(0.041)	(0.037)
Capitalists (asinh)				
Urban		0.096*	0.107**	0.119***
		(0.057)	(0.042)	(0.041)
Rural		0.059	0.058**	0.060**
		(0.040)	(0.029)	(0.025)
Rural (dummy)	-0.453***	-0.233**	-0.174**	-0.165**
	(0.059)	(0.097)	(0.074)	(0.078)
Observations	181	181	181	181

Robust standard errors in parentheses (clustered by hundreds)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

the emergence of early forces. Second, the emergence of the police forces before the enactment of the Act, is positively and significantly associated with the size of the capitalist class (given the total population), irrespective of whether the borough is sufficiently urban. That is, the emergence of a relatively larger wealthy landless class was positively associated with the existence of publicly provided law enforcement. A potential concern is that the coefficient corresponding to $Capitalists$ is actually capturing the effect of the size of the urban sector in itself. However, the results in column (4) indicate that the relationship is truly between the emergence of the police forces and the relative size of the capitalist population, and not with the other urban occupations.

To further explore the relationship between the timing of emergence of publicly paid law enforcement and the profile of the local population, the relationship between the first year with a police or publicly paid watch, as reported in Clark (2014), and the characteristics of the local population is quantified. The estimation results are reported in table 2.3.4 and rely on OLS estimations. The results from these estimations reveal a pattern that is consistent with the previous exercises. More inequality in the access to land is associated with a later emergence of police forces in the rural boroughs. And, a relatively larger capitalist class is associated with police forces emerging earlier; while the size of the other urban classes does not appear to be related to the pace of emergence of the police.

As a final exercise, the relationship between the local occupational profile and the size of the early police forces (those by 1835) is explored. Given the left censoring

Table 2.3.4: Emergence police forces (first year with police) [OLS]

	(1)	(2)	(3)	(4)
Land Ineq.	-2.648***	-3.736***	-0.340	0.040
	(0.766)	(0.852)	(1.142)	(1.129)
Land Ineq.*Rural	3.583**	5.218***	4.866***	4.481***
	(1.349)	(1.088)	(1.258)	(1.632)
Rural (dummy)	8.178**	-12.903*	-16.659**	-18.617
	(3.299)	(6.897)	(7.756)	(11.242)
Capitalists (asinh)		-8.085***	-8.358***	-11.412***
		(1.335)	(1.619)	(3.007)
Pop. Density			-0.213*	-0.230**
			(0.109)	(0.109)
Originally Reformed (dummy)			-18.086***	-17.230***
			(5.755)	(5.874)
Empl. Manuf or Trade (asinh)				-4.925
				(7.246)
Non-agric Laborers (asinh)				-3.159
				(2.052)
Geo. controls	No	No	Yes	Yes
Regional dummies	No	No	Yes	Yes
N	179	179	179	179
R^2	0.097	0.194	0.326	0.333

Robust standard errors in parentheses (clustered by hundreds)
* p < 0.10, ** p < 0.05, *** p < 0.01

of the dependent variable, the estimations follow a tobit specification. Table 2.3.5 presents the estimation results and table 2.3.6 reports the average marginal effects on the size of these early forces, conditional on the size being larger than 0. For these estimations, the dependent variable is the number of officers in the force in 1835 per 1000 inhabitants in the borough or parish (as per the 1831 census). The results in table 2.3.5 indicate that there is a negative and significant relationship between inequality in the access to agricultural land in rural boroughs, and the latent (unobserved) variable behind the size of the police forces in 1835. The marginal effect of land access inequality on the size of the police forces, conditional on the existence of a police force, is of course negative but it is not significant (table 2.3.6). These results suggest that land access inequality (in the relatively rural boroughs) had an effect on the existence of the early police forces, but not on their size. Regarding the size of

Table 2.3.5: Size of police forces (by 1835) [Tobit]

	(1)	(2)	(3)	(4)
Land Ineq.	0.147***	0.230***	0.105	0.103
	(0.040)	(0.047)	(0.070)	(0.063)
Land Ineq.*Rural	-1.990*	-1.513	-1.950*	-1.918*
	(1.030)	(1.103)	(1.089)	(1.110)
Rural (dummy)	2.379	2.617	4.194*	4.378*
	(1.883)	(2.146)	(2.283)	(2.433)
Capitalists (asinh)		0.606***	0.576***	0.559*
		(0.149)	(0.134)	(0.292)
Pop. Density			0.005	0.006
			(0.006)	(0.007)
Originally Reformed (dummy)			0.697**	0.678**
			(0.299)	(0.297)
Empl. Manuf or Trade (asinh)				0.491
				(0.748)
Non-agric Laborers (asinh)				0.019
				(0.213)
Geo. controls	No	No	Yes	Yes
Regional dummies	No	No	Yes	Yes
N	145	145	145	145
pseudo R^2	0.075	0.179	0.249	0.251

Robust standard errors in parentheses (clustered by hundreds)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

the capitalist class, a relatively larger capitalist class is related to a larger police force. Again, this relationship does not seem to be mechanically driven by the size of the urban sector (model 4).

Beyond the historical accounts on the emergence of the early police forces in England, the evidence in this section suggests that indeed there is a relationship between the occupational profile at the local level and the emergence and size of the early municipal police forces. Specifically, boroughs and parishes with a sufficiently large rural population (i.e., a large proportion of families involved in agriculture), and located in areas in which a larger fraction of the agricultural population did not have access to land, experienced a slower emergence of publicly paid police forces. Moreover, the emergence of an industrial elite, as measured by the size of the capitalist population, came along with earlier and larger police forces.

Table 2.3.6: Average marginal effects on [Size of police | size> 0]

	(1)	(2)	(3)	(4)
Land Ineq.				
Urban	0.065***	0.094***	0.043	0.041*
	(0.019)	(0.017)	(0.027)	(0.024)
Rural	-0.120	-0.179	-0.380	-0.414
	(0.128)	(0.189)	(0.266)	(0.292)
Capitalists (asinh)				
Urban		0.248***	0.234***	0.225*
		(0.049)	(0.044)	(0.118)
Rural		0.085***	0.119***	0.128*
		(0.028)	(0.032)	(0.065)
Rural (dummy)	-5.231**	-3.169	-3.263*	-2.957
	(2.206)	(2.140)	(1.926)	(1.880)
Observations	145	145	145	145

Robust standard errors in parentheses (clustered by hundreds)
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

With these empirical patterns in mind, the next sections develop a theoretical model of the endogenous emergence of publicly provided law enforcement in a dual economy, undergoing a process of structural change. The model allows for private protective efforts and publicly provided law enforcement. In this theory, the main difference between private protection and public law enforcement is that the latter (endogenously) serves as a crime prevention device. This is in line with the view that preemptive policing was one of the main innovations introduced with the "modern police forces". Moreover, the model provides a theoretical underpinning for the slower emergence of publicly paid police forces in economies where access to land is more unequal, and it links the emergence of the publicly provided law enforcement with the surge of a wealthy urban class.

2.4 Model

The economy is characterized by a sequence of non-ovelapping generations of individuals that live for one period.[22] A unique final good, which serves for consumption and investment, is produced in two sectors: rural and urban. The rural sector uses labor and land as inputs, the urban sector uses labor and capital. Property rights over final output in the urban sector are imperfectly protected and output is exposed to theft. The level of protection of property rights depends on the public provision of

[22] Or that are economically relevant only for one period.

law enforcement, financed through taxation, and the private protective effort exerted by the producers in the urban sector. At the beginning of their lives individuals are endowed with capital, labor, and land; and these endowments will determine their preferred level of provision of law enforcement.

2.4.1 Setup

2.4.1.1 Production

Production is organized in two sectors, rural (x) and urban (u), that produce the same final good using two different technologies. The final good can be used for consumption or investment, and it serves as the numeraire. The rural sector uses land and labor as inputs while the urban sector uses capital and labor. Production in both sectors exhibits constant returns to scale, and each sector is characterized by a representative firm. More specifically, each sector produces using a Cobb-Douglas technology, so that their total outputs at time t are given by

$$Y_{x,t} = X_t^{\alpha} l_{x,t}^{1-\alpha};\ Y_{u,t} = K_t^{\alpha} l_{u,t}^{1-\alpha}$$

where X_t is the amount of land used by the rural sector and $l_{x,t}$ is the amount of labor it employs; K_t and $l_{u,t}$ respectively are the total capital used by the urban sector at time t; and $\alpha \in (0, 1)$ is a parameter. Total output in the economy is $Y_{T,t} = Y_{x,t} + Y_{u,t}$. This is a standard productive structure for dual economy models, as the one in Galor et al. (2009). The model makes no distinction between the individuals that derive part of their income from the use of land, so landowners and tenants are treated as a unified class with access to land. Hereafter I refer to them as landowners. The factor markets in the urban sector are perfectly competitive, and as a result factors are remunerated at their marginal productivity. In the rural sector, however, the distribution of income between land and labor is determined by the relative bargaining power of the landowners. This distortion means that landowners may enjoy sufficient market power in the labor market to set prices. From the historical perspective, this assumption is meant to resemble the fact that the organization of production in the rural areas was not only characterized by the distribution of land but also by the relative market power of those with access to land.[23]From the view point of the theory, and following Bertocchi (2006), a fraction $\chi \geq \alpha$ of the rural output goes to remunerate land and so the total wage bill of the rural sector is

[23]In the case of 19th century England, the focus of the empirical section, the Corn Laws were a clear manifestation of the ability of the landowning elites to use the political apparatus to distort prices. These laws, designed to maintain the grain prices high, were fiercely defended by the landowning elite and largely opposed by the urban based classes. Their repeal by the mid of the century came along with the demise of the landowner's political power (Schonhardt-Bailey, 1996).

$$w_{x,t} l_{x,t} = (1 - \chi)\, X_t^{\alpha} l_{x,t}^{1-\alpha}$$

where $\chi/\alpha \geq 1$ can be interpreted as measure of how distortive is the price setting power of the landowners, with $\chi = \alpha$ meaning no distortion.[24]

2.4.1.2 Agents, preferences and endowments

Each household is composed of a single individual that lives for one period. At the end of each period all individuals have a single offspring, thus population remains constant over time. Agents derive utility from the consumption of a unique final good, and from bequeathing part of their income to the next generation. Specifically, the lifetime utility of an individual from generation t belonging to dynasty i is given by

$$u_{i,t} = \ln c_{i,t} + \frac{\gamma}{1-\gamma} \ln b_{i,t+1}$$

Where $c_{i,t}$ is the individual consumption, $b_{i,t+1}$ is the bequest left to the next generation $(t+1)$, and $\gamma \in (0, 1)$ is the utility weight of the "warm glow" feeling from bequeathing. The total population size is L, and each individual is endowed with $l_{i,t} = 1$ unit of labor which they supply inelastically in the labor market. Moreover, individuals are endowed with a dynasty specific land plot of size x_i, which may differ between dynasties. The land endowment of a dynasty remains constant over time (i.e., land is non-tradable between dynasties) and land is rented out for production in the rural sector. Finally, at the beginning of each period individuals receive the fraction of income bequeathed by the previous generation in the form of the final good; they rent this out in the capital market and it fully depreciates after use. The total income of an individual i, t is determined by the rental prices of land ($r_{x,t}$), labor (w_t), and capital ($r_{k,t}$) and by her own endowment of these factors (x_i, $l_{i,t}$, $b_{i,t}$):

$$I_{i,t} = r_{x,t} x_i + w_t l_{i,t} + r_{k,t} b_{i,t}$$

The objective of the representative individual is to maximize her lifetime utility $u_{i,t}$ subject to the budget constraint $c_{i,t} + b_{i,t+1} \leq I_{i,t}$.

[24]By constituting an additional dimension of the rural productive structure, χ provides an additional dimension along which one can perform comparative dynamics analyzes. In other words, χ is an additional degree of freedom of the model, but $\chi > \alpha$ is not necessary for the results to hold. In Bertocchi (2006) this distortion endogenously fades away with the surge of the industrial sector.

2.4.1.3 Insecure property and law enforcement

A distinctive element of the model is the imperfect protection of property rights in the urban sector. More specifically, output in the urban sector is exposed to theft, and by assumption theft only occurs in that sector. This is in line with the historical view that, during the process of industrialization, property crimes were a more widespread phenomenon in urban than in rural areas. As noted by Shelley (1981) "the transition from a society dominated by crimes of violence to one characterized by property offenses is the hallmark of modernization" (p. 36). "In early nineteenth-century England, towns undergoing both rapid expansion and important changes in economic structure frequently experienced, a greater sensitivity to working-class delinquency, and a high crime rate" (D. J. Jones, 1982, p. 5). Referring to the same period, Allen and Barzel (2009) point out that, "with industrial growth came industrial theft . . . property crimes without violence accounted for 85% of the indictable committals handled by the new police. Industrial theft . . . was the most common accounting for 28.2% of all committals" (p. 555).[25] These authors identify the standardization of inputs and outputs, a typical feature of the industrialized manufacturing production, as one of the causes why theft mainly affected urban production. They argue this was the case because standardization made legitimate ownership harder to prove. Furthermore, the standardization of inputs facilitated the appropriation of raw materials, and this also serves to explain the pervasiveness of urban crime in industrializing England (Becker, 1983). Similarly, the density of economic activity, the open display of goods, and the anonymity of life made property crime relatively more prominent in the urban areas (Beattie, 1974).

To model the imperfect protection of property in the urban sector, it is assumed that the fraction (π) of output net of theft retained by the firm is determined by a contest success function (CSF) (Hirshleifer, 1995b; M. R. Garfinkel & Skaperdas, 2007):

$$\pi\,(p,\,g;\,e) = \frac{p+e}{p+g+e}$$

Where p is the private protective effort exerted by the urban firm, e is the level of law enforcement supplied by the government, and g is the theft effort by the criminals. This specification implies that the effective capacity to protect urban output against theft, amounts to the sum of the private protection by the firm and the level of publicly provided law enforcement: $p+e$. That is, for a given g the fraction retained by the firm is strictly increasing in $p+e$. Similarly, the fraction retained by the firm is

[25] These figures were originally taken from Philips (1977).

strictly decreasing in the effort exerted by the criminals for a given $p + e$. Theft effort is essential for the criminals to capture some of the output, i.e., $\pi(p, 0; e) = 1 \, \forall \, p, e$. The three inputs of the theft contest are measured in units of the final good and have a constant marginal cost. Each unit of p or e is assumed to have a unitary cost, while a unit of e is assumed to cost $1/\zeta$.[26] Moreover, the criminal sector is modeled as a single entity, which seeks to maximize its total revenues net of effort; that is, there are no coordination issues between criminals. By assumption, criminals are outsiders to the economy; plainly speaking thieves come, steal, and leave with the booty.[27] The private efforts p and g are respectively paid by the firm and by the criminals; the public provision of law enforcement is financed through a tax of rate τ on gross urban output. The government's budget is balanced, and so all the tax proceeds are used to finance the provision of law enforcement. That is, $e = \zeta T = \zeta \tau Y_u$.[28] Finally, and as detailed below, the urban firm and the criminals first observe the urban output net of taxation and the level of law enforcement e, and only then they engage in the contest over urban output. This means that publicly provided law enforcement has a first mover advantage with respect to p and g. This assumption is meant to resemble the relatively more preventive focus of the public police forces, as opposed to the more reactive nature of the traditional systems of protection (watches and constables). After all, one of the arguments of those supporting the creation of the "new" police forces in 19th century England was that by they mere presence they would deter crime.[29]

[26] $\zeta > 1$ would imply that there is a potential technological advantage in publicly provided security. While $\zeta < 1$ would imply that public provision is more costly than private provision. See Monkkonen (1992) for a discussion on the advantages of publicly provided security.

[27] Alternatively one could assume that criminals live on a hand-to-mouth basis.

[28] From here one can see that the parameter ζ could also be associated with the state's capacity in the provision of property enforcement (e.g Besley & Persson, 2009). A higher ζ allows for a higher provision of enforcement given a tax revenue.

[29] The main mechanism in the model is at play as long as the provision of law enforcement improves the efficiency of the urban sector relative to the rural one. This could occur through different channels. As chosen here, it could be the case that crime, or at least the type of crime that law enforcement is mainly preventing, is more prominent in (or exclusive of) the urban sector. Alternatively, one could assume that theft affects both sectors but, the efficiency of law enforcement is higher in the urban sector than in the rural one. This may occur, for instance, because the agglomeration of economic activity reduces the cost of patrolling. In the model this is equivalent to assume that ζ is lower in the rural sector, and therefore, for a given level of tax revenues the effective provision of law enforcement (and so its effect on productivity) is higher in the urban sector. Under this alternative scenario the main mechanism would be milder, but still relevant. As a third alternative, one could assume that law enforcement is (initially) only introduced in the urban areas, as the actual timing of the police-related reforms in England suggests. In this scenario one would then need to take into account that the introduction of police forces in the urban areas could displace crime towards the rural areas. The displacement of crime to the rural areas would lead to an even lower relative productivity of the rural sector, reinforcing the model's main mechanism.

2.4.1.4 Timing

The timing of events within each period is as follows:

1. At the beginning of the period individuals are endowed with the production factors: they are all endowed with $1/L$ units of labor, they receive the capital bequeathed by the previous generation, and some are entitled to a dynasty specific land plot.

2. Voting rights are allocated, conferring the right vote over the tax rate and the level of publicly provided property enforcement (the enfranchising mechanism is described in section 2.4.2.6).

3. Individuals decide on the tax rate and this is announced.

4. After observing τ, production in both sectors takes place and the tax on urban output is collected. This leaves $(1-\tau)\,Y_u$ as the potential reward of the theft game.[30]

5. Given the tax revenues τY_u, law enforcement $e = \zeta\tau Y_u$ is supplied.

6. With τ and Y_u as common knowledge, and given the observable level of law enforcement $e = \zeta\tau Y_u$, the urban firm and the criminals simultaneously decide how much effort, p and g respectively, to commit into the contest over urban output and the contest takes place.

7. Total output net of theft, taxation, and protection is distributed to remunerate the production factors. Based on their income, individuals decide how much to consume and how much to leave as a bequest to the next generation.

2.4.2 Intra-temporal Equilibrium

2.4.2.1 Theft game

After observing τ, Y_u, and e the urban firm and the criminals engage in a contest over urban output net of taxation. The contest is such that they choose their theft and protection effort simultaneously. The objective is to maximize their profits net of taxation and the cost of effort. The individual efforts p and g, as functions of e and Y_u, are determined by the Nash equilibrium in pure strategies of the theft game.[31]

[30] Alternatively one could assume the tax is collected after the theft contest, leaving Y_u as total prize of the theft game without affecting the results qualitatively.

[31] Although for the moment I omit the time subscript, it is important to note that this game is played *ad infinitum* by each generation of criminals and urban firms.

The protection decision by the firm is based on the trade-off between maximizing the fraction of output that it can keep and paying the protective cost that this entails. That is, the firm seeks to maximize

$$\Pi_u = \pi\left(p, g; e\right)\left(1-\tau\right)Y_u - p$$

subject to $p \geq 0$. Similarly, the criminals want to maximize the fraction of output that they appropriate net of the cost of exerting theft effort. So the criminals maximize

$$\Pi_g = \left(1 - \pi\left(p, g; e\right)\right)\left(1-\tau\right)Y_u - g$$

subject to $g \geq 0$. The FOCs of the corresponding problems are:

$$\frac{g}{\left(p+e+g\right)^2}\left(1-\tau\right)Y_u - 1 + \mu_p = 0;\ \mu_p \geq 0;\ p \geq 0;\ \mu_p p = 0$$

$$\frac{p+e}{\left(p+e+g\right)^2}\left(1-\tau\right)Y_u - 1 + \mu_g = 0;\ \mu_g \geq 0;\ g \geq 0;\ \mu_g g = 0$$

with μ_i's being the multipliers of the respective non-negativity constraints. Rearranging these expressions, one obtains the following reaction functions for the theft game:

$$p\left(g\right) = \max\left\{\sqrt{g\left(1-\tau\right)Y_u} - g - e,\ 0\right\} \tag{2.4.1}$$

$$g\left(p\right) = \max\left\{\sqrt{\left(p+e\right)\left(1-\tau\right)Y_u} - p - e,\ 0\right\} \tag{2.4.2}$$

Taking the level of law enforcement as a given, the reaction functions expand with Y_u, that is for a given level of p the theft effort g (or for a given level of g the protective effort p) is strictly increasing in Y_u. This is a well known property of the CSF. As the urban economy increases in size, the size of the contest's prize increases and so the incentives to engage in the contest are higher. Consequently, a larger urban economy reduces the effectiveness of law enforcement (i.e., the same level of e is less efficient at protecting property). What matters for the effect of enforcement on the contest is not its absolute level, but its level relative to the size of the economy. This means that the critical variable determining the effect enforcement on the contest over urban output is the tax rate τ (i.e., the size of e relative Y_u). Depending on τ three different types of equilibrium may arise:

1. Private protection: $p, g > 0$

In this type of equilibrium both the firm and the criminals exert positive effort into the theft game.[32] This type of equilibrium emerges when the level of law enforcement is relatively low, more specifically it arises as long as $e < (1-\tau)\,{}^{Y_u}/_4$ which, using the government's budget constraint is equivalent to

$$\tau < \underline{\tau} \equiv \frac{1}{1+4\zeta}$$

Using the reaction functions (2.4.1) and (2.4.2), the efforts p and g as functions of e, τ and Y_u are

$$p + e = g = (1-\tau)\,\frac{Y_u}{4}$$

given that in equilibrium $p + e = g$, then $\pi = {}^1/_2$. Therefore, the revenues of the urban firm net of taxation and protective effort are

$$\Pi_u = \pi\,(1-\tau)\,Y_u - p = \frac{1-\tau}{2}Y_u - \frac{1-\tau}{4}Y_u + e = \frac{1-(1-4\zeta)\,\tau}{4}Y_u$$

where the last equality uses the government's budget constraint and the superscript denotes the fact that this is an equilibrium outcome. Similarly, the net profits of the criminal sector are

$$\Pi_g = (1-\pi)\,(1-\tau)\,Y_u - g = \frac{1-\tau}{4}Y_u$$

2. Public protection and partial theft deterrence: $p = 0$, $g > 0$

In the second type of equilibrium, the level of law enforcement is sufficiently high for the firm not to spend effort on private protection, but not high enough to deter the criminals from engaging in the contest for urban output. More precisely, this equilibrium emerges when $(1-\tau)\,{}^{Y_u}/_4 \leq e < (1-\tau)\,Y_u$ which, using the government's budget constraint is equivalent to

$$\frac{1}{1+4\zeta} \equiv \underline{\tau} \leq \tau < \bar{\tau} \equiv \frac{1}{1+\zeta}$$

Using the reaction functions (2.4.1) and (2.4.2), protection and theft efforts are

$$p = 0$$

$$g = \sqrt{e\,(1-\tau)\,Y_u} - e$$

[32] Note that with $\pi\,(0,0;\,0) = 1$, $p = g = e = 0$ cannot be a Nash equilibrium, as criminals would have incentives to deviate and exert a minimum amount of effort to capture the whole urban output.

The fraction of output that the urban sector keeps is

$$\pi = \frac{e}{g+e} = \sqrt{\frac{e}{(1-\tau)\,Y_m}} = \sqrt{\frac{\zeta\tau}{1-\tau}}$$

where the last equality follows from the government's budget constraint. The revenues of the urban firm net of taxation and protective effort are

$$\Pi_u = \sqrt{\frac{\zeta\tau}{1-\tau}}\,(1-\tau)\,Y_m = \sqrt{\zeta\tau\,(1-\tau)}Y_m$$

while the net revenues of the criminal sector are

$$\begin{aligned}\Pi_g &= \left(1-\sqrt{\frac{\zeta\tau}{1-\tau}}\right)(1-\tau)\,Y_u - \left(\sqrt{\zeta\tau\,(1-\tau)}-\zeta\tau\right)Y_u \\ &= \left(1+(\zeta-1)\,\tau-2\sqrt{\zeta\tau\,(1-\tau)}\right)Y_u\end{aligned}$$

3. Public protection and complete theft deterrence: $p = g = 0$

The third, and last, type of equilibrium occurs when the level of law enforcement is sufficiently high such that not only $p = 0$, but also criminals are fully deterred from exerting theft effort (i.e., $g = 0$). This equilibrium emerges when $\phi \geq (1-\tau)\,Y_u$ which, using the government's budget constraint is equivalent to

$$\tau \geq \bar{\tau} \equiv \frac{1}{1+\zeta}$$

In this type of equilibrium, urban output is fully protected (i.e., $\pi = 1$), and the net revenues of the urban sector are simply

$$\Pi_u = (1-\tau)\,Y_u$$

while the criminal sector makes no profit ($\Pi_g = 0$). Figure 2.4.1 depicts the three types of equilibriums that may arise in this game, depending on the relative level of existing law enforcement.[33]

In summary, the net revenues of the urban sector can be expressed as $f_u(\tau)\,Y_u$, with

$$f_u(\tau) = \begin{cases} \frac{1-(1-4\zeta)\tau}{4} \text{ if } \tau < \underline{\tau} \\ \sqrt{\zeta\tau\,(1-\tau)} \text{ if } \tau \in [\underline{\tau}, \bar{\tau}) \\ 1-\tau \text{ if } \tau \geq \bar{\tau} \end{cases}$$

[33] In this figure the pair of reaction curves $p_i(g)$, $g_i(p)$ corresponds to the type of equilibrium i, with $i \in \{1, 2, 3\}$.

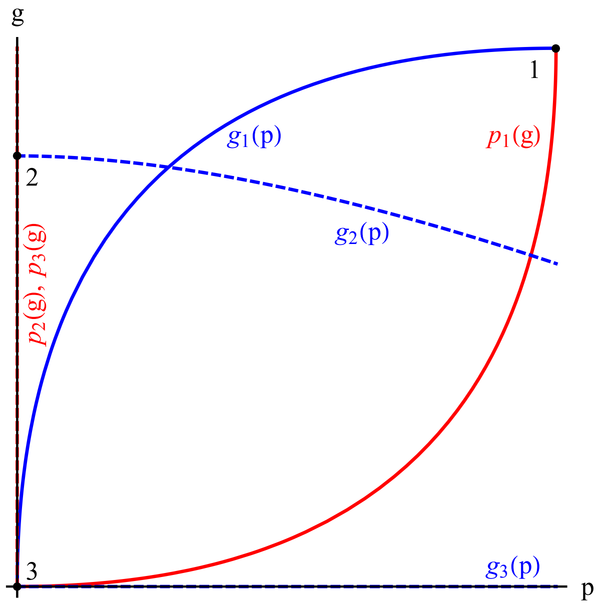

Figure 2.4.1: Equilibriums of the Theft Game

being the fraction $f_u(\tau)$ of output left for the urban firm after taxation, theft, and the cost of protection. In a similar fashion, the profits of the criminals can be expressed as $f_g(\tau)\,Y_u$, with

$$f_g(\tau) = \begin{cases} \frac{1-\tau}{4} \text{ if } \tau < \underline{\tau} \\ \left(1 + (\zeta - 1)\,\tau - 2\sqrt{\zeta\tau\,(1-\tau)}\right) \text{ if } \tau \in [\underline{\tau}, \bar{\tau}) \\ 0 \text{ if } \tau \geq \bar{\tau} \end{cases}$$

Note that both fractions f_u and f_g are continuous in τ for any $\tau \in [0, 1]$, and f_u' is continuous in τ for $\tau < \bar{\tau}$. Moreover, because of the wasteful nature of allocating resources through a protection and theft contest $f_u + f_g < 1 - \tau$ for any $\tau < 1$ (i.e., resources committed to the contest cannot be consumed or accumulated). From this point on let us assume that the maximum tax rate that can be implemented is $\tau = \bar{\tau}$. This assumption simply ensures that taxation cannot be used purely as a tool to strip the urban sector out of its profits. Once $\tau = \bar{\tau}$, a further increase in τ merely increases the tax burden of the urban sector without any effective improvement in the protection of property (which is already fully protected).

On top of reducing the need to spend effort on private protection, the structure of the theft game highlights another important aspect of law enforcement. By being set before the contest takes place, law enforcement actually serves as a deterrent.

From the efficiency point of view this aspect clearly distinguishes the role of law enforcement and of private protection. While it is true that both serve to counter the effect of theft effort, law enforcement can also the eliminate any potential gains for the criminals from the theft contest, and as such it effectively serves as a crime deterrent. This aspect is in line with the view that an emphasis on prevention, rather than on detection, was one of the main innovations of the public law enforcement in 19th century England with respect to the traditional system of watches and constables (e.g. Koyama, 2012).

2.4.2.2 Equilibrium in the factor markets

The demand for labor and capital in the urban sector is determined according to the net marginal productivity of these factors that is, their productivity net of taxation and the cost of insecure property

$$w_{u,t} = (1-\alpha) f_u(\tau) K_t^{\alpha} l_{u,t}^{-\alpha}$$

$$r_{k,t} = \alpha f_u(\tau) K_t^{\alpha-1} l_{u,t}^{1-\alpha}$$

In the rural sector, factor shares are determined by the relative bargaining power of the landowners (χ), and consequently the demand for labor and land in this sector are

$$w_{x,t} = (1-\chi) X_t^{\alpha} l_{x,t}^{-\alpha}$$

$$r_{x,t} = \chi X_t^{\alpha-1} l_{x,t}^{1-\alpha}$$

Assuming that labor is perfectly mobile between sectors, in equilibrium the sectoral allocation of workers is such that remuneration in urban and rural equalize[34]

$$(1-\chi) X_t^{\alpha} l_{x,t}^{-\alpha} = (1-\alpha) f_u(\tau) K_t^{\alpha} l_{u,t}^{-\alpha}$$

and the labor market clears $L = l_{u,t} + l_{x,t}$. Rearranging, the labor market equilibrium can be characterized by

[34]The assumption of perfectly mobile labor is an extreme one. In the case of England for instance, rural and urban labor markets were not fully integrated. Nevertheless, the main mechanism of the model is present as long as there is some degree of labor mobility. That is, wage equalization is not crucial, what matters is that increases (decreases) in urban wages result in labor moving out of the rural (urban) sector, and the other way around. Of course the higher the labor mobility, i.e., the higher the degree of co-movement between w_u and w_x, the stronger the mechanism presented here.

$$\left(\frac{z_t}{1-z_t}\right)^\alpha \equiv \left(\frac{l_{x,t}}{l_{u,t}}\right)^\alpha = \frac{(1-\chi)\, X_t^\alpha}{(1-\alpha)\, f_{u,t}(\tau)\, K_t^\alpha} \tag{2.4.3}$$

where z_t is the fraction of the total workforce L that works in the rural sector. Note that $z = {}^{qX}/_{K}\left(f_u^{\frac{1}{\alpha}} + {}^{qX}/_{K}\right)^{-1}$ is increasing in ${}^{qX}/_{K}$ and it is decreasing in τ for $\tau \in [0, \bar{\tau}]$, and q is defined as $(1-\alpha)^{\frac{-1}{\alpha}}(1-\chi)^{\frac{1}{\alpha}}$. The rental prices of capital and land must ensure that these markets clear as well, that is

$$X_t = \sum_i x_i = X$$

and

$$K_t = \sum_i b_{i,t}$$

2.4.2.3 Individual income

Income of household i, t is a function of its factor endowments and the factor prices, $I_{i,t} = r_{x,t}x_i + w_t l_{i,t} + r_{k,t}b_{i,t}$, which in equilibrium can be expressed as

$$I_{i,t} = X^\alpha (z_t L)^{1-\alpha}\, \omega_i^x + f_{u,t}(\tau)\, K_t^\alpha\, ((1-z_t)\, L)^{1-\alpha}\, \omega_{i,t}^u \tag{2.4.4}$$

where x_i and $k_i = b_i$ respectively are the individual endowments of land and capital. ω_i^j stands for the effective ownership of household i in sector j; these effective ownerships are given by

$$\omega_i^x \equiv \chi\frac{x_i}{X} + \frac{1-\chi}{L}$$

and

$$\omega_{i,t}^u \equiv \alpha\frac{k_{i,t}}{K_t} + \frac{1-\alpha}{L}$$

2.4.2.4 Consumption and bequests

The objective of the representative household is to maximize the lifetime utility $u_{i,t}$ subject to budget constraint $c_{i,t} + b_{i,t+1} \leq I_{i,t}$. As a result of this optimization process, total income is allocated in constant fractions between consumption and bequests:

$$c_{i,t} = (1-\gamma)\, I_{i,t};\ b_{i,t+1} = \gamma I_{i,t}$$

2.4.2.5 Individual's preferred tax rate $\tau_{i,t}^{*}$

When evaluating what their preferred tax rate is, individuals face a fundamental trade-off. Changes in τ have opposing effects on the total income derived from each of the two productive sectors. In the urban sector, income is strictly increasing in τ. This is the case because a higher τ not only implies that the fraction of output effectively retained by the urban sector is higher, but it also means that a larger share of labor is allocated to this sector. On the contrary, income in the rural sector decreases because, better protection makes the urban sector more thriving, pulling labor away. Clearly this mechanism relies on the potential for labor mobility between rural and urban activities, which was the case of 19th century England. Internal migration resulted in about 3 million people moving from rural areas to towns between 1841 and 1901 (J. Long, 2005). Moreover, this migration occurred mostly within short distances (Redford, 1976), implying that, at least to a certain extent, the competition for labor took place at the local level and was therefore influenced by the local institutions.

With $\tau \leq \bar{\tau}$ the fraction of output net of theft protection and taxation kept by the urban firm, f_u and its first derivative f' are continuous in τ. Using this in (2.4.4) one gets that

$$\begin{gathered}\frac{\partial I_{i,t}}{\partial \tau} = X^{\alpha} \left(z_t L\right)^{1-\alpha} \omega_i^x \left(\frac{(1-\alpha)}{z_t}\frac{\partial z_t}{\partial \tau}\right)\\ + f_{u,t} K_t^{\alpha} \left(\left(1-z_t\right) L\right)^{1-\alpha} \omega_{i,t}^u \left(-\frac{(1-\alpha)}{1-z}\frac{\partial z_t}{\partial \tau} + \frac{1}{f_{u,t}}\frac{\partial f_{u,t}}{\partial \tau}\right)\end{gathered}$$

By working out the sign of this expression, (as shown by the proof of lemma 2.1) it is obtained that

Lemma 2.1. *With $\tau \in (0, \bar{\tau})$, any individual has only two candidates for the preferred tax level $\tau_{i,t}^{*}$, namely $\tau = 0$ and $\tau = \bar{\tau}$.*

Proof: See Appendix 2.A.1.

This result implies that in order to find the preferred tax by any individual, the relevant comparison is $I_{i,t}|_{\tau=\bar{\tau}} \gtreqless I_{i,t}|_{\tau=0}$.

Proposition 2.1. *The preferred tax level by an individual i at time t ($\tau_{i,t}^{*}$) is $\bar{\tau}$ if*

$$\frac{\omega_{i,t}^u}{\omega_i^x} > \Omega_t \equiv \frac{X^{\alpha}\left(z_{0,t}^{1-\alpha} - z_{\bar{\tau},t}^{1-\alpha}\right)}{K_t^{\alpha}\left(f_{u,t}\left(\bar{\tau}\right)\left(1-z_{\bar{\tau},t}\right)^{1-\alpha} - f_{u,t}\left(0\right)\left(1-z_{0,t}\right)^{1-\alpha}\right)} \tag{2.4.5}$$

Otherwise i's preferred $\tau_{i,t}^{*} = 0$. Where $z_0 \equiv z|_{\tau=0}$, $z_{\bar{\tau}} \equiv z|_{\tau=\bar{\tau}}$, and $0 < \Omega_t < (1-\alpha)(1-\chi)^{-1}$.

Proof: See Appendix 2.A.2.

Lemma 2.2. *$\chi \leq \alpha(2-\alpha)$ is a sufficient condition for $\Omega_t < 1$.*

Proof: See Appendix 2.A.1.

Condition (2.4.5) has two components, an individual one $\omega^u_{i,t}/\omega^x_i$ and an aggregate one Ω_t. The individual component is a measure of the relative participation in the urban sector. The higher the $\omega^u_{i,t}/\omega^x_i$ ratio the more an individual benefits from the implementation of urban law enforcement. The aggregate component, Ω_t, measures the reduction in the aggregate production of the rural sector, relative to the gain in the urban sector, due to the implementation of $\tau = \bar{\tau}$ instead of $\tau = 0$.

First note that $\Omega_t > 0$ suggests that an individual with a sufficiently low, $\omega^u_{i,t}$ may prefer $\tau = 0$. Moreover, defining $s_{Ki,t}$ as $k_{i,t}/K_t$ and s_{Xi} as x_i/X, and using (2.4.5) it is obtained that

Proposition 2.2. *$(1-\chi)\,\alpha s_{Ki,t} \geq (1-\alpha)\,\chi s_{Xi}$ is a sufficient condition for $\tau^*_{i,t} = \bar{\tau}$*

Proof. *Follows directly from (2.4.5) and $\Omega_t < (1-\alpha)(1-\chi)^{-1}$* □

From this proposition it is immediate that, if all the production factors are equally distributed ($s_{Xi} = s_{Ki} = s_{Li} = 1/L\ \forall i$) and there are no distortions in the rural labor market ($\chi = \alpha$), all individuals at any point in time support the implementation of a high tax and of a high provision of law enforcement to protect urban property rights. Furthermore, individuals from landless dynasties (i.e., $s_{Xi} = 0$, $s_{Ki} \geq 0$, $s_{Li} > 0$) always prefer $\bar{\tau}$. This comes as no surprise because the gains from better protection of property rights are completely accrued by the urban sector, while the rural sector faces the cost of more intense competition from the urban one in the labor market.

Whether an individual prefers $\tau = 0$ or $\tau = \bar{\tau}$ is plainly determined by how much of her income is generated by land relative to the income coming from labor and capital. Over time this relationship depends both on the capital abundance of the economy and the relative participation of a household in the two sectors. Individuals belonging to landless dynasties ($x_i = 0$) support the implementation of a system of public law enforcement regardless of the level of development of the economy (i.e., the level of aggregate capital). Individuals belonging to dynasties with relatively large stakes in the rural sector may support $\tau = \bar{\tau}$ only if the economy is relatively industrialized (i.e., aggregate capital is relatively high), simply because a high level of aggregate capital means a larger fraction of income coming from the urban sector.

Up to this point the analysis has focused on the static elements of the model, since from the perspective of an individual $\omega^u_{i,t}$ and $s_{Ki,t}$ are pre-determined. However, these variables evolve endogenously as dynasties accumulate capital over time. Given that both the relative individual stakes in the urban sector and the aggregate level of industrialization determine the preferred tax level, characterizing the dynamics of K and $s_{Ki,t} = {}^{k_{i,t}}/_{K_t}$ is central for the derivation of the dynamic evolution of $\tau^*_{i,t}$. These dynamic processes are the focus of the next section.

2.4.2.6 Implemented tax rate

Arguably, from the historical perspective a natural political economy process to aggregate the preferences over τ is to allocate voting rights to the wealthiest households i.e., those with sufficiently large land plots or sufficiently high capital. Specifically, those households with large landholdings $x_i > \bar{x}$ or with $b_{i,t} \geq \bar{b}$ vote over the level of τ_t. The implemented level of τ is the median voter's preferred tax. This 2-dimensional voting threshold is meant to resemble the fact that political power was traditionally vested on the large landowning elites, and during the process of structural transformation, as the urban based classes started to accumulate wealth they also gained access to the political process, either directly through enfranchisement, or indirectly by through the relationship between wealth and access to the circle of influential members of the society.[35]

This completes the picture of the static elements of the model. Using this, I proceed to analyze the dynamics of the model, which provide the full characterization of the equilibrium sequences of factor prices, factor quantities, final output, consumption, and bequests.

Definition 2.1. An equilibrium in this model is a sequence $\{c_{i,t},\ b_{i,t},\ K_t,\ l_{u,t},\ l_{x,t},\ w_t,\ r_{x,t},\ r_{k,t}\ p_t,\ g_t,\ \tau_t\}_{t=0}^{\infty}$ such that individual utility is maximized, the profits of each sector are maximized, markets clear, the theft game is in a Nash equilibrium, and the tax rate and the level of law enforcement are chosen as described in section 2.4.2.6, given X, L, the distribution of land and labor and an initial capital K_0 and its distribution.

[35]Before the introduction of universal suffrage, it was not uncommon for political rights to be dependent on the level of wealth. In England, for example, before the Great Reform Act of 1832 parliamentary enfranchisement at the county level was based on real estate ownership (the forty shilling rule), while at the municipal level diverse parliamentary enfranchisement rules co-existed, some like the burgage ownership or the payment of scot and lot (tax) were clearly dependent on the individual's land tenure and level of capital (Phillips & Wetherell, 1995). The 1832 Reform Act created a uniform parliamentary franchise in the boroughs, by conferring voting rights to all the householders "who occupied premises worth at least £10 per annum" (Phillips & Wetherell, 1995, p. 414). Although, this implied a significant franchise extension, its scope was still limited and less than one fifth of the adult male population had voting rights for the parliamentary elections after the Act. Regarding the local governments, before the 1835 Corporations Act, municipal corporations where largely undemocratic self-perpetuating bodies controlled by oligarchic powers (i.e., wealthy individuals) (Lizzeri & Persico, 2004). Among other things, the Corporations Act reformed the local franchise. The Act established that each ratepayer (tax payer) was entitled to cast one vote to elect the members of the municipal council, and that these (popularly) elected members should compose three quarters of the total municipal council.

2.5 Dynamic Analysis

2.5.1 Aggregate capital accumulation

From the household's utility maximization problem (section 2.4.2.4) it follows that the savings rate (i.e., the fraction of income bequeathed to the next generation) is constant and equal to γ. The law of motion of aggregate capital, taking into account that it fully depreciates, is: $K_{t+1} = \gamma I_t = \gamma \sum_i I_{i,t}$, with aggregate income I_t being

$$I_t = X^{\alpha} (z_t L)^{1-\alpha} + f_{u,t}(\tau) K_t^{\alpha} ((1 - z_t) L)^{1-\alpha}$$

Using the labor market equilibrium (2.4.3) and with $q \equiv (1-\alpha)^{\frac{-1}{\alpha}} (1-\chi)^{\frac{1}{\alpha}}$:

$$I_t = K_t^{\alpha} ((1 - z_t) L)^{1-\alpha} f_{u,t} \left(\frac{1-\alpha}{1-\chi} \frac{z_t}{1-z_t} + 1 \right) = L^{1-\alpha} \frac{\frac{1-\alpha}{1-\chi} qX + f_{u,t}^{\frac{1}{\alpha}} K_t}{\left(qX + f_{u,t}^{\frac{1}{\alpha}} K_t \right)^{1-\alpha}} \tag{2.5.1}$$

Plugging this back into the law of motion of capital

$$K_{t+1} = \gamma I_t = \gamma L^{1-\alpha} \frac{\frac{1-\alpha}{1-\chi} qX + f_{u,t}^{\frac{1}{\alpha}} K_t}{\left(qX + f_{u,t}^{\frac{1}{\alpha}} K_t \right)^{1-\alpha}} = v(K_t)$$

Therefore, the law of motion of aggregate capital does not depend on how the aggregate factors are distributed. Moreover,

Lemma 2.3. *For a given level of τ and with $\chi \leq \bar{\chi}(\alpha) \equiv {}^{\alpha}/_{2}(3-\alpha)$ the aggregate capital has a unique and stable steady state characterized by:*

$$K_{ss} \left(qX + f_u^{\frac{1}{\alpha}} K_{ss} \right)^{1-\alpha} = \gamma L^{1-\alpha} \left(\frac{1-\alpha}{1-\chi} qX + f_u^{\frac{1}{\alpha}} K_{ss} \right)$$

and this steady state is strictly increasing in f_u.

Proof: See Appendix 2.A.1.

From this point on it is assumed that $\chi \leq \bar{\chi}(\alpha)$ holds.

2.5.2 Individual share of capital

From the individual perspective, on the one hand, the shares of the non-reproducible factors ($s_{Xi} = {}^{x_i}/_{X}$ and $s_{Li} = {}^{1}/_{L}$) are exogenous and remain constant for a given dynasty over time. On the other, the share of capital $s_{Ki} = {}^{k_{i,t}}/_{K_t}$ is endogenously determined by the households' savings decisions. Given that the savings rate is constant over time and across households, the share of capital held by generation $t+1$ of dynasty i is equal to the ratio of generation t's income to total income: $s_{Ki,t+1} = I_{i,t}/I_t$. From (2.4.4), the labor market equilibrium (2.4.3) and the definitions of z and q we can rewrite the income of individual i, t as:

$$I_{i,t} = \left(\frac{L}{f_{u,t}^{\frac{1}{\alpha}} K_t + qX} \right)^{1-\alpha} \left(\frac{1-\alpha}{1-\chi} qX \left(\chi \frac{x_i}{X} + \frac{1-\chi}{L} \right) + f_{u,t}^{\frac{1}{\alpha}} K_t \left(\alpha s_{Ki,t} + \frac{1-\alpha}{L} \right) \right)$$

dividing by the aggregate income (2.5.1) and after some algebra one arrives to the law of motion of s_{Ki}:

$$s_{Ki,t+1} = \underbrace{\frac{\frac{1-\alpha}{1-\chi} qX \left(\chi \frac{x_i}{X} + \frac{1-\chi}{L} \right) + \frac{1-\alpha}{L} f_{u,t}^{\frac{1}{\alpha}} K_t}{\frac{1-\alpha}{1-\chi} qX + f_{u,t}^{\frac{1}{\alpha}} K_t}}_{\rho_{0i}} + \underbrace{\frac{\alpha f_{u,t}^{\frac{1}{\alpha}} K_t}{\frac{1-\alpha}{1-\chi} qX + f_{u,t}^{\frac{1}{\alpha}} K_t}}_{\rho_1} s_{Ki,t}$$

$$s_{Ki,t+1} = \rho_{0i} (K_t) + \rho_1 (K_t) s_{Ki,t}$$

which is a linear and non-homogeneous difference equation, with both $\rho_{0i}(.)$ and $\rho_1(.)$ being positive.[36]

Note further that the "slope" coefficient $\rho_1 \in (0, 1)\ \forall K_t$ and $\rho_1' > 0$. The former property implies that if there is a unique and stable steady state for K, then there is a unique and stable steady state for s_{Ki}:[37]

$$s_{Ki,ss} = \frac{\rho_{0i} (K_{ss})}{1 - \rho_1 (K_{ss})} \in [s_{Li}, s_{Xi}]$$

Lemma 2.4. *When aggregate capital is increasing over time (i.e., it is below its steady state value), the individual share of capital (s_{Ki}) follows a monotonic path over time under the following (sufficient) conditions: i) If $s_{Ki,m} \geq s_{Xi} > s_{Li}$, $s_{Ki,t}$ decreases over time $\forall t \geq m$ during the transition towards the steady state; and, ii) If $s_{Ki,m} \leq s_{Xi} < s_{Li}$, $s_{Ki,t}$ increases over time $\forall t \geq m$ during the transition towards the steady state.*

Proof: See Appendix 2.A.1.

Proposition *2.1* and lemma 2.4 imply that during the process of development, as aggregate capital accumulates, dynasties with a share of land below s_{Li} continuously

[36] The coefficients ρ_{0i} and ρ_1 are functions of K_t, therefore they change over time. Moreover, the coefficient ρ_{0i} is also different for different households as it depends positively on s_{xi}.

[37] One can easily show that $s_{Xi} \gtreqless (\rho_{0i}(K))(1-\rho_1(K))^{-1}$ if $s_{Xi} \gtreqless s_{Li}$, and $s_{Li} \gtreqless (\rho_{0i}(K))(1-\rho_1(K))^{-1}$ if $s_{Li} \gtreqless s_{Xi}$, therefore $s_{Ki,ss} \in [s_{Li}, s_{Xi}]$

increase their relative participation in the urban sector. Therefore, for these dynasties the LHS of condition 2.4.5 increases over time while the RHS (Ω_t) decreases.[38] In combination, these dynamic processes mean that for the small landowning and landless dynasties the gain from shifting to a regime with high provision of law enforcement is increasing over time. On the one hand, their individual participation in the urban sector is increasing. On the other hand the economy as a whole is becoming more capital intensive, and in the eyes of a small landowning or landless dynasty these two effects reinforce each other.

For dynasties of large landowners things are more involved during the transition. While the reduction in Ω_t makes them more prone to support the implementation of public law enforcement, their individual share of capital (and so the LHS of 2.4.5) decreases during the transition, making them less likely to support the implementation of $\tau = \bar{\tau}$.

From the perspective of the dynamic evolution of condition (2.4.5), one more thing needs to be taken into account. Namely, that the ordering of the land distribution is reflected in the final distribution of capital. This means that those dynasties with a larger share of land, and so a higher ω_i^x, are also the ones with more means to accumulate capital and thus have a higher ω_i^u. This becomes evident from noting that in steady state $s_{Ki,ss} = (\rho_{0i}(K_{ss}))(1 - \rho_1(K_{ss}))^{-1}$, and that ρ_{0i} is strictly increasing in s_{Xi}. In practice, given the constant savings rate, the long-run distribution of capital reflects the distribution of the non-reproducible factors in the economy: land and labor. As labor is equally distributed across households, in the long-run the distribution of capital is less disperse than the distribution of land. Nevertheless, it is possible to characterize under which conditions the sorting of $\omega_{i,t}^u/\omega_i^x$ remains unchanged over time, and how this sorting depends on s_{Xi}. In particular,

Lemma 2.5. *If $\omega_{i,m}^u/\omega_i^x$ is not increasing in the dynasty's share of land s_{Xi}, then at any point in time $t > m$, $\omega_{i,t}^u/\omega_i^x$ is strictly decreasing in s_{Xi}.* [39]

Proof: See Appendix 2.A.1.

The dynamic positive effect of s_{Xi} on $\omega_{i,t}^u$ (through s_{Ki}) is less than proportional than the direct effect of s_{Xi} on ω_i^x. So even dynasties with higher ω_i^x are also the ones with a higher $\omega_{i,t}^u$, the ratio $\omega_{i,t}^u/\omega_i^x$ is decreasing in s_{Xi} at any point in time. Therefore, for some given initial conditions and transitional dynamics of aggregate capital, those dynasties with larger land shares are in fact the ones less likely to

[38]The negative relationship between Ω_t and K_t can be derived from a series of numeric simulations. See for example figure 2.B.1 in Appendix 2.B.

[39]An intuitive initial condition fulfilling the requirement of this proposition is $s_{Ki,0} = s_{Xi}$. In such case $\omega_{i,0}^u/\omega_i^x$ is the same for all i if $\chi = \alpha$ and it is strictly decreasing in s_{Xi} if $\chi > \alpha$. Alternatively, if the economy starts with no capital ($K_0 = 0$ and so condition 2.4.5 holds with equality), $\omega_{i,1}^u/\omega_i^x$ is decreasing in s_{Xi}, and so the ordering of $\omega_{i,m}^u/\omega_i^x$ with respect to s_{Xi} remains decreasing in s_{Xi} and unchanged over time.

support the implementation of $\tau = \bar{\tau}$ at any t, in spite of the positive relationship between s_{Xi} and $\omega^{u}_{i,t}$. In other words, if there is opposition to the implementation of public law enforcement, this will come from the large landowners even though they have a higher (capital) wealth.

2.6 Results and Discussion

2.6.1 Tax rate τ_t and law enforcement e_t during the process of development

As noted above, the individual preference for τ_t evolves over time depending on the dynasty's share of land. Those with landholdings above s_{Li} experience a reduction in their $\omega^{u}_{i,t}/\omega^{x}_{i}$ ratio over time, which makes them less keen to support $\tau = \bar{\tau}$. And if there is opposition to the emergence of public law enforcement at any point in time, this comes from the dynasties owning the largest shares of land. The evolution of the relative individual gain or loss from the emergence of publicly provided law enforcement is given by the time path of $I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}$. This ratio reveals how much an individual gains (or loses) from the public provision of law enforcement as compared to a situation with no public provision of it.

Taking the absence of public law enforcement as the default, one can construct the time path of $I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}$ for dynasties with different land endowments. With the specific individual factor endowments and the state of aggregate capital at time t one can calculate the individual income if law enforcement is not implemented $I_{i,t}|_{\tau=0}$, and if it is $I_{i,t}|_{\tau=\bar{\tau}}$. Then, assuming that law enforcement is not implemented, one can obtain the factor endowments and the aggregate capital in $t+1$ and calculate again $I_{i,t+1}|_{\tau=0}$ and $I_{i,t+1}|_{\tau=\bar{\tau}}$. This procedure shows how the preferred level of $\tau^{*}_{i,t}$ evolves, provided that the economy remains in a regime with no provision of law enforcement. These paths are indicative of whether the economy is likely to remain with no public law enforcement, or if support for its provision is likely to emerge. The paths in figure 2.6.1 simulate $I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}$ over time for dynasties with different shares of land, and compares it to the indifference level $I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0} = 1$ (represented by the horizontal line). The upper most curve corresponds to a landless dynasty, the middle one to a dynasty with a share of land equal to s_{Li} (i.e., the share that prevails under perfect equality), and the lowest line corresponds to a large landowning dynasty (i.e., $s_{Xi} = 20 s_{Li}$).[40] These simulations illustrate how the relative gain from

[40] Parameters and initial conditions are chosen in such a way that $K_0 = 0$, $s_{Li} = 0.01$. That is, the large landowners in this figure are a 1% of the population and own 20% of the land. In 19th century England and Wales, the top 1% of the population owned between 50 and 60% of the real estate (Lindert, 1986, 1987).

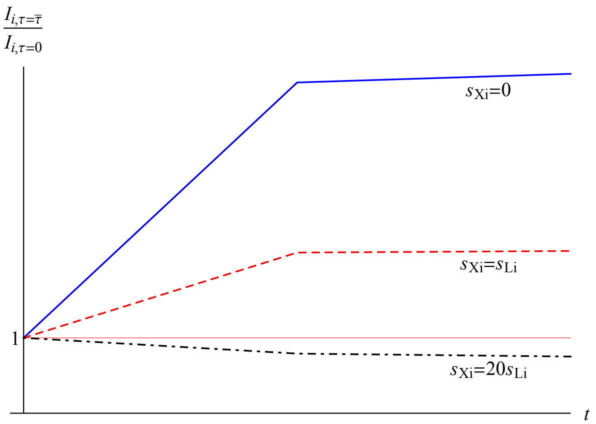

Figure 2.6.1: Income ratio dynamics $\left(I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}\right)$

high protection increases over time for dynasties with no land. It also shows that for dynasties with relatively large landholdings, the effect of a decreasing participation in the urban sector may dominate over the structural transformation of the economy as whole. When that is the case, those dynasties not only lose from the implementation of high law enforcement, but their relative loss increases over time, as the decreasing dot-dashed line shows.

With the help of lemma 2.5, from which we know that $\omega^{u}_{i,t}/\omega^{x}_{i}$ is negatively related to the share of land at any point in time, and some additional internally consistent assumptions it is possible to recreate two potential paths for individual income and law enforcement provision during the process of development.[41]

Assumption (A1): The initial share of capital, $s_{Ki,0}$, is equal to s_{Xi}.

Assumption (A2): K_0 is below the steady state level of capital that arises if τ is permanently set to 0.

Proposition 2.3. *Under (A1) and (A2) land inequality is necessary for the provision of law enforcement to be initially blocked.*

Proof. $\Omega_t < 1$, and under perfect equality $\omega^{u}_{i,t}/\omega^{x}_{i} = 1 \; \forall t$.[42] Thus, under perfect equality the representative individual supports the provision of law enforcement, regardless of the level of development □

Lemma 2.6. *If $\chi\Omega^{0}_{ss} > \alpha$, $s_{Li}\left(1-\alpha-(1-\chi)\,\Omega^{0}_{ss}\right)\left(\chi\Omega^{0}_{ss}-\alpha\right)^{-1} < 1$, and under assumptions (A1) and (A2), there exists $\bar{s}_{Xi} < 1$ such that landowners with a share of land*

[41] Recall that lemma 2.5 establishes that if $\omega^{u}_{i,0}/\omega^{x}_{i}$ is not increasing in s_{Xi} then $I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}$ is strictly decreasing in s_{Xi} for any t.

[42] $\Omega_t < 1$ follows from lemma 2.2 and $\chi \leq \bar{\chi} < \alpha\,(2-\alpha)$.

$s_{Xi} \geq \bar{s}_{Xi}$ *always oppose to the emergence of law enforcement. Where* $\Omega^0_{ss} \in (0, 1)$ *is the steady state value of* Ω *if* τ *is permanently set to* 0.[43]

Proof: See Appendix 2.A.1.

Assumption (A3): The conditions of lemma 2.6 hold (i.e., $\bar{s}_{Xi} < 1$ *exists).*

Assumption (A4): The economy is divided in two groups according to their share of land. The first group is that of the (large) landowners, which hold a share of land $s_{Xi} = s^L_X \geq \bar{s}_{Xi}$. *The second group is that of the landless, i.e.,* $s_{Xi} = s^0_X = 0$, *which constitutes the majority of the population.*

Proposition 2.4. *Under assumptions (A3) and (A4) the economy is permanently trapped in an equilibrium with low law enforcement if* $\bar{b} > b^0_{i,ss}$. *Otherwise there exists a* $\tilde{t} \in (0, \infty)$ *such that for any* $t < \tilde{t}$ *no law enforcement is provided (i.e.,* $\tau_t = 0$*) and for any* $t \geq \tilde{t}$ $\tau_t = \bar{\tau}$.

Proof: Follows directly from the voting allocation process, and lemmas 2.4 and 2.6.

Figure 2.6.2 illustrates the point of this proposition. The figure shows the total income schedules under no provision of law enforcement (the lower schedule) and under public provision of it (the upper schedule). Initially, when only the large landowners have access to voting rights, the implemented level of law enforcement is low. This keeps the net marginal return to capital low, hampering the development of the urban sector and reducing the overall capacity to accumulate. If the wealth requirement to access power is too high, i.e., $\bar{b} > b^0_{i,ss}$, the landless population does not gain access to political rights, the economy remains indefinitely in the regime of low protection, and ends up being trapped in equilibrium E_0. If $\bar{b}$ is low enough, the emergent landless class eventually gains access to voting rights. With this change in the political setting, the economy shifts to a regime of publicly provided law enforcement, favoring a further surge of the urban sector, and allowing to reach a better equilibrium ($E_{\bar{\tau}}$) in the long run.

2.6.2 Discussion

According to the theory (proposition 2.4) during the process of development there may be a transition in the nature of property rights protection: from a regime where the protection of property rights is solely based on private efforts, to one in which the public provision of law enforcement becomes central to protection. This result broadly follows the historical evidence from England presented in section 2.3, where up the 18th century the public provision of law enforcement was virtually nonexistent, and the protection of property rights was largely dependent on private efforts.

[43] $\Omega^0_{ss} < 1$ follows from lemma 2.2 and $\chi \leq \bar{\chi} < \alpha(2-\alpha)$.

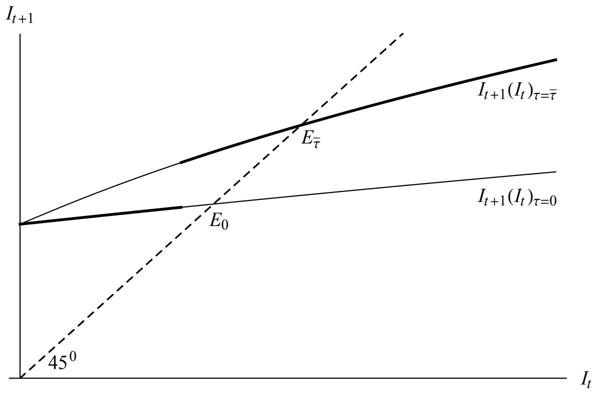

Figure 2.6.2: Total output dynamics [institutional traps]

Besides this general pattern, three specific regularities emerge from the empirical evidence on the relationship between local occupational profiles and the existence of police forces in 19th century England: *i)* inequality in the access to land is associated with a later emergence of law enforcement; *ii)* inequality only plays a role if the economic activity is relatively rural; and, *iii)* there is a positive association between the emergence and size of the police forces and the emergence of a wealthy landless (capitalist) class.

Land inequality In the model, whether and how fast law enforcement emerges depends on the preferences of those with voting rights (i.e., in control of the political process). From the individual perspective the preference for the implementation of law enforcement comes from condition (2.4.5). From it we know that an individual prefers $\tau = 0$ if $\omega^u_{i,t}/\omega^x_i < \Omega_t$. Inequality in the access to land is reflected by LHS of this condition.

As shown in proposition 2.3, in the absence of land inequality and its effect on the distribution of wealth, no individual opposes to the emergence of law enforcement. For $\omega^u_{i,t}/\omega^x_i < \Omega_t$ to hold, the individual participation in the rural sector needs to be relatively large. According to the model this is something that only occurs and is sustained over time if there is land inequality (i.e., there are individuals with $s_{Xi} > s_{Li}$) to begin with. Using lemma 2.5 and *(A4)*, the more unequal the distribution of land (i.e., the larger the share of land per landed individual) the smaller $\omega^u_{i,t}/\omega^x_i$, and the less likely is law enforcement to emerge in the early stages of development when the landed control the political process. So, land inequality is a necessary condition, and a more unequal distribution of land makes the landed more likely to oppose to the emergence of law enforcement.

Urbanization According to proposition 2.3 land inequality is necessary, but it is not sufficient, for the no emergence of law enforcement. The empirical evidence points out that land inequality is only negatively related to the emergence of the police forces, if the level of urbanization of economic activity is low. Ω_t (which is increasing in X/K), can be interpreted as an inverse indicator of how urbanized the overall economic activity is. When economic activity is urbanized, the aggregate cost of implementing law enforcement (i.e., the contraction of the rural sector) is relatively small compared to the gain of implementing it (i.e., a larger and more efficient urban sector).

A deep parameter in the model determining the evolution of Ω_t over time is α. The role of α on the dynamics of Ω_t is two-fold. On the one hand, it determines the pace of aggregate capital accumulation, the higher α the faster the transformation of capital into output and so into further capital. On the other hand, it determines how sensitive is Ω_t to K. If $X/L \geq 1$, a higher α implies a faster accumulation of capital in the initial stages of development. This is the case because a higher α is associated with a higher initial rural output and so a higher aggregate capital in the following periods.

With a faster accumulation of capital, Ω_t contracts at a faster pace. On top of this, a higher α makes Ω_t more sensitive to changes in K (see figure 2.B.1 in appendix 2.B). As capital accumulates the contraction in the production of the rural sector, that results from the implementation of urban law enforcement, becomes smaller relative to the gain of the urban sector from implementing it, and the more so if α is high. Both a faster accumulation of aggregate capital and a higher sensitivity of Ω_t to K makes Ω_t decrease faster over time. If the pace of urbanization (i.e., the pace at which Ω_t decreases) is fast, the level of land inequality is irrelevant for the emergence of law enforcement. As seen in figure 2.6.3, an individual controlling all the land endowment (i.e., $s_{Xi} = 1$, so land inequality is at its maximum), still prefers $\tau = \bar{\tau}$ if α is relatively high, as this implies that Ω_t declines fast enough to overcome the decline in $\omega^u_{i,t}/\omega^x_i$.

Wealthy landless Finally, proposition 2.4 highlights that if the landowners do indeed oppose to the implementation of $\bar{\tau}$, the emergence of the public provision of law enforcement is only possible if there is a large enough group of landless with wealth above $\bar{b}$. That is, a sufficiently large wealthy landless class is necessary to counter the opposition to the provision of law enforcement by the landowners. The theory also speaks to the positive feedback between law enforcement and the accumulation of wealth by the landless. While a sufficiently large capitalist class is necessary for the implementation of law enforcement to gain sufficient political support and emerge, the public provision of law enforcement enhances the allocative efficiency of the urban sector and therefore facilitates a further accumulation of wealth. This feature resembles the positive association between the emergence of the police forces in England and the relative size of a wealthy landless (capitalist) class, while pointing out at the inherent dual causality in this relationship.

Moreover, according to the model, once law enforcement is provided its "intensity" ($e = \zeta\tau Y_u$) is positively associated with the size of the urban economy, which in equilibrium is an increasing function of K. Now, for the sake of the argument suppose that the landless have heterogeneous initial capital endowments. Still, all the landless reach the same level of wealth in steady-state, but some will be ahead in the accumulation process. If the individual level of wealth of the landless in steady-state is larger than $\bar{b}$, then as the economy develops (i.e., as K increases) the fraction of wealthy landless increases (i.e the fraction of landless with $b_i > \bar{b}$ increases, and it eventually becomes equal to 1). Thus, as K increases there is both a relatively larger class of wealthy landless and more intense law enforcement.

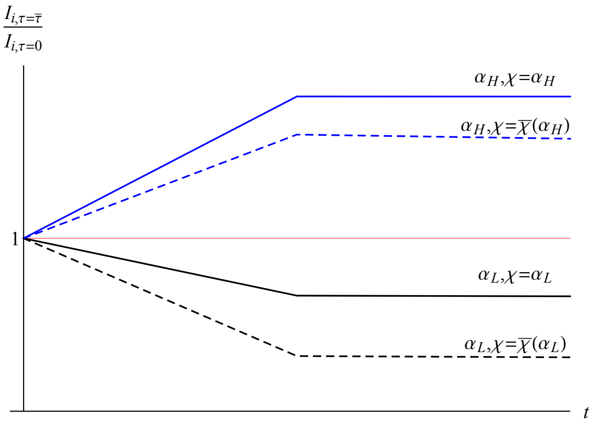

Figure 2.6.3: Income ratio dynamics $\left(I_{i,t}|_{\tau=\bar{\tau}}/I_{i,t}|_{\tau=0}\right)$ [maximum land inequality]

2.7 Conclusions

The theory developed in this chapter shows how the public provision of law enforcement emerges endogenously during the development process. Law enforcement is a central element in the protection of property rights: the higher its provision, the lower the need to spend resources on private protective efforts. Therefore, an adequate provision of law enforcement improves the allocative efficiency of the economy by reducing the amount of resources diverted into protective activities. However, providing law enforcement is costly, and therefore its implementation requires the support of the groups with access to the political process.

According to the theory, in the early stages of development when the large landowners control the political process, the provision of law enforcement remains low and the protection of property rights depends solely on private efforts. The diversion of productive resources into protective activities, as well as the higher level of insecurity prevailing in the absence of strong law enforcement, reduce the net marginal return to physical capital and slow down the development of an urban sector. In the later stages of development, if the pace of urbanization is sufficiently fast or if a sufficiently large wealthy landless class emerges, the provision of law enforcement gains enough political support and it is publicly provided.

These patterns described by the theory are motivated by the historical evidence from England. Before the 19th century England had virtually no public provision of law enforcement. In the absence of public policing, the protection of property rights was mainly left to private efforts. Public law enforcement only emerged later in the development process, with the Metropolitan Police Act of 1829 and the Municipal Corporations Act of 1835 constituting the cornerstones of the "new" police. From a closer perspective the evidence indicates that inequality in the access to land is negatively correlated with the emergence of the police forces in relatively rural boroughs and parishes. Moreover, a relatively larger capitalist class is associated with an earlier and larger paid police force. The theory links the delay in the provision of law enforcement to the combination of land inequality and a low urban development. And, it provides an underpinning for the joint emergence of law enforcement and a wealthy landless (capitalist) class.

The mechanism put forward by the theory rests on the efficiency and distributional effects of the public provision of law enforcement. Due to its preventive nature, public law enforcement improves the overall efficiency of the economy, and leads to a higher level of aggregate income in the long run. However, this efficiency gain is not evenly distributed across all economic activities. The public provision of law enforcement directly benefits the urban sector by reducing the need to divert productive resources into protection. At the same time a more efficient urban sector raises the cost of labor, which is detrimental for the holders of land. As a consequence, individuals deriving their income mainly from urban activities are in favor of the public provision of law enforcement, while individuals with a relatively large participation in the rural sector (i.e., large land holders) may oppose to it.

Appendix 2

2.A Proofs

2.A.1 Proof of Lemmas

Proof of Lemma 2.1

Proof. From the labor market equilibrium (2.4.3), the fraction of labor that stays in the rural sector (z) can be written as

$$z_t = \frac{qX}{f_{u,t}^{\frac{1}{\alpha}} K_t + qX}; \; q \equiv \left(\frac{1-\chi}{1-\alpha}\right)^{\frac{1}{\alpha}}$$

so,

$$\frac{\partial z_t}{\partial \tau} = -\frac{q\frac{X}{K}}{\alpha} \frac{f_{u,t}^{\frac{1}{\alpha}-1} \frac{\partial f_{u,t}}{\partial \tau}}{\left(f_{u,t}^{\frac{1}{\alpha}} + q\frac{X}{K_t}\right)^2} = -\frac{1}{\alpha} z_t \left(1 - z_t\right) \frac{1}{f_{u,t}} \frac{\partial f_{u,t}}{\partial \tau} < 0$$

Back into $\partial I_{i,t}/\partial \tau$:

$$\frac{\partial I_{i,t}}{\partial \tau} = -\frac{(1-\alpha)}{\alpha} \frac{1}{f_{u,t}} \frac{\partial f_{u,t}}{\partial \tau} X^{\alpha} \left(z_t L\right)^{1-\alpha} \omega_i^x \left(1 - z_t\right)$$
$$+ \frac{(1-\alpha)}{\alpha} \frac{1}{f_{u,t}} \frac{\partial f_{u,t}}{\partial \tau} K_t^{\alpha} \left(\left(1 - z_t\right) L\right)^{1-\alpha} f_{u,t} \left(\omega_{i,t}^u\right) \left(z_t + \frac{\alpha}{1-\alpha}\right)$$

Rearranging and using the labor market equilibrium (2.4.3), $\partial I_{i,t}/\partial \tau \gtreqless 0$ is equivalent to

$$\frac{1-\chi}{1-\alpha} \frac{\omega_{i,t}^u}{\omega_i^x} \gtreqless \frac{z_t}{z_t + \frac{\alpha}{1-\alpha}} \tag{2.A.1}$$

Given that $RHS < 1$, $\left(\alpha k_i\right) \left(\left(1-\alpha\right) K\right)^{-1} > \left(\chi x_i\right) \left(\left(1-\chi\right) X\right)^{-1}$ is a sufficient condition for $\partial I_{i,t}/\partial \tau > 0$ for any τ. Also note that the LHS does not depend on τ while the $RHS(\tau)$ is strictly decreasing in τ (through its effect on z). This means that with $\tau \in [0, \bar{\tau}]$, income is strictly increasing in τ if $LHS > RHS\,(0)$, strictly decreasing if $LHS < RHS\,(\bar{\tau})$, or it has a unique minimum if there is a $\tilde{\tau}$ such that $LHS = RHS\,(\tilde{\tau})$. More specifically:

If

$$\frac{1-\chi}{1-\alpha} \frac{\omega_{i,t}^u}{\omega_i^x} > \frac{z_{t,0}}{z_{t,0} + \frac{\alpha}{1-\alpha}}; \; z_{t,0} \equiv z_t|_{\tau=0} = \frac{q\frac{X}{K}}{\left(\frac{1}{4}\right)^{\frac{1}{\alpha}} + q\frac{X}{K}}$$

then income is always increasing in τ, and so $I_{i,t}$ is maximum at $\tau = \bar{\tau}$

If

$$\frac{1-\chi}{1-\alpha}\frac{\omega_{i,t}^{u}}{\omega_{i}^{x}} < \frac{z_{t,\bar{\tau}}}{z_{t,\bar{\tau}} + \frac{\alpha}{1-\alpha}};\; z_{t,\bar{\tau}} \equiv z_t|_{\tau=\bar{\tau}} = \frac{q\frac{X}{K}}{\left(\frac{\zeta}{1+\zeta}\right)^{\frac{1}{\alpha}} + q\frac{X}{K}}$$

then income is always decreasing in τ, and so $I_{i,t}$ is maximum at $\tau = 0$

If

$$\frac{z_{t,\bar{\tau}}}{z_{t,\bar{\tau}} + \frac{\alpha}{1-\alpha}} < \frac{1-\chi}{1-\alpha}\frac{\omega_{i,t}^{u}}{\omega_{i}^{x}} < \frac{z_{t,0}}{z_{t,0} + \frac{\alpha}{1-\alpha}}$$

then, individual's i income has a global minimum in the interval $\tau \in (0, \bar{\tau})$, and $I_{i,t}$ could be maximum either at $\tau = 0$ or at $\tau = \bar{\tau}$. □

Proof of Lemma 2.2

Proof. Using the definition of z, $\Omega_t < 1$ is equivalent to:

$$q^{1-\alpha}\frac{X}{K_t}\frac{\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha} - \left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha}}{f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha} - f_{u,t}\left(0\right)^{\frac{1}{\alpha}}\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha}} < 1$$

Rearranging this expression

$$\frac{f_{u,t}\left(0\right)^{\frac{1}{\alpha}} + q^{1-\alpha}\frac{X}{K}}{\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha}} < \frac{f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}} + q^{1-\alpha}\frac{X}{K}}{\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}} + q\frac{X}{K}\right)^{1-\alpha}}$$

Let us define $F\left(s\right) \equiv \left(s + q^{1-\alpha}X/K\right)\left(s + qX/K\right)^{\alpha-1}$, so that the above condition reads $F\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}}\right) < F\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}\right)$. Given that $f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}} > f_{u,t}\left(0\right)^{\frac{1}{\alpha}}$, $F' > 0$ is sufficient for $\Omega_t < 1$. Taking the first derivative of F with respect to s and rearranging, F' is greater than zero if

$$\alpha s + q\frac{X}{K}\left(1 - \left(1-\alpha\right)q^{-\alpha}\right) > 0$$

Noting that αs is strictly positive, $1 - \left(1-\alpha\right)q^{-\alpha} \geq 0$ is sufficient for $F' > 0$. Using $q \equiv \left(1-\alpha\right)^{\frac{1}{\alpha}}\left(1-\chi\right)^{\frac{-1}{\alpha}}$ this is,

$$1 - \chi - \left(1-\alpha\right)^2 \geq 0 \leftrightarrow \chi \leq \alpha\left(2-\alpha\right)$$

Therefore $\chi \leq \alpha(2-\alpha)$ is sufficient for F to be increasing, and so it is sufficient for $\Omega_t < 1$. □

Proof of Lemma 2.3

Proof. The law of motion of K is given by

$$K_{t+1} = \gamma L^{1-\alpha} \frac{\frac{1-\alpha}{1-\chi} qX + f_{u,t}^{\frac{1}{\alpha}} K_t}{\left(qX + f_{u,t}^{\frac{1}{\alpha}} K_t\right)^{1-\alpha}} = v(K_t)$$

First note that $v(0) > 0$. The first derivative of v w.r.t K_t is

$$v' = \frac{f_u^{\frac{1}{\alpha}} \left(qX + f_u^{\frac{1}{\alpha}} K\right)^{1-\alpha}}{\left(qX + f_u^{\frac{1}{\alpha}} K\right)^{2(1-\alpha)}} \\ \frac{-(1-\alpha)\left(qX + f_u^{\frac{1}{\alpha}} K\right)^{-\alpha} f_u^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{1-\chi} qX + f_u^{\frac{1}{\alpha}} K\right)}{\left(qX + f_u^{\frac{1}{\alpha}} K\right)^{2(1-\alpha)}}$$

$$v' > 0 \rightarrow qX \left(1 - \frac{(1-\alpha)^2}{1-\chi}\right) > -\alpha f_u^{\frac{1}{\alpha}} K$$

$\chi \leq \alpha(2-\alpha)$ is sufficient for this to hold. Moreover, $\lim_{K\rightarrow\infty} v' = 0$. The second derivative of v with respect to K is:

$$v'' = -(1-\alpha) \frac{f_u^{\frac{2}{\alpha}}}{\left(qX + f_u^{\frac{1}{\alpha}} K\right)^{2-\alpha}} \\ - \frac{(1-\alpha) f_u^{\frac{2}{\alpha}}}{\left(qX + f_u^{\frac{1}{\alpha}} K\right)^{3-\alpha}} \left(qX \left(1 - (2-\alpha)\frac{1-\alpha}{1-\chi}\right) - (1-\alpha) f_u^{\frac{1}{\alpha}} K\right)$$

and $v'' < 0$ if

$$-\left(qX + f_u^{\frac{1}{\alpha}} K\right) - qX\left(1 - (2-\alpha)\frac{1-\alpha}{1-\chi}\right) + (1-\alpha) f_u^{\frac{1}{\alpha}} K < 0$$

$$\leftrightarrow -qX - qX\left(1 - (2-\alpha)\frac{1-\alpha}{1-\chi}\right) - \alpha f_u^{\frac{1}{\alpha}} K < 0$$

$$\leftrightarrow -qX\left(2 - (2-\alpha)\frac{1-\alpha}{1-\chi}\right) - \alpha f_u^{\frac{1}{\alpha}} K < 0$$

Therefore, $\chi \leq \alpha/2\,(3-\alpha)$ is a sufficient for $v(.)$ to be always increasing and concave in K (note that $\alpha/2\,(3-\alpha) < \alpha\,(2-\alpha)$ so that the concavity condition is stricter than the positive slope condition). Therefore, for a given τ and with $\chi \leq \alpha/2\,(3-\alpha)$ aggregate capital has a unique and stable steady state characterized by:

$$K_{ss}\left(qX + f_u^{\frac{1}{\alpha}} K_{ss}\right)^{1-\alpha} = \gamma L^{1-\alpha}\left(\frac{1-\alpha}{1-\chi} qX + f_u^{\frac{1}{\alpha}} K_{ss}\right)$$

Moreover, $\chi \leq \alpha\,(2-\alpha)$ is also sufficient for v to be increasing in f_u. Therefore, if $\chi \leq \alpha/2\,(3-\alpha)$ holds, K_{t+1} increases with f_u for any K_t, and so the steady state value of K is necessarily higher. □

Proof of Lemma 2.4

Proof. Defining $\bar{s}_{Ki}\,(K_t)$ as the level of s_{Ki} that solves $s_{Ki,t+1} = s_{Ki,t}$ given K_t:

$$\bar{s}_{Ki,t} \equiv \frac{\rho_{i0}\,(K_t)}{1-\rho_1\,(K_t)} = \frac{\frac{1-\alpha}{1-\chi} qX\left(\chi\frac{x_i}{X} + \frac{1-\chi}{L}\right) + \frac{1-\alpha}{L} f_m^{\frac{1}{\alpha}} K}{\frac{1-\alpha}{1-\chi} qX + (1-\alpha)\, f_m^{\frac{1}{\alpha}} K}$$

$$\frac{\partial \bar{s}_{Ki,t}}{\partial K_t} = \frac{f_u^{\frac{1}{\alpha}}\left(\frac{1-\alpha}{L}\right)}{\left(\frac{1-\alpha}{1-\chi} qX + (1-\alpha) f_u^{\frac{1}{\alpha}} K\right)} - \frac{f_u^{\frac{1}{\alpha}}(1-\alpha)\left(\frac{1-\alpha}{1-\chi} qX\left(\chi\frac{x_i}{X} + \frac{1-\chi}{L}\right) + \frac{1-\alpha}{L} f_u^{\frac{1}{\alpha}} K\right)}{\left(\frac{1-\alpha}{1-\chi} qX + (1-\alpha) f_u^{\frac{1}{\alpha}} K\right)^2}$$

Therefore, $\partial \bar{s}_{K,t}/\partial K_t \gtreqless 0$ is equivalent to

$$(1-\alpha)\,\chi\left(\frac{1}{L} - \frac{x_i}{X}\right) \gtreqless 0$$

Hence if $s_{Xi} > s_{Li}$ then $\partial \bar{s}_{K,t}/\partial K_t < 0$. Moreover, from the definition of $\bar{s}_{Ki,t}$, $s_{Ki,t} \geq s_{Xi}$ and $s_{Xi} > s_{Li}$ are sufficient for $s_{Ki,t} > \bar{s}_{Ki,t}$. To see this, set $s_{Ki,t} = s_{Xi}$ and compare to $\bar{s}_{Ki,t}$

$$s_{Ki,t} = s_{Xi} \gtreqless \frac{\frac{1-\alpha}{1-\chi} qX\left(\chi s_{Xi} + (1-\chi)\, s_{Li}\right) + (1-\alpha)\, f_m^{\frac{1}{\alpha}} K s_{Li}}{\frac{1-\alpha}{1-\chi} qX + (1-\alpha)\, f_m^{\frac{1}{\alpha}} K} \equiv \bar{s}_{Ki,t}$$

which can be rewritten as

$$s_{Xi}\left(\frac{1}{1-\chi} qX + f_m^{\frac{1}{\alpha}} K\right) \gtreqless \frac{1}{1-\chi} qX\left(\chi s_{Xi} + (1-\chi)\, s_{Li}\right) + f_m^{\frac{1}{\alpha}} K s_{Li}$$

and reduces to

$$s_{Xi} \gtreqless s_{Li}$$

Now, assume that for an arbitrary $t \geq 0$ $K_t < K_{ss}$ (i.e., K is increasing during the transition), that $s_{Ki,t} \geq s_{Xi} > s_{Li}$ (i.e., $\bar{s}_{Ki,t}$ is decreasing over time and $s_{Ki,t} > \bar{s}_{Ki,t}$). From $s_{Ki,t} > \bar{s}_{Ki,t}$ it immediately follows that $s_{Ki,t} > s_{Ki,t+1}$:

$$s_{Ki,t} > \frac{\rho_{i0}\left(K_t\right)}{1-\rho_1\left(K_t\right)} = \bar{s}_{K,t} \longleftrightarrow s_{Ki,t} > \rho_{i0}\left(K_t\right) + \rho_1\left(K_t\right) s_{Ki,t} = s_{Ki,t+1}$$

Using $\bar{s}_{Ki,t} > \bar{s}_{Ki,t+1}$ (which comes from the conditions for $\bar{s}_{Ki}$ to follow a decreasing path), it follows that

$$\rho_{i0}\left(K_t\right) + \rho_1\left(K_t\right) \bar{s}_{Ki,t+1} > \bar{s}_{Ki,t+1}$$

and as $s_{Ki,t} > \bar{s}_{Ki,t} > \bar{s}_{Ki,t+1}$, then

$$\rho_{i0}\left(K_t\right) + \rho_1\left(K_t\right) s_{Ki,t} > \bar{s}_{Ki,t+1} \longleftrightarrow s_{Ki,t+1} > \bar{s}_{K,t+1}$$

Hence, provided that $K_m < K_{ss}$: *i)* $s_{Ki,m} > \bar{s}_{Ki,m}$ (for which $s_{Ki,m} \geq s_{Xi} > s_{Li}$ is a sufficient condition) and $\bar{s}_{Ki,t}$ decreasing over time (for which $s_{Xi} < s_{Li}$ is necessary), are sufficient for s_{Ki} to follow a decreasing trajectory over time; following the same arguments, *ii)* $s_{Ki,m} < \bar{s}_{Ki,m}$ (for which $s_{Ki,m} \leq s_{Xi} < s_{Li}$ is a sufficient condition), and $\bar{s}_{Ki}$ increasing over time (for which $s_{Xi} < s_{Li}$ is necessary) are sufficient for s_{Ki} to follow an increasing trajectory over time. □

Proof of Lemma 2.5

Proof. Defining $m_{i,t} \equiv \frac{\omega^u_{i,t}}{\omega^x_i})$

$$m_{i,t+1} \equiv \frac{\alpha s_{Ki,t+1} + (1-\alpha)\, s_{Li}}{\omega^x_i} = \alpha \frac{\frac{1-\alpha}{1-\chi} q X \omega^x_i + f_u^{\frac{1}{\alpha}} K \omega^u_{i,t}}{I_t \omega^x_i} + (1-\alpha)\frac{s_{Li}}{\omega^x_i}$$

$$m_{i,t+1} = \underbrace{\alpha \frac{\frac{1-\alpha}{1-\chi} q X}{\frac{1-\alpha}{1-\chi} q X + f_u^{\frac{1}{\alpha}} K} + (1-\alpha)\frac{s_{Li}}{\omega^x_i}}_{\equiv d_i} + \underbrace{\alpha \frac{f_u^{\frac{1}{\alpha}} K}{\frac{1-\alpha}{1-\chi} q X + f_u^{\frac{1}{\alpha}} K}}_{e} m_{i,t}$$

$$m_{i,t+1} = d_i\left(K_t\right) + e\left(K_t\right) m_{i,t}$$

The dynamics of m_i fully resemble those of s_{Ki}. As $e' > 0$ and $e \in (0,\, 1)$ $\forall K_t$, a unique and stable steady state in K implies that there is a unique and stable steady state in m_i. Note further that $d'_i < 0$. Defining $\bar{m}_{i,t}$ in a similar fashion to $\bar{s}_{Ki,t}$, namely $\bar{m}_{i,t}(K_t) \equiv d_i\left(K_t\right)\left(1-e\left(K_t\right)\right)^{-1}$, it is obtained that $\partial \bar{m}_{i,t}(K_t)/\partial K_t \gtreqless 0$ if $\tilde{s}_X \gtreqless s_{Xi}$.

Back to relationship between $m_{i,t}$ and s_{Xi}, note that $d_i(K_t)$ is decreasing in s_{Xi} while $e(K_t)$ does not depend on individual endowments. In other words, at any point in time the $m_{i,t+1}$ ($m_{i,t}$) schedules of all individuals are parallel, and those with a higher s_{Xi} will have a lower $m_{i,t+1}$ ($m_{i,t}$) schedule. Therefore, if $m_{i,0}$ is not increasing in s_{Xi}, those with a higher s_{Xi} will always have a lower m_i. □

Proof of Lemma 2.6

Proof. From condition (2.4.5) we know that an individual prefers $\tau = 0$ if

$$\frac{\omega^u_{i,t}}{\omega^x_i} < \Omega_t$$

A sufficient condition for this to hold at any point in time is

$$\frac{1}{\omega^x_i} \max_t \left\{\omega^u_{i,t}\right\} |_{\tau=0} \leq \min_t \left\{\Omega_t\right\} |_{\tau=0} \tag{2.A.2}$$

Where $\max_t \left\{\omega^u_{i,t}\right\} |_{\tau=0}$ and $\min_t \left\{\Omega_t\right\} |_{\tau=0}$ respectively are the maximum value of $\omega^u_{i,t}$ and the minimum value of Ω_t over time, provided that $\tau = 0$ is permanently implemented. From proposition 2.4, $K_0 < K_{ss}$ and $s_{Ki,0} = s_{Xi} > s_{Li}$ imply that $s_{Ki,t}$ and so $\omega^u_{i,t}$ are decreasing over time. Therefore $\max_t \left\{\omega^u_{i,t}\right\} |_{\tau=0} = \omega^u_{i,0} = \alpha s_{Xi} + (1-\alpha) s_{Li}$. Moreover, given that Ω_t is decreasing in K, $\min_t \left\{\Omega_t\right\} |_{\tau=0} = \Omega^0_{ss}$. Using these into (2.A.2) and rearranging, provided that $\chi\Omega^0_{ss} - \alpha > 0$, then the sufficient condition is equivalent to

$$s_{Xi} \geq \bar{s}_{Xi} \equiv s_{Li} \frac{\left(1 - \alpha - (1-\chi)\,\Omega^0_{ss}\right)}{\chi\Omega^0_{ss} - \alpha}$$

Note that $\bar{s}_{Xi} > s_{Li}$, hence $s_{Xi} > \bar{s}_{Xi}$ implies $s_{Xi} > s_{Li}$. □

2.A.2 Proofs of Propositions

Proof of Proposition 2.1

Proof. $I_{i,t}$ is maximum at $\tau = \bar{\tau}$ (rather than at $\tau = 0$) if $I_{i,t}|_{\tau=\bar{\tau}} > I_{i,t}|_{\tau=0}$. Using (2.4.4)

$$\begin{aligned} I_{i,t}|_{\tau=\bar{\tau}} &= X^\alpha \left(z_{t,\bar{\tau}} L\right)^{1-\alpha} \omega^x_i + f_{u,t}(\bar{\tau})\, K^\alpha \left((1 - z_{t,\bar{\tau}})\, L\right)^{1-\alpha} \omega^u_{i,t} \\ &> X^\alpha \left(z_{t,0} L\right)^{1-\alpha} \omega^x_i + f_{u,t}(0)\, K^\alpha \left((1 - z_{t,0})\, L\right)^{1-\alpha} \omega^u_{i,t} = I_{i,t}|_{\tau=0} \end{aligned}$$

which can be rewritten as

$$\frac{\omega_{i,t}^{u}}{\omega_{i}^{x}} > \frac{1-\alpha}{1-\chi}\left(q\frac{X}{K_t}\right)^{\alpha}\frac{z_{t,0}^{1-\alpha}-z_{t,\bar{\tau}}^{1-\alpha}}{f_{u,t}\left(\bar{\tau}\right)\left(1-z_{t,\bar{\tau}}\right)^{1-\alpha}-f_{u,t}\left(0\right)\left(1-z_{t,0}\right)^{1-\alpha}} \equiv \Omega_t \qquad (2.A.3)$$

Given that z is strictly decreasing in τ for $\tau < \bar{\tau}$, Ω_t is positive. Furthermore,

$$\frac{1-\chi}{1-\alpha}\Omega_t = q\frac{X}{K_t}\frac{\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{1-\alpha}-\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{1-\alpha}}{f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{1-\alpha}-f_{u,t}\left(0\right)^{\frac{1}{\alpha}}\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{1-\alpha}} \gtreqless 1$$

which is equivalent to

$$\frac{\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)}{\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{\alpha}}-\frac{\left(f_{u,t}\left(\bar{\tau}\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)}{\left(f_{u,t}\left(0\right)^{\frac{1}{\alpha}}+q\frac{X}{K_t}\right)^{\alpha}} \gtreqless 0$$

Given that $f_{u,t}\left(0\right) < f_{u,t}\left(\bar{\tau}\right)$ the last expression is < 0, and therefore

$$\Omega_t < \left(1-\alpha\right)\left(1-\chi\right)^{-1}$$

□

2.B Figures

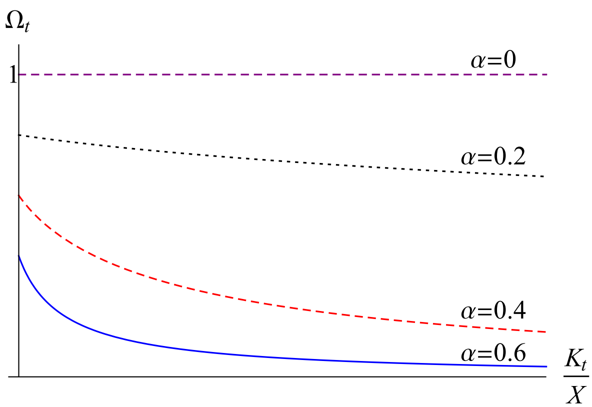

Figure 2.B.1: Urbanization and aggregate capital

2.C Data

2.C.1 Occupations in the 1831 census

2.C.1.1 Agricultural occupations and agricultural inequality

The exact question dealing with the agricultural occupations is: "*How many Males upwards of Twenty Years old are employed in Agriculture, including Graziers, Cowkeepers, Shepherds, and other Farm Servants, Gardeners (not taxed or taxable as Male Servants), and Nurserymen? In answering this Question, you will carefully distinguish these Males into Three Classes; viz; First, Occupiers of Land who constantly employ and pay One or more than One Labourer or Farm Servant in Husbandry; Secondly, Occupiers of Land who employ no Labourer other than of their own Family; Thirdly, Labourers in Husbandry and Farm Servants employed by Occupiers of the First Class*" (GBHG, 2004).

The measure of inequality in the access to agricultural land uses the three categories in which the agricultural male population is classified, namely: *a)* Occupiers employing laborers; *b)* Occupiers not employing laborers; and, *c)* Landless laborers. Specifically the inequality measure is:

$$LandIneq_j = \frac{Agricultural\ laborers_j}{Agricultural\ occupiers_j} = \frac{c_j}{a_j + b_j}$$

2.C.1.2 Urban occupations

Urban occupations are originally separated in 4 groups (GBHG, 2004):

1. Employed in Manufacture
2. Employed in Retail Trade or Handicraft
3. Merchants, Capitalists, Bankers . . . , and other Educated Men
4. Non-agricultural laborers

The main variable of interest in the analysis comes from the third category, to which I refer as the "Capitalists", which measures the extent of the local capitalist class and so how large was landless elite.

The size of the adult male population "Employed in manufacturing or trade", comes from adding up categories 1 and 2. While the size of the non-agricultural laborer population is simply the size of category 4.

2.C.2 Sample

Due to the limitations of the police and census data, the exercises dealing with the existence of police forces (dichotomous variable) consist of 181 observations of which the majority are boroughs originally reformed in 1835.

For some of the police forces there is evidence of existence by 1835 but their size is unknown (Clark, 2014), therefore when looking at the size of the police forces in 1835 the sample is reduced to 145 observations. Out of these, 86 had no paid police force by 1835, implying a strong left-censoring of the dependent variable of interest (size of the police force) at zero. For this reason, and in order to correctly account for the information provided by an observed zero, I rely on Tobit models as the estimation method. All the specifications include robust standard errors clustered at the ancient hundreds.

Table 2.C.1: List of boroughs in the sample

Borough	Ancient County	First year police	Borough	Ancient County	First year police	Borough	Ancient County	First year police
Bedford	Bedfordshire	1836	Romsey	Hampshire	1831	Shrewsbury	Shropshire	1755
Dunstable	Bedfordshire	1865	Ryde	Hampshire	1869	Wenlock	Shropshire	1836
Luton	Bedfordshire	1876	Winchester	Hampshire	1770	Bath	Somerset	1757
Abingdon	Berkshire	1825	Hereford	Herefordshire	1783	Bridgwater	Somerset	1826
Newbury	Berkshire	1825	Leominster	Herefordshire	1836	Chard	Somerset	1850
Reading	Berkshire	1827	Hertford	Hertfordshire	1789	Yeovil	Somerset	1854
Wallingford	Berkshire	1794	St Albans	Hertfordshire	1803	Burslem	Staffordshire	1825
Windsor	Berkshire	1768	Godmanchester	Huntingdonshire	1836	Burton upon Trent	Staffordshire	
Buckingham	Buckinghamshire	1836	Huntingdon	Huntingdonshire	1836	Lichfield	Staffordshire	1836
Chepping Wycombe	Buckinghamshire	1812	Canterbury	Kent	1786	Newcastle under Lyme	Staffordshire	1834
Birkenhead	Cheshire	1833	Deal	Kent	1811	Stafford	Staffordshire	1830
Chester	Cheshire	1761	Dover	Kent	1777	Stoke upon Trent	Staffordshire	1910
Congleton	Cheshire	1841	Folkestone	Kent	1795	Tamworth	Staffordshire	1841
Hyde	Cheshire	1899	Gravesend	Kent	1822	Walsall	Staffordshire	1824
Macclesfield	Cheshire	1813	Hythe	Kent	1855	Wolverhampton	Staffordshire	1837
Stalybridge	Cheshire	1830	Maidstone	Kent	1818	Beccles	Suffolk	1795
Stockport	Cheshire	1826	Margate	Kent	1812	Bury St Edmunds	Suffolk	1836
Bodmin	Cornwall	1854	Sandwich	Kent	1855	Eye	Suffolk	1836
Falmouth	Cornwall	1847	Tenterden	Kent	1836	Southwold	Suffolk	1786
Helston	Cornwall	1836	Accrington	Lancashire	1882	Sudbury	Suffolk	1836
Launceston	Cornwall	1841	Ashton-under-Lyne	Lancashire	1827	Godalming	Surrey	1825
Liskeard	Cornwall	1836	Barrow-in-Furness	Lancashire	1881	Guildford	Surrey	1758
Penryn	Cornwall	1853	Blackburn	Lancashire	1852	Kingston upon Thames	Surrey	1773
Penzance	Cornwall	1836	Bootle cum Linacre	Lancashire	1887	Arundel	Sussex	1836
St Ives	Cornwall	1842	Burnley	Lancashire	1819	Chichester	Sussex	1836
Truro	Cornwall	1839	Bury	Lancashire		Hastings	Sussex	1831
Durham and Framwellgate	County Durham	1789	Clitheroe	Lancashire	1836	Rye	Sussex	1836
Gateshead	County Durham	1814	Lancaster	Lancashire	1824	Birmingham	Warwickshire	1769
Hartlepool	County Durham	1851	Liverpool	Lancashire	1744	Coventry	Warwickshire	1789
South Shields	County Durham	1830	Manchester	Lancashire	1792	Royal Leamington Spa	Warwickshire	1825
Stockton-on-Tees	County Durham	1820	Preston	Lancashire	1815	Stratford-on-Avon	Warwickshire	1837
Sunderland	County Durham	1810	Rochdale	Lancashire	1825	Warwick	Warwickshire	1851
Carlisle	Cumberland	1827	Southport	Lancashire	1870	Calne	Wiltshire	1836
Chesterfield	Derbyshire	1836	St Helens	Lancashire	1887	Chippenham	Wiltshire	1836
Derby	Derbyshire	1836	Warrington	Lancashire	1838	Devizes	Wiltshire	1825
Glossop	Derbyshire	1867	Wigan	Lancashire	1836	Marlborough	Wiltshire	1836
Barnstaple	Devon	1836	Leicester	Leicestershire	1836	Salisbury	Wiltshire	1814
Bideford	Devon	1836	Boston	Lincolnshire	1834	Bewdley	Worcestershire	1852
Dartmouth	Devon	1836	Grantham	Lincolnshire	1836	Droitwich	Worcestershire	1836
Exeter	Devon	1805	Great Grimsby	Lincolnshire	1846	Dudley	Worcestershire	1791
Great Torrington	Devon	1836	Louth	Lincolnshire	1825	Evesham	Worcestershire	1822
Plymouth	Devon	1824	Stamford	Lincolnshire	1832	Kidderminster	Worcestershire	1812
South Molton	Devon	1842	Great Yarmouth	Norfolk	1809	Worcester	Worcestershire	1823
Tiverton	Devon	1836	Kings Lynn	Norfolk	1802	Barnsley	Yorkshire	1822
Blandford Forum	Dorset	1856	Norwich	Norfolk	1805	Bradford	Yorkshire	1803
Bridport	Dorset	1784	Thetford	Norfolk	1836	Dewsbury	Yorkshire	1863
Dorchester	Dorset	1774	Daventry	Northamptonshire	1805	Doncaster	Yorkshire	1802
Lyme Regis	Dorset	1836	Northampton	Northamptonshire	1788	Halifax	Yorkshire	1823
Poole	Dorset	1836	Peterborough	Northamptonshire	1790	Huddersfield	Yorkshire	1820
Shaftesbury	Dorset	1836	Berwick upon Tweed	Northumberland	1837	Kingston upon Hull	Yorkshire	1754
Weymouth and Melcombe Regis	Dorset	1847	Morpeth	Northumberland	1836	Leeds	Yorkshire	1815
Colchester	Essex	1836	Newcastle upon Tyne	Northumberland	1762	Middlesbrough	Yorkshire	1841
Harwich	Essex	1811	Tynemouth	Northumberland	1850	Pontefract	Yorkshire	1836
Maldon	Essex	1853	East Retford	Nottinghamshire	1836	Richmond	Yorkshire	1839
Cheltenham	Gloucestershire	1821	Newark upon Trent	Nottinghamshire	1821	Ripon	Yorkshire	1836
Gloucester	Gloucestershire	1821	Nottingham	Nottinghamshire	1820	Rotherham	Yorkshire	1801
Tewkesbury	Gloucestershire	1785	Banbury	Oxfordshire	1824	Scarborough	Yorkshire	1840
Andover	Hampshire	1836	Oxford	Oxfordshire	1825	Sheffield	Yorkshire	1801
Basingstoke	Hampshire	1815	Bridgnorth	Shropshire	1836	Wakefield	Yorkshire	1848
Newport	Hampshire	1785	Ludlow	Shropshire	1792			
Portsmouth	Hampshire	1768	Oswestry	Shropshire	1836			

Chapter 3

Fiscal Weakness, the (Under-)Provision of Public Services, and Institutional Reform[1]

Abstract

The fact that many developing countries spend little on growth-promoting public services is often blamed on "fiscal weakness", i.e., on low public revenues. This chapter studies the consequences of an exogenous rise in public revenues in a model where the government has three different spending alternatives: Public services, transfers, and repression. We further examine how exogenous increases in public revenues affect the institutions required for economic growth. Our framework delivers two main insights. First, at high levels of public revenues, additional revenues reduce the provision of growth-promoting public services in the short run because under-spending on such services—next to repression—becomes a pillar of the government's strategy to secure power. Second, we find that a rise in public revenues can improve institutional quality in the long run. Our model therefore does not support the often voiced view that inflows of public resources *necessarily* undercut the institutions required for economic growth.

[1]This chapter is the result of joint work with Manuel Oechslin.

3.1 Introduction

It is undisputed that the state plays an important role in the process of economic development. For instance, in an environment that offers little protection against expropriation by parasitic elites or mafias, investment levels tend to be low and growth is anemic (e.g., Acemoglu & Johnson, 2005). Similarly, without adequate investment in public infrastructure (transport; electricity; telecommunications), economic growth can hardly be sustained (e.g., Röller & Waverman, 2001). Given these observations, it is natural to conclude that the lack of growth might at least partially be the result of "fiscal weakness": If the state's capacity to extract resources from the economy is low, as is the case in many developing countries, the government might not command the resources necessary to play a key developmental role (e.g., Herbst, 2000).[2] A closely related conjecture holds that an increase in the resources available to a fiscally weak government would promote the provision of public goods and hence spur economic growth (e.g., Sachs, 2006). This kind of idea also seems to inform the UN's current "Financing For Development" agenda, which estimates the necessary infrastructure investment in developing countries to be about $1.5 trillion p.a. and calls on rich countries to contribute towards the funding of these needs (United Nations Department of Economic and Social Affairs, DESA, 2015).

But recent experiences with sudden increases in resources earmarked for development spending sound a note of caution. Consider, for example, the case of Chad, a country which has experienced a huge increase in public revenues after the completion (in 2003) of an oil pipeline connecting the country's oil fields with the Gulf of Guinea. Between 2000 and 2010, the annual revenues generated by the exploitation of natural resources rose by a factor of 13, from $10.2 per capita (p.c.) to $129.8 p.c. (World Bank, 2015). Yet, in spite of the resulting surge in public revenues, there is little evidence suggesting a marked rise in the spending on sectors that were identified to be key for development. Quite the contrary; Chad's annual public health spending, one of the few development spending categories for which time-series data is available, fell from $4.5 p.c. in 2000 to just under $3.4 p.c. in 2010. During the same period, military spending rose from $2.6 p.c. to $52.5 p.c. (Stockholm Peace Research Institute, SIPRI, 2015), arguably in response to attempted coups and rebel attacks (Pegg, 2009). This allocation of public revenues became feasible after the Chadian government (in late 2005) significantly weakened provisions which required the allocation of 85% of the oil revenues into poverty reduction priority sectors.[3]

[2] More recently, a new literature has emerged that endogenizes fiscal capacity and explores why developing countries might fail to make progress in this dimension over time (see, for example, Besley & Persson, 2009, 2013).

[3] When negotiating the financing of the pipeline with the World Bank, the Chadian government

Can similar harmful effects of skyrocketing public revenues be found in other countries as well? A look at the evidence suggests that one of the worrying patterns observed in Chad, rising public revenues going hand in hand with falling development spending, may not be a singular case among countries with weak constraints on the executive. Using a panel dataset that includes up to 45 countries with relatively unconstrained executives, we find that the relationship between rents from natural resources (which generally boost public revenues through taxes and royalties) and public health spending is hump-shaped. Our estimates suggest that, other things equal, an exogenous increase in the rents from natural resources leads to a rise in public health spending as long as the resource rents are less than $370 p.c.; and to a fall in public health spending if the rents are greater than this threshold.[4]

Against this background, the present chapter proposes a theoretical framework to systematically explore the effects of exogenous increases in public revenues in an environment where the incumbent government faces only weak constraints on the allocation of public revenues. Our model is rich in the sense that the government has a number of ways in which it can spend public revenues. In particular, they can be used (i) to finance public services that serve as inputs to private production (as, e.g., in Barro, 1990); (ii) to finance transfers, which can be group-specific to the extent the political institutions allow for this (as, e.g., in Besley & Persson, 2011b); and (iii) to pay for the repression of opposition groups that compete for power in a contest with sequential input choice (as, e.g., in Leininger & Yang, 1994). In an extension of the basic framework, we further allow for an endogenous evolution of the political institutions. Our main interest lies in how an exogenous rise in the resources available to the government affects the division of public revenues into the three categories of public services, transfers, and repression. We are further interested in whether large inflows of public resources necessarily undercut the institutions required to promote long-run growth, as was suggested by Rajan and Subramanian (2007), Deaton (2013), and others.

Our framework delivers two main insights. First, if public revenues are beyond a critical threshold, a further rise in revenues lowers the provision public services and hence reduces private-sector output. Put differently, when pushed past a critical threshold, additional revenues are more than fully absorbed by transfers and repression; part of the resources that used to finance public services before the rise in rev-

agreed to use the oil revenues for developmental purposes. The original agreement—which was then weakened—identified five priority sectors to which the revenues should be directed, among them public health.

[4] Among countries with stronger constraints on the chief executive, we do not find a systematic relationship between the size of the natural-resource sector and public spending on health (see section 3.2 for the details).

enues are redirected towards transfers and repression. Intuitively speaking, this happens because underspending on public services—in combination with repression—is part of the incumbent government's strategy to remain in power. What is the exact mechanism? With non-cohesive political institutions and comparatively high public revenues, holding political power offers privileged access to transfers.[5] So an increase in public revenues strengthens the opposition's incentives to compete for power. To remain in office, the government therefore has to increase the cost opposition groups would incur if they decide to attack—and one way to do so is to reduce the provision of public services: A reduction in public services lowers private-sector output and hence reduces the levels of income and consumption of the members of the opposition. As a result, a given cost associated with ousting the incumbent translates into a larger contemporaneous utility loss. This simple logic is also reflected in an observation by a young Cairo lawyer quoted in the The Economist, (February 3, 2011). When asked why the incumbent regime has survived for such a long time, the response was:

> "People survive on a day-to-day basis. They can't go for long without a daily wage and daily bread, so they can't afford to make trouble." (p. 22).

The situation is different if public revenues are at a low level. Since the marginal effect of public services on private-sector output is comparatively high under these circumstances (with respect to the case when public revenues are high), transfers—and hence power struggles—play a negligible role. As a result, additional revenues will mostly be used to finance additional public services. Overall, our theoretical framework suggests a hump-shaped relationship between public revenues and the provision of public services. The critical threshold, above which higher public revenues result in a lower provision of public services, is shown to be increasing in the degree to which the political institutions are cohesive and in the productivity of private-sector technologies.

The second main insight comes from the version of the framework that endogenizes the cohesiveness of the political institutions. In particular, we show that the incumbent government strictly prefers to raise cohesiveness when public revenues fall into a certain range. The lower bound of this range coincides with the critical threshold just described, while the upper bound depends on parameters like the efficiency of the repression technology. An immediate implication of this finding is that a measured increase in public revenues beyond the critical threshold can promote

[5] Following Besley and Persson (2011b), we say that the political institutions are cohesive (non-cohesive) if the extent to which specific groups can have privileged access to transfers is strongly (hardly) restricted.

institutional cohesiveness, thereby inducing an improvement in economic performance in the future. For the government, strengthening institutional cohesiveness presents an alternative option to avoid a loss of power (which would mean an underprivileged access to transfers in the future). This alternative is the preferred one if public revenues are at a relatively low level: In this situation, a privileged access to transfers offers little gain, while the alternative defense strategy—repression and underspending—is comparatively expensive. However, if public revenues exceed the upper bound of the range, the government behaves as in the basic framework and resorts to repression and underspending.

This chapter is related to two different strands of literature within the field of political economy of development. On the one hand, we assume that the provision of public services raises private-sector output as, for example, in Acemoglu (2005), Besley and Persson (2009), Caselli and Cunningham (2009), and Oechslin (2010). On the other hand, we follow Besley and Persson (2011b), Acemoglu, Robinson, and Torvik (2013), and Besley, Persson, and Reynal-Querol (2015) among others, by turning the parameter representing political institutions into an endogenous variable, where political institutions are understood to be provisions that constrain the discretionary power of the executive. This particular combination of elements allows us to make two contributions to the existing literature. By endowing the incumbent government with a relatively rich set of policy tools (public services, group-specific transfers, repression), and by explicitly modeling the technology of insurrection, we are able to systematically explore how under-providing public services and repression are combined to form a pre-emptive defense strategy.[6] By allowing for an endogenous change in the cohesiveness of the political institutions, we can analyze under what circumstances the government adjusts its defense strategy, away from under-provision and repression and towards committing to a more equal distribution of transfers in the future.

With its focus on the effects of exogenous increases in public revenues (e.g., because of surging rents from the natural-resource sector), our analysis is further linked to the resource-curse and rent-seeking literature. This literature is primarily concerned with the negative correlation between economic performance and the availability of natural resources. The basic line of argument is as follows: Countries with

[6]Other papers that study the role of public spending in securing political power include Robinson, Torvik, and Verdier (2006) and Robinson and Torvik (2005). The former emphasizes excessive public-sector employment, while the latter focuses on the construction of "white elephants". Oechslin (2014) on the other hand, shows how under-providing public services can be used as a defense tool by dictatorial regimes that face international economic sanction imposed to promote "regime change and democratization". In the context of democratic politics, a number of papers (e.g., Acemoglu, Robinson, & Santos, 2013; Fergusson, Larreguy, & Riano, 2015; Fergusson, Robinson, Torvik, & Vargas, 2014; Saint-Paul, Ticchi, & Vindigni, 2015) find that the under-provision of productive public services—for instance, preserving the state's monopoly of violence—may actually generate an electoral advantage for incumbent governments.

weak political institutions tend to have poorly defined property rights over natural riches; as a result, higher natural-resource rents increase the return on rent-seeking activities—and hence divert resources from productive activities to non-productive ones, thereby reducing the overall allocative efficiency of the economy (see, e.g., Hodler, 2006; Mehlum, Moene, & Torvik, 2006; Torvik, 2002; Wick & Bulte, 2006). However, this literature usually approaches the political-economy problem as one between (politically) symmetric groups and hence leaves no role for a government that has to decide on public services or the future access to transfers. As a result, there is no particular focus on the (under-)provision of public services or the evolution of institutions.

The remainder of this chapter is organized as follows. Section 3.2 takes a closer look at the case of Chad and presents some motivating panel-data evidence on the relationship between natural-resources rents (which proxy for public revenues) and public health spending (which is a prime category of public services). Section 3.3 sets out our basic theoretical framework. The following two sections solve for the equilibrium, thereby treating the political institutions as exogenously fixed (section 3.4) or as a variable to be determined within the model (section 3.5). Section 3.6 discusses the main implications of our framework. Section 3.7 concludes.

3.2 Motivating Evidence

3.2.1 The case of the Chad-Cameroon pipeline project

If fiscal weakness were the main cause behind low levels of public spending on sectors key to economic development (e.g., health or education), we should expect a sharp increase in public revenues to be reflected in a rise in the public funding of these sectors. In this context, the case of Chad is interesting to look at. Ever since independence from France in 1960, this central African country has been among the poorest in the world. Since 2003, however, the government of Chad has benefited form an oil pipeline—the Chad-Cameroon pipeline—that connects Chad's vast oil reserves in the south of the country with offshore export facilities in the Gulf of Guinea (World Bank, 2009). The completion of this pipeline involved many parties, among them the government of Chad and the World Bank. The intention of the World Bank was to transform the riches in the ground into funds that could be used to alleviate poverty and spur economic development. This intention prompted Chad to pass the 1999 Revenue Management Law, which required the allocation of 85% of the oil revenues into poverty reduction priority sectors (which included education, health and social services, rural development, infrastructure, and environmental and water resources).

The new pipeline is generally considered to be a financial success. In 2000, three years before its opening, Chad's total annual rents from the natural-resource sector amounted to $10 p.c., according to data from the World Bank (2015, World Development Indicators). By 2010, the rents had surged to $130 p.c.—with positive consequences for the public purse: Since 2003, the project has generated more than $10 billion in public revenues. However, this surge in public revenues is neither reflected in higher development spending nor in better development outcomes. For instance, public health spending fell from $4.5 p.c. in 2000 to $3.4 p.c. in 2010; it is therefore no surprise to find Chad still among the least developed countries (184 out of 187), according to the UN's Human Development Index (United Nations, 2014). As a result, in spite of the safeguards put in place on the World Bank's request, the high hopes that had been invested in addressing Chad's fiscal weakness have been dashed.

What went wrong? Detailed accounts of the pipeline project (e.g., van Dijk, 2007; Pegg, 2006) suggest that growing political instability over the years 2004-06 played a significant role. Over this period, the government of President Idriss Déby was facing several coup attempts and a growing rebellion involving armed opposition groups. As for the motives of these opposition groups, van Dijk (2007) notes that it appears that

> "they are after the goose with the golden eggs: the Chad-Cameroon pipeline project and its revenues." (p. 701).

As a result, President Déby felt the need to step up military spending. In December 2005, the Chadian parliament amended the 1999 Revenue Management Law, adding the security sector (among others) to the list of priority sectors (in violation of its Loan Agreement with the World Bank, as Pegg, 2009, p. 313, notes). In the ensuing conflict with the World Bank, President Déby succeeded in weakening the conditions of the original pipeline deal further. By mid-2006, the Chadian government was no longer bound by the stringent external conditions of the original project;[7] since internal checks on the government's power were also lacking, Déby was eventually in a position to step up military spending in order to secure power. According to data from the SIPRI, military spending per capita rose by a factor of 4 (from $5.5 to $21.5) between the years 2005 and 2006 and eventually reached $52.5 p.c. in 2010. As from 2008, after a three-day rebel assault on the capital ("Second Battle of N'Djaména"), the security situation in Chad started to calm down, partly in response to the rise

[7] According to Pegg (2009, p. 314), Déby's strategy to achieve this included threats to make already difficult situations worse by expelling a large number of Darfur refugees from Chad and by shutting down oil supplies.

in defense spending.[8] Another factor leading to the definite gain of control by the government was that in its fight against opposition groups the government could count on France's relentless military support (van Dijk, 2007, p. 699).

In summary, these observations suggest that weak constraints on the executive's power to allocate public revenues were at the heart of the problem. The perception that acquiring executive power would be like acquiring the "goose with the golden egg" led to the rise of armed opposition groups that challenged the incumbent government. In response, the incumbent government got rid of the externally imposed constraints on the use of the oil money. Since internal constraints were also lacking, the loosening of the stringent external conditions cleared the way for redirecting public spending toward the security sector—at the cost of investments that would have improved the economic situation of the broad population. While military spending surged, public health spending fell even below levels observed prior to the completion of the pipeline. These spending choices, together with the military support provided by foreign powers, ensured the incumbent government's survival.

While the Chad-Cameroon pipeline project is a relatively well studied case, many policy-relevant questions remain: For instance, why did the spending on public health (or, more generally, spending aimed at promoting development) fall despite a dramatic improvement in fiscal strength? What would have been the impact on development spending if the rise in public revenues had been more nuanced? How did the possibility to rely on French military support influence the defense strategy chosen by the Chadian government? Or: What would have been the outcome if there had been an institutional arrangement available that truly committed governments to spend future oil revenues on the original priority sectors? Section 3.3 sets up a rich theoretical framework to systematically explore possible answers to these questions—and eventually to draw conclusions for development policy.

3.2.2 Panel data evidence

Before moving to the theory, we explore whether the inverse relationship between fiscal strength and development spending observed in Chad is a more general pattern among countries with weak constrains on the executive. More specifically, we estimate the effect of an exogenous increase in the rents from natural resources on public health spending, relying on a panel of countries with low constraints on the executive. We take again public health spending as proxy for development spending in general because public health spending is one of the few spending categories

[8] In the 2005-2008 period, clashes between Chadian government forces and armed opposition groups caused more than 2300 battle related deaths. By 2010, this number was down to only four (World Bank, 2015).

for which time-series data is consistently available. Our specification will allow for a non-monotonic relationship between the two variables by including a linear and a quadratic rents term. Such a specification is sufficiently flexible to capture, for instance, a relationship that is positive at lower levels of rents (because fiscal weakness is reduced without prompting political instability) and negative at higher levels (because of surging political instability). Our specification can be interpreted as the reduced form of a structural model—like the one developed in section 3.3—that includes two main equations: An equation specifying the impact of public revenues (from taxes on the resource sector and the non-resource sector) on public health spending and an equation specifying the impact of public health spending on the output of the non-resource sector (while resource rents are unaffected by development spending).[9]

Our measure of rents is the variable "total rents from natural resources (p.c.)", which aggregates rents from oil, gas, coal, minerals, and forestry. Health spending is measured by the variable "total public expenditure on health (p.c.)". Both variables come from the World Bank's World Development Indicators (WDI) database (World Bank, 2015). They are expressed in 2000 US$ p.c. and we rely on their inverse hyperbolic sine transformation (*asinh*).[10] We use yearly data covering the 1995-2010 period (so that we have at most 16 observations per country). Next to rents and health spending, we rely on two additional variables: A non-agricultural commodity price index and an index of executive constraints. The commodity price index is taken from Collier and Goderis (2012) and will serve as an instrument for the natural-resource rents. The index of executive strength, which is the executive constraints component (*xconst*) from the Polity-IV project, is required because we focus on countries that are similar to Chad in the sense that the executive faces only weak or moderate constraints when making public spending decisions. According to Marshall, Jaggers, and Gurr (2011), a country's executive faces weak or moderate constraints if the *xconst* score is 3 or below (*xconst* ranges from 1 to 7, with higher values signal stronger constrains).[11] We classify a country to be one with only weak or moderate constraints if the average *xconst* score for the period 1995-2010 is at most

[9] A change in public health spending (resulting in, e.g., better access to antibiotics, etc.) can be expected to have an immediate impact on the non-resource sector of the economy. Weil (2007, p. 1266) observes that "healthier people are better workers. They can work harder and longer and also think more clearly." On the other hand, higher public health spending is unlikely to affect the rents from natural resources as the extraction of oil and gas is mostly done by big international corporations that provide health facilities for their workers.

[10] This is an approximation to the logarithmic transformation, meaning that the estimated coefficients can be interpreted as elasticities. The advantage of the *asinh* transformation is that it is well defined for the value 0.

[11] We re-code the observations that are assigned a "Standardized Authority Code" (−66, −77, −88) exactly as Marshall et al. (2011, p. 17) re-code the combined *Polity* score into the *Polity2* variable.

Table 3.2.1: Descriptive statistics

Variable	Obs.	Countries	Mean	S.D. all	S.D. within
Health exp p.c. (in asinh)	686	45	3.967	1.585	0.373
Rents p.c. (in asinh)	686	45	5.411	2.430	0.565
Executive Constraints	686	45	2.285	0.654	-
Commodity Price Index	621	43	0.413	0.608	0.076

3. Table 3.2.1 presents descriptive statistics (based on the whole sample of countries with weak or moderate constraints) of all the variables used in our analysis.

We rely on fixed effects (FE) panel data estimation throughout. Next to the rents variables (linear and quadratic) and the country fixed effects, our regression equation includes year fixed effects and country-specific time trends. The former controls for year-specific shocks that are common to all countries, while the latter cleans out potential systematic co-movements between the rents from natural resources and public health spending. The use of country fixed effects, time dummies, and country-specific time trends cannot, of course, completely dispel concerns about identification. For instance, unusual weather conditions may affect both public health spending and natural-resource extraction. To address this potential issue, we also rely on fixed effects instrumental variables (FEIV) estimations (using heteroskedasticity-cluster-robust GMM). As an instrument for the rents, we use Collier and Goderis (2012) non-agricultural commodity price index (linear and squared). This index is based on international commodity prices and on a fixed trade pattern per country. The yearly variation in this index can therefore be viewed as exogenous from the perspective of a single country. Moreover, we expect the price index to be a relevant instrument: The rents variable is constructed by multiplying the yearly depletion with the price (less an extraction cost) per extracted unit, and there is a significant overlap between the commodities included in the index and those included in the calculation of the natural-resource rents.[12, 13] The main drawback of using this in-

[12]The World Bank describes the calculation of the rents as follows: "The estimates of rents from natural resources are calculated as the difference between the price of a commodity and the average cost of producing it. This is done by estimating the world price of units of specific commodities and subtracting estimates of average unit costs of extraction or harvesting costs (including a normal return on capital). These unit rents are then multiplied by the physical quantities countries extract or harvest to determine the rents for each commodity as a share of gross domestic product (GDP)." See http://wdi.worldbank.org/table/3.15

[13]Among the commodities included in the index one finds oil, gas, and coal, i.e., commodities that are also included in the rents variable. Moreover, from the list of minerals used by the World Bank to calculate the mineral rents (i.e., tin, lead, zinc, iron, copper, nickel, silver, phosphate, gold, and bauxite), only the last two are not included in the index (see Collier & Goderis, 2012, Table 1). Finally, there are four commodities that are included in price index but not in the calculation of the rents: Aluminium, gasoline, uranium, and urea.

Table 3.2.2: FE and FEIV estimations (Health expenditure)

	(1)	(2)	(3)	(4)	**(5)**
Method	FE	FE	FE	FEIV	FEIV
Executive Constraints	Low	Low	High	Low	Low
Rents	0.261	0.236**	-0.001	1.187***	0.668***
	(0.188)	(0.108)	(0.035)	(0.386)	(0.199)
$Rents^2$	0.002	-0.018*	-0.005	-0.074**	-0.050***
	(0.018)	(0.010)	(0.004)	(0.033)	(0.018)
Year F.E.	No	Yes	Yes	No	Yes
Country T.T.	No	Yes	Yes	No	Yes
Rents' Threshold		6.676***		7.993***	6.615***
		(1.456)		(1.367)	(1.174)
First Stage				Rents	
Index				7.995***	10.294***
				(2.272)	(3.407)
$Index^2$				-2.003***	-2.857***
				(0.739)	(1.030)
				$Rents^2$	
Index				78.778***	96.741***
				(22.465)	(31.686)
$Index^2$				-16.805**	-22.049**
				(7.251)	(9.034)
Kleibergen-Paap rk Wald (F-stat)				4.657	4.248
Observations	686	686	1758	621	621
Countries	45	45	111	43	43

Robust standard errors clustered by country in parentheses

*** p<0.01, ** p<0.05, * p<0.1

strument is that it does not cover the whole set of countries in our sample; moreover, it is only available up to 2009, with the consequence that we lose one year of observations.[14]

Table 3.2.2 presents the results of the FE (columns 1-3) and FEIV (columns 4-5) estimations. The first column is based on a specification that does not include any further controls. Apparently, according to the signs of the coefficients, there is an unambiguously positive relationship between rents and health spending, although the coefficients are not significantly different from zero. However, once we include the year fixed effects and the country specific time trends (column 2), we obtain that the relationship between rents and health spending is hump-shaped. Higher rents from natural resources are associated with a higher public spending on health if the level of rents is low; and with lower health spending if the level of rents is high. The threshold beyond which an increase in rents reduces the public spending on health is 6.68 (or $390 p.c.). This value is above the mean of the rents variable (5.411), but it is still within the sample.[15] In column 3, we use the same specification as in column 2, but we estimate it on the sample of countries with strong constraints on the executive (strong constraints means an average *xconst* score that exceeds 3). It turns out that for this group of countries both coefficients are negative and insignificant. This reveals that the hump-shaped relationship observed for the countries with weak institutions is not a mechanical one.

Turning to the first-stage results of the FEIV estimations in columns 4 and 5, we note regarding instrument strength that the Kleibergen-Paap rk Wald statistics is greater than the Stock-Yogo critical value that must be surpassed to reject the Null hypothesis that the actual size of the 5% Wald test is greater than $r = 20\%$.[16] Moreover, the (weak-instruments robust) Anderson-Rubin test implies that our endogenous variables are jointly significant determinants of public health spending. The second-stage results show that the main insights of the FE estimations follow through. Both specifications suggest a hump-shaped relationship between rents and health spending (with point estimates significant at least at the 5% level). The specification in column 5 (which includes year fixed effects and country-specific time trends) suggests that the threshold beyond which an exogenous increase in rents causes a reduction in public health spending is 6.62 (or 370 in 2000 USD p.c.), a num-

[14] For the FEIV estimations, the year fixed effects and country-specific time trends are simultaneously included in the first and the second stage.

[15] Over a third of the observations in the sample (212) report rents greater than $390. Moreover, in 19 out of the 43 countries in the sample we observe at least one observation that is above this threshold.

[16] In our case, the Stock and Yogo (2005) critical values for $r = 10\%, 15\%, 20\%$ are given by 7.03, 4.58, and 3.95, respectively. Note that the Stock-Yogo critical values are constructed to be compared against the Cragg-Donald statistic (which relies on the i.i.d assumption). However, using these thresholds as reference point for the Kleibergen-Paap (heteroskedasticity robust) statistic is the standard practice in the literature.

ber that is almost identical to the threshold suggested by the corresponding FE estimate in column 3. So increases in natural-resource rents—i.e., in public revenues—do not appear to be uniformly "good" or "bad" for public health spending. The results in Table 3.2.2 consistently suggest that the level of rents matters. At lower levels, the effect of natural-resource rents on public health spending is positive; however, the effects weakens as rents rise—and eventually turns negative.

3.3 Model

3.3.1 Assumptions

Agents, preferences, and economic activity. We consider a two-period economy that is populated by a continuum 1 of individuals. Each individual belongs to one of the two different groups that exist in the economy. The two groups are of equal size and denoted by A and B. As we will discuss below, in each period, one of these groups holds political power and we will refer to this group as the "incumbent". The other group makes up the "opposition". Apart from political power, agents are identical in all dimensions.

Individuals derive utility from consumption of a unique non-storable consumption good (which is also the numéraire). Preferences are represented by the intertemporal utility function

$$U_i = \ln(c_{1,i}) + \beta \ln(c_{2,i}), \tag{3.3.1}$$

where $c_{t,i}$ refers to consumption by the representative member of group $i \in \{A, B\}$ in period $t \in \{1, 2\}$ and $\beta \in (0, 1]$ denotes the discount factor. In what follows, we normalize β to 1 as this simplifies the analysis without affecting any of the results in qualitative terms.

Regarding the supply-side of the economy, we assume that all individuals have access to a uniform technology that allows them to generate an income of

$$y_t = x \cdot (G_t)^{\alpha}, \tag{3.3.2}$$

per period, where $\alpha \in (0, 1)$. $G_t \geq 0$ refers to the level of public services provided by the government in period t. Following Barro (1990), production function (3.3.2) is meant to capture in a simple way that the government plays an important role in promoting the productivity of the private sector by, for instance, entertaining a public-health system, maintaining infrastructure, or enforcing private contracts. The factor $x > 0$, on the other hand, mirrors the productivity of private-sector technologies (or, alternatively, the stock of physical or human capital available to the average individual in the economy). Note that the aggregate private-sector income, Y_t, is equal to y_t as the population size is normalized to 1.

Assuming that G_t is an input in private production rather than a consumption good (as, e.g., Besley & Persson, 2011b) is important. As we will discuss below, in the current setup, public services have an impact on individual budget constraints. Therefore, other things equal, reductions in G_t limit the capacity of individuals to afford goods.

Public revenues, policies, and institutions. In each period, public revenues are given by $R > 0$ units of the consumption good. For simplicity, we assume that this revenue stream is exogenous, i.e., does not depend on private-sector output. It is natural to think that R reflects the recurrent income from the extraction of publicly-owned natural resources.

The government can spend public revenues in three different ways. *First*, it can provide public services, G_t, that lift private-sector incomes (as described above). *Second*, there is spending on repression, D_t, which helps the incumbent retain political power (as described below). *Third*, the government can make direct (non-negative) transfers to each of the two groups; these transfers are denoted by $T_{t,A} \geq 0$ and $T_{t,B} \geq 0$, respectively.

We further assume that the government does not have access to the capital market. This, together with the assumption that the consumption good is non-storable, implies that the government's flow budget constraint must be satisfied in each period:

$$G_t + D_t + T_{t,A} + T_{t,B} \leq R. \tag{3.3.3}$$

The government may face institutional constraints when allocating transfers. In particular, the government has to give to the opposition at least a share $I_t \in [0,1]$ of the transfer that goes to the incumbent. Provided that the transfer to the opposition does not go beyond this minimum, and assuming that budget constraint (3.3.3) holds with equality, we obtain

$$T_{t,i} = \frac{1}{1+I_t}\left(R - G_t - D_t\right) \quad \text{and} \quad T_{t,j} = \frac{I_t}{1+I_t}\left(R - G_t - D_t\right), \tag{3.3.4}$$

where $i \in \{A, B\}$ refers to the incumbent and $j \neq i$ to the opposition. The higher the value of I_t, the lower the extent to which one group can be favored over the other. Following Besley and Persson (2011b), we therefore say that I_t reflects the degree to which the political institutions are cohesive. If $I_t = 0$, the incumbent enjoys maximally privileged access to government transfers; on the other hand, if

$I_t = 1$, holding political power does not entail any privileges. In what follows, we assume that the degree of cohesiveness in $t = 1$ is exogenous: $I_1 = \lambda$, where

$$0 \leq \lambda < 1 \tag{3.3.5}$$

In section 3.4, we assume that the degree of cohesiveness remains unchanged over time. Section 3.5 considers the case of an endogenous I_2.

Political power and its transition. The state variable $P_t \in \{A, B\}$ indicates which one of the two groups currently holds political power. The group holding political power in period t, i.e., the incumbent, determines the policy vector (G_t, D_t, $T_{t,A}$, $T_{t,B}$), thereby observing the budget constraint as well as the institutional constraint.

P_1 is assumed to be exogenous. However, there may be an endogenous change in the allocation of political power between periods 1 and 2. Specifically, we assume that

$$P_2 \begin{cases} = P_1 & : \quad S_1^G \geq S_1^O \\ \neq P_1 & : \quad S_1^G < S_1^O \end{cases}, \tag{3.3.6}$$

where S_1^G and S_1^O refer to, respectively, the military strength of the government and the opposition in $t = 1$. Military strength requires resources. The production functions are

$$S_t^G = z^G D_t \quad \text{and} \quad S_t^O = z^O M_t, \tag{3.3.7}$$

As noted above, D_t refers to spending on repression by the government; M_t is the spending by the opposition on a private militia that could enter a fight with regular government forces in order to take over political power.[17] While D_t comes from the government budget, M_t is raised through a levy that the opposition is able to impose on its own members. In what follows, we assume that spending on repression by the government is more productive than the spending by the opposition on the private militia:

$$0 < Z < 1 \tag{3.3.8}$$

where $Z \equiv z^O/z^G$. This is a natural assumption, given that regular government forces are likely to have access to more efficient technologies than private militias. We further assume that the opposition chooses M_t after the determination of the policy vector.[18] This assumption is meant to characterize that the strength of the

[17]The cost of producing military strength is unrelated to the current economic situation. This is meant to reflect that military strength requires input factors that must be bought in international markets (e.g., transportation capacities, communication tools, or weapons) at prices unrelated to current domestic circumstances.

[18]This way of modeling the political contest is equivalent to a setup based on a ratio CSF with sequential

regular government forces is observable before actual confrontations (for instance through public military expenditure), but this is not the case for clandestine militias.

Time line and equilibrium concept. The events occur in the following sequence:

- $t = 1$: *First*, the incumbent group determines the policy vector, (G_1, D_1, $T_{1,A}$, $T_{1,B}$). *Second*, observing the incumbent's choices, the opposition group decides on how much to spend on its militia, M_1. *Third*, all decisions are implemented, $P_2 \in \{A, B\}$ is determined, the payoffs materialize, and the period ends.
- $t = 2$: *First*, the incumbent group, $P_2 \in \{A, B\}$, determines (G_2, D_2, $T_{2,A}$, $T_{2,B}$). *Second*, all decisions are implemented, payoffs materialize, and the game ends.

We recur to backward induction to solve for the Sub-game Perfect Nash Equilibrium (SPNE) of this game. So we start with the second-period choices, taking the degree of cohesiveness in $t = 2$ as given (Subsection 3.3.2). Sections 3.4 and 3.5 then focus on the determination of the first-period choices. Section 3.4 assumes $I_1 = I_2 = \lambda$, while section 3.5 treats I_2 is a choice variable (to be determined in $t = 1$). Finally, without loss of generality, we impose $P_1 = A$.

3.3.2 Second Period $(t = 2)$

Assume first that group A continues to hold political power in $t = 2$. When deciding on (G_2, D_2, $T_{2,A}$, $T_{2,B}$), the representative A-member wants to maximize second-period consumption

$$c_{2,A} = x(G_2)^{\alpha} + (1/2)^{-1} T_{2,A},$$

where $T_{2,A} \geq 0$ is the total transfer received by group A and the factor $(1/2)^{-1}$ reflects that the mass of the group is $1/2$. Maximizing consumption of its representative member, group A does not have any incentive to provide the opposition with more transfers than is mandated by the political institutions. At the same time, spending on repression would not serve any purpose as the second period is also the final one (hence $D_2 = 0$). As a result, equation (3.3.4) implies that $T_{2,A} = (1 + I_2)^{-1}(R - G_2)$. So, taking into account that $T_{2,A} \geq 0$, the representative member of group A solves the simple optimization problem

$$\max_{\{G_2\}} \left\{ x(G_2)^{\alpha} + 2(1 + I_2)^{-1}(R - G_2) \right\} \quad s.t. \quad R \geq G_2. \tag{3.3.9}$$

It is straightforward to verify that the solution to this problem is given by $G_2 = R$ if $R \leq G^*(x, I_2)$; and by $G_2 = G^*(x, I_2)$ if $R > G^*(x, I_2)$, where $G^*(x, I_2)$ is defined

input choice and an infinite "decisiveness parameter" (to use Hirshleifer's, 1995, terminology).

as follows:

$$G^*(x, I_2) \equiv \left[\frac{\alpha x(1+I_2)}{2}\right]^{1/(1-\alpha)}. \tag{3.3.10}$$

Hence, group A will appropriate public resources through direct transfers only if public revenues exceed some threshold level. Otherwise, if $R \leq G^*$, transfers are zero as the marginal impact on $c_{2,A}$ of the last unit of public money is higher when spent on public services. However, as long as $I_2 < 1$, G^* is less than the socially optimal level, which is given by $(\alpha x)^{1/(1-\alpha)}$. This "under-investment" is due to the fact that group A captures only half of the return on public services (the other half goes to group B), while the group is able to capture a share $(1+I_2)^{-1} > 1/2$ of total transfers. Note that the degree of under-investment falls monotonically in the level of cohesiveness of the political institutions; when the cohesiveness parameter goes to one, G approaches the socially optimal level.

To describe equilibrium consumption levels, we use the notation $c_{t,i}^{P_t}$, which means consumption in period t by the representative member of group i, given the current allocation of political power $P_t \in \{A, B\}$. For the representative member of group A, we obtain

$$c_{2,A}^A(I_2) = \begin{cases} xR^\alpha & : \quad R \leq G^*(x, I_2) \\ 2(1+I_2)^{-1}\alpha^{-1} \cdot [(1-\alpha)G^*(x, I_2) + \alpha R] & : \quad R > G^*(x, I_2) \end{cases}. \tag{3.3.11}$$

The representative member of group B, on the other hand, consumes

$$c_{2,B}^A(I_2) = \begin{cases} xR^\alpha & : \quad R \leq G^*(x, I_2) \\ 2(1+I_2)^{-1}\alpha^{-1} \cdot [(1-\alpha I_2)G^*(x, I_2) + \alpha I_2 R] & : \quad R > G^*(x, I_2) \end{cases}. \tag{3.3.12}$$

Since public revenues are spent entirely on public services if $R \leq G^*$, there is no difference in consumption between the incumbent and the opposition. However, if $R > G^*$, consumption by the representative member of group A exceeds consumption by the representative B-member if the political institutions are not fully cohesive (i.e., if $I_2 < 1$).

We obtain similar expressions for consumption levels if in period 2 political power is held by group B (which is the case if $S_1^G < S_1^O$). In particular, $c_{2,A}^B$ is given by the right-hand side (RHS) of equation (3.3.12), while $c_{2,B}^B$ is given by the RHS of equation (3.3.11).

3.4 Exogenous Institutional Cohesiveness

We now move on to the decisions taken in the first period. Throughout this section, we assume that the degree of institutional cohesiveness is deeply ingrained and cannot be altered by policy makers from one period to the other: $I_1 = I_2 = \lambda$.

3.4.1 Decision by the Opposition (in $t = 1$)

The final decision in period 1 is taken by the opposition, which has to determine the spending on its private militia, M_1. To inform this decision, the representative member of group B derives the maximum amount—denoted by $\overline{M}_1$—she is prepared to spend in order to acquire political power in $t = 2$. This level is pinned down by

$$\ln\left[x(G_1)^\alpha + 2T_{1,B}\right] + \ln\left[c^A_{2,B}(\lambda)\right] = \ln\left[x(G_1)^\alpha + 2(T_{1,B} - \overline{M}_1)\right] + \ln\left[c^B_{2,B}(\lambda)\right], \tag{3.4.1}$$

where the left-hand side (LHS) assumes that political power stays with group A and the RHS assumes that P switches from A in period 1 to B in period 2. Rearranging terms yields

$$\overline{M}_1 = \frac{1}{2}\frac{c^B_{2,B}(\lambda) - c^A_{2,B}(\lambda)}{c^B_{2,B}(\lambda)}\left[x(G_1)^\alpha + 2T_{1,B}\right]. \tag{3.4.2}$$

Equation (3.4.2) suggests that the members of the opposition are prepared to spend a non-negative fraction $\left(c^B_{2,B} - c^A_{2,B}\right)/c^B_{2,B}$ of their income after transfers on acquiring political power, a fraction that is independent of the policy vector in $t = 1$.

It is now convenient to distinguish two cases, $R \leq G^*(x,\lambda)$ and $R > G^*(x,\lambda)$, where $G^*(x,\lambda)$ is given by equation (3.3.10). Assume first that $R \leq G^*$. In this case, the discussion in Subsection 3.3.2 suggests that holding political power in period 2 does not entail any rents, i.e., that $c^B_{2,B} = c^A_{2,B}$. As a result, the maximum amount group B is willing to spend on acquiring power in $t = 2$ is zero. In formal terms: $\overline{M}_1 = 0$.

On the other hand, if $R > G^*$, power is associated with rents, and equation (3.4.2) turns into

$$\overline{M}_1 = f(R,x,\lambda)\left[x(G_1)^\alpha + 2T_{1,B}\right], \tag{3.4.3}$$

where

$$f(R,x,\lambda) \equiv \frac{(1-\lambda)\alpha}{2}\frac{-G^*(x,\lambda) + R}{(1-\alpha)G^*(x,\lambda) + \alpha R}, \tag{3.4.4}$$

The following lemma discusses some properties of function f:

Lemma 3.1. *Suppose that (3.3.5) holds and assume $R > G^*(x,\lambda)$. Then, the maximum share of income the opposition (group B) is willing to spend on acquiring power, $f(R,x,\lambda)$,* *lies in the interval* $(0, (1-\lambda)/2)$*, where* $\lim_{R \to G^*} f(R, x, \lambda) = 0$ *and* $\lim_{R \to \infty} f(R, x, \lambda) = (1 - \lambda)/2$*. The signs of the partial derivatives are*

$$\frac{\partial f(R, x, \lambda)}{\partial R} > 0, \quad \frac{\partial f(R, x, \lambda)}{\partial x} < 0, \quad \frac{\partial f(R, x, \lambda)}{\partial \lambda} < 0.$$

Proof: See Appendix 3.A.1.

The fraction of first-period income the opposition is prepared pay is increasing in public revenues because—as long as the political institutions are not fully cohesive—the rents associated with holding power are increasing in R. On the other hand, if x or λ rise, private-sector incomes improve because of the increase in the provision of public services. As a result, government transfers have a smaller effect on second-period utility.

To determine the opposition's actual spending on its militia, note that equation (3.3.7) implies that the military strength associated with $\overline{M}_1$ is given by

$$\overline{S}_1^O = z^O \overline{M}_1, \tag{3.4.5}$$

while the military strength of the government—which is observed by the opposition—is given by $S_1^G = z^G D_1$. So the opposition will acquire political power if $\overline{S}_1^O > S_1^G$. In this case, the amount spent on its militia is given by $M_1 = Z^{-1} D_1 + \varepsilon$, where $\varepsilon \to 0$ ensures that S_1^O is marginally greater than S_1^G, so that P_t switches from A in period 1 to B in period 2 (equation 3.3.6). Otherwise, if $\overline{S}_1^O \leq S_1^G$, group B does not attempt to take over power, implying that the spending on its militia is zero. To summarize,

$$M_1 = \begin{cases} 0 & : \quad \overline{S}_1^O \leq S_1^G(D_1) \\ Z^{-1} D_1 + \varepsilon & : \quad \overline{S}_1^O > S_1^G(D_1) \end{cases}, \tag{3.4.6}$$

where the notation $S_1^G(D_1)$ indicates that the military strength of the government depends on its spending on repression, which is determined at the preceding stage.

3.4.2 Decisions by the Incumbent (in $t = 1$)

3.4.2.1 No rents ($R \leq G^*(x, \lambda)$)

It is again convenient to distinguish two cases, $R \leq G^*(x, \lambda)$ and $R > G^*(x, \lambda)$. If $R \leq G^*$, holding political power in $t = 2$ does not entail any advantage, as discussed in the previous subsection. So the incumbent does not rely on repression: $D_1 = 0$. However, since the opposition's spending on its militia will also be zero ($M_1 = 0$), group A continues to hold political power in $t = 2$. Because D_1 is equal to 0, as is spending on repression in $t = 2$, the representative member of group A solves an optimization problem that is similar to the one stated in (3.3.9). Hence, the incumbent—group A—chooses in period 1 the same economic policies as in period 2: $G_1 = R$ and $T_{1,A} = T_{1,B} = 0$.

3.4.2.2 Positive rents ($R > G^*(x, \lambda)$)

If $R > G^*$, holding political power in $t = 2$ carries an advantage (because $I_2 = \lambda < 1$), so that the opposition is willing to spend a strictly positive amount on acquiring power (equation 3.4.3). In this situation, the incumbent has to choose between two a prior sensible levels of spending on repression. One option, to which we will return further below, is to set $D_1 = 0$ and hence to accept the loss of power. The alternative options is

$$\underline{D}_1 \equiv Z\overline{M}_1,$$

which implies $\overline{S}_1^O = S_1^G(D_1)$ and hence is the minimum spending on repression that ensures $P_1 = P_2 = A$. Note that, from the perspective of the incumbent, spending more than $\underline{D}_1$ is necessarily sub-optimal. Increasing D_1 above $\underline{D}_1$ does not affect the second-period outcomes, namely for any $D_1 \geq \underline{D}_1$ the incumbent retains power in $t = 2$. However, increasing D_1 comes at the cost of a lower consumption in $t = 1$ due to the reduction in resources available to finance $T_{1,A}$. Using equation (3.4.2) to substitute for $\overline{M}_1$, we obtain

$$\underline{D}_1 = Zf(R, x, \lambda)\left[x(G_1)^\alpha + 2T_{1,B}\right]. \tag{3.4.7}$$

Note that equation (3.3.4) suggests $T_{1,B} = (R - G_1 - D_1)\,\lambda/(1 + \lambda)$. Taking this into account, equation (3.4.7) can be turned into

$$\underline{D}_1 = \frac{Zf(R, x, \lambda)}{1 + 2\lambda Zf(R, x, \lambda)/(1 + \lambda)}\left[x(G_1)^\alpha + \frac{2\lambda}{1 + \lambda}(R - G_1)\right]. \tag{3.4.8}$$

Consider now the incumbent group's decision problem, still assuming that it wants to stay in power. When maximizing first-period consumption

$$c_{1,A}^A = x(G_1)^\alpha + 2T_{1,A} = x(G_1)^\alpha + \frac{2}{1 + \lambda}(R - G_1 - D_1), \tag{3.4.9}$$

the incumbent has to observe two constraints. First, as was the case in $t = 2$, transfers must be non-negative: $R - G_1 - D_1 \geq 0$. Second, the actual spending on repression has to match the minimum spending that secures power in the second period: $D_1 = \underline{D}_1$. In formal terms, the representative member of group A solves the constrained maximization problem

$$\max_{\{G_1,D_1\}} \left\{x(G_1)^\alpha + 2(1+\lambda)^{-1}(R - G_1 - D_1)\right\} \quad s.t. \quad R \geq G_1 + D_1 \text{ and } D_1 = \underline{D}_1, \tag{3.4.10}$$

where $\underline{D}_1$ is stated in equation (3.4.8).

Lemma 3.2. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x, \lambda)$. Assume further that the incumbent (group A) wants to stay in power. Then, solving the incumbent's appropriate decision problem, stated in (3.4.10), results in*

$$G_1 = \left\{ \frac{\alpha x(1+\lambda)}{2} \left[1 - \frac{1-\lambda}{1+\lambda} 2Zf(R, x, \lambda) \right] \right\}^{1/(1-\alpha)}, \tag{3.4.11}$$

an expression that implies $G_1 < G^*$, $\partial G_1/\partial R < 0$, and $\lim_{R \to G^*} G_1 = G^*$. Moreover, the corresponding level of consumption by the representative member of group A is given by

$$c_{1,A}^A = \frac{2}{(1+\lambda)\alpha} \left[1 + \frac{\lambda}{1+\lambda} 2Zf(R, x, \lambda) \right]^{-1} \left[(1-\alpha)G_1 + \alpha R \right], \tag{3.4.12}$$

where $\lim_{R \to G^*} c_{1,A}^A = x(G^*)^\alpha$.

Proof: See Appendix 3.A.1.

The implication that in the first-period less public services are provided than in the second-period ($G_1 < G_2 = G^*$) is a consequence of the incumbent holding on to power. Starting from a low level, an increase in the provision of public services raises the opposition's total income—and hence lifts the maximum amount the representative opposition member is willing to spend on adopting power (equation 3.4.3).[19] The incumbent is therefore required to complement an increase in the provision of public services with an appropriate increase in the spending on repression. This requirement, by raising the perceived marginal cost of providing public services, reduces G_1 below the second-period level of spending.

The spending on repression associated with G_1 can be found by combining (3.4.8) and (3.4.11):

$$D_1 = \underline{D}_1 = \frac{Zf(R, x, \lambda)}{1 + 2\lambda Zf(R, x, \lambda)/(1+\lambda)} \left[(1 - \alpha\lambda\Lambda)x\,(G_1)^\alpha + \frac{2\lambda}{1+\lambda} R \right], \tag{3.4.13}$$

where

$$\Lambda \equiv \left[1 - \frac{1-\lambda}{1+\lambda} 2Zf(R, x, \lambda) \right]. \tag{3.4.14}$$

[19] For $G \leq G^*$, a rise in G lifts the private-sector income of the representative opposition member by more than it reduces her transfer income (in the limiting case of $\lambda = 0$, there is no reduction in transfer income).

Let us now return to the option $D_1 = 0$, whose implementation means that the current opposition—group B—will hold power in $t = 2$. Then, the relationship between G_1 and $c^A_{1,A}$ is as in the second period: $c^A_{1,A} = x(G_1)^\alpha + 2(1+\lambda)^{-1}(R - G_1)$. As a result, the decision problem solved by the representative member of group A takes again the form stated in (3.3.9). Since we focus on the case $R > G^*$, the solution to this maximization problem is $G_1 = G_2 = G^*$, while

$$c^A_{1,A} = \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)G^* + \alpha R\right]. \tag{3.4.15}$$

A comparison of equations (3.4.12) and (3.4.15) reveals that first-period consumption is higher if group A chooses not to retain power, reflecting that there is no unproductive spending on repression in this case. However, as we will see below, higher first-period consumption comes at the cost of less consumption in the second period as the access to rents will be lost.

To find out which one of the two options—$D_1 = \underline{D}_1$ or $D_1 = 0$—the incumbent prefers, we compare the corresponding overall utilities. The incumbent prefers to hold on to power if

$$\begin{aligned}&\ln\left\{\frac{2\alpha^{-1}}{1+\lambda}\left[1 + Zf(R,x,\lambda)\frac{2\lambda}{1+\lambda}\right]^{-1}\left[(1-\alpha)G_1 + \alpha R\right]\right\} + \ln\left\{\frac{2\alpha^{-1}}{1+\lambda}\left[(1-\alpha)G^* + \alpha R\right]\right\}\\ &\geq \ln\left\{\frac{2\alpha^{-1}}{1+\lambda}\left[(1-\alpha)G^* + \alpha R\right]\right\} + \ln\left\{\frac{2\alpha^{-1}}{1+\lambda}\left[(1-\alpha\lambda)G^* + \alpha\lambda R\right]\right\},\end{aligned}$$

where the first line gives the overall utility if power is retained and the second line represents the overall utility if power is ceded.[20] Simplifying yields

$$\left(1 + Zf(R,x,\lambda)2\frac{\lambda}{1+\lambda}\right)^{-1}\left[(1-\alpha)G_1 + \alpha R\right] \geq \left[(1-\alpha\lambda)G^* + \alpha\lambda R\right]. \tag{3.4.16}$$

Lemma 3.3. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x,\lambda)$. Then, condition (3.4.16) holds with strict inequality, implying that the incumbent prefers to stay in power.*

Proof: See Appendix 3.A.1.

From Lemma 3.3 we conclude that—when political power offers access to rents—the provision of public services, G_1, and spending on repression, D_1, are given by equations (3.4.11) and (3.4.13), respectively; because the associated military strength

[20] The consumption levels on the first line are given by (3.4.12) and (3.3.11), respectively. On the second line, the first consumption level is given by (3.4.15); the second one, $c^B_{2,A}$, is equivalent to $c^A_{2,B}$—which is given by (3.3.12).

of the government matches the maximum military strength the opposition is willing to build up (i.e., $\overline{S}_1^O = S_1^G(D_1)$), the opposition does not try to adopt political power in the second period and hence sets the spending on its militia, M_1, equal to zero (equation 3.4.6). As a result, $P_2 = P_1 = A$.

3.4.2.3 Summary

Lemma 3.3, and the subsequent discussion, complete the characterization of equilibrium choices. The following proposition provides a summary:

Proposition 3.1. *Suppose that (3.3.5) and (3.3.8) hold. Then, in the Sub-game Perfect Nash Equilibrium (SPNE) of this game, the incumbent (group A) makes the following choices in* $t \in \{1, 2\}$*:*

• *If* $R \leq G^*(x, \lambda)$*, public resources are spent entirely on public services in both periods:* $G_t = R$, $D_t = 0$, *and* $T_{t,A} = T_{t,B} = 0$.

• *If* $R > G^*(x, \lambda)$*, part of the public resources are spent on repression and transfers:* G_1 *is given by (3.4.11) and* $G_2 = G^*$; D_1 *is given by (3.4.13) and* $D_2 = 0$; $T_{t,A} > 0$, $T_{t,B} \geq 0$.

The opposition (group B) never attempts to adopt political power ($M_1 = 0$*), either because holding political power does not entail any rents (if* $R \leq G^*$*) or because the required spending on the opposition's militia is prohibitively high (if* $R > G^*$*).*

Before moving on to the comparative-static analysis, note two particular characteristic of this equilibrium. First, in order to secure political power when public revenues are high, the incumbent group relies on just two of the three policy tools that are available: It combines repression with under-spending on public services. It does not, however, try to "appease" the opposition by giving it transfers that would go beyond the level mandated by the political institutions. Such a strategy of "appeasement" would be counterproductive as it would lower the opposition's cost (in terms of utility) of producing military strength—and hence would increase the maximum strength the opposition is willing to produce.

The second characteristic is that the incumbent group (first mover) chooses a defense strategy that discourages the opposition (last mover) from any attempt to compete for political power. A similar result is obtained in rent-seeking games in which two actors sequentially bid for a contestable rent. As shown by Leininger and Yang (1994), the first mover preempts the last mover by making a bid that is sufficiently large to discourage the latter from bidding a positive amount.

3.4.3 Comparative-static properties

We now describe the relationship between public revenues and the provision of public services, thereby paying attention to the role of institutional cohesiveness, the productivity of private-sector technologies, and the productivity of the repression technology.

3.4.3.1 Public revenues and public services

Together, Proposition 3.1 and Lemma 3.2 imply a hump-shaped relationship between public revenues and the provision of public services: As illustrated by figure 3.4.1, G_1 is strictly increasing in R if $R < G^*$ and strictly decreasing in R thereafter. Because $\lim_{R\to\infty} f(R, x, \lambda) = (1-\lambda)/2$ (Lemma 3.1), the provision of public services approaches the limit

$$G^\infty \equiv G^* \left[1 - \frac{(1-\lambda)^2}{1+\lambda} Z\right]^{1/(1-\alpha)} < G^* \tag{3.4.17}$$

as R goes to infinity.

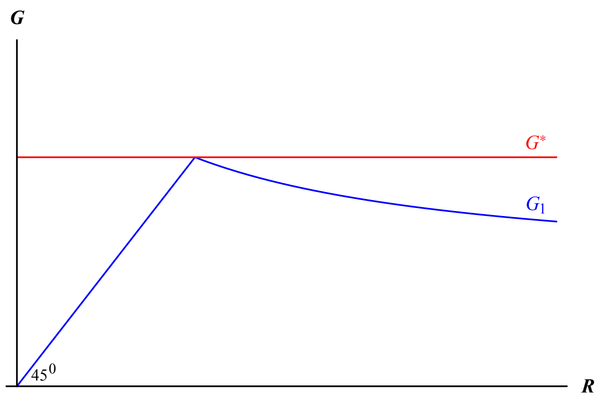

Figure 3.4.1: Public revenues (R) and the provision of public services (G)

The relationship between G_1 and R is influenced by the degree to which institutions are cohesive, λ, and by the productivity of private-sector technologies, x. A rise in λ lifts the threshold G^*; in addition, if $R > G^*$, equation (3.4.11), together with the fact that $\partial f / \partial \lambda < 0$ (Lemma 3.1), implies $\partial G_1 / \partial \lambda > 0$. The overall effect of a rise in λ is illustrated in figure 3.4.2, where λ^H and λ^L respectively stand for high and low institutional cohesiveness. In qualitative terms, the effect of a rise in x is similar. To summarize:

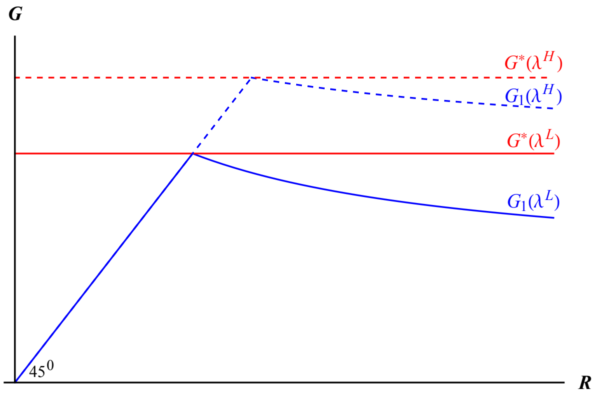

Figure 3.4.2: Public revenues (R) and the provision of public services (G) [high and low λ]

Proposition 3.2. *Suppose that (3.3.5) and (3.3.8) hold. Then*

• *The relationship between R and G_1 is hump-shaped, where $G^*(x, \lambda)$ is the threshold at which the effect on G_1 of additional public revenues turns from positive to negative.*

• *Improvements in institutional cohesiveness, λ, and/or in the productivity of private-sector technologies, x, increases the threshold G^* and—if $R > G^*$—raises G_1.*

There is a one-to-one positive association between R and G_1 at low levels of R because a high marginal product of public services prevents the incumbent from using public resources for transfers. However, as soon as R reaches G^*, the incumbent prefers to spend a positive share of public revenues on transfers. Then, a rise in public revenues implies a rise in the rents associated with holding power—and hence increases the amount the opposition is willing to spend on ousting the incumbent. To avoid the loss of power, the incumbent has to bring back in line the opposition's willingness to pay with the actual cost of seizing power. Reducing the provision of public services is part of this realignment: A fall in G_1 lowers the opposition's first-period income, thereby reducing its willingness to pay.

The decisive threshold at which the impact of R turns from positive to negative, G^*, increases in the degree of institutional cohesiveness because—from the incumbent's perspective—the marginal benefit from transfers falls in λ; similarly, G^* is increasing in the productivity of private-sector technologies because the opportunity cost of transfers rises in x. If $R > G^*$, both λ and x exert a positive effect on the provision of public services, G_1. Both variables increase the opposition's second-period income, thereby reducing the marginal utility of consumption. As a result, the benefit from holding power in the second period—and hence the opposition's willingness to pay for power—shrink. The incumbent can therefore reduce the extent of underspending on public services without being forced out of power.

The result that the $\partial G_t / \partial R$ changes its sign from positive to negative at G^* reflects the fact that—at this point—public services becomes a variable in the incumbent's attempt to hold on to power. When R passes G^*, the incumbent not only resorts to repression in order to raise the input in terms of resources required to take over power; it also reduces the opposition's income—and hence its level of consumption—in order to increase the price of an attack in terms of utility. The incumbent thus follows a defense strategy that rests on two pillars, a rise in the spending on repression and a reduction in the provision of public services.

3.4.3.2 Productivity of the repression technology and public services

The fact that the choice of G_t is part of the incumbent's defense strategy means also that changes to $Z = z^O / z^G$, the inverse measure of the relative productivity of the repression technology, affects the provision of public services. Consider, for instance, a reduction in z^G. If $R > G^*$, equation (3.4.11) implies that G_1 will decrease in response to this fall in the productivity of the repression technology. We establish this result in the following proposition:

Proposition 3.3. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x, \lambda)$. Then, a fall in the productivity of the repression technology (i.e., a rise in Z) causes a reduction in G_1.*

Proposition 3.3 suggests that ineffective repression technologies go and in hand with poor public services. With fixed values of G_1 and D_1, a reduction in z^G would induce the opposition to contest power. To prevent this, the incumbent reduces the opposition's income by lowering the provision of public services, with the aim of reducing the maximum amount the opposition is willing to spend on its militia. A similar positive relationship between the incumbent's strength and the public provision of goods or services can be found in Oechslin (2010) and Besley and Persson (2011b). While both of these contributions emphasize a political-instability channel, the relationship in the present framework is due to adjustments in the incumbent's defense strategy: A lower productivity of the repression technology makes the incumbent more reliant on under-providing public services in order to retain power.

3.5 Endogenous Institutional Cohesiveness

Fending off attacks from the opposition when political power offers privileged access to transfers is costly. Holding on to power demands costly repression and a suboptimally low provision of public services. These requirements could be avoided if the government found a way to commit to a more equal distribution of aggregate transfers: When the opposition understands that political power does no longer offer any privileged access to transfers, it has weaker incentives to challenge the government. This section explores whether the incumbent would commit to a more equal distribution of transfers in the second period if it had the option to do so.

3.5.1 The modified model

The variable governing the extent to which transfers can differ between the two groups is I. A higher value of I means that the political institutions are more cohesive in the sense that the incumbent must offer the opposition a higher share of aggregate transfers. We continue to assume that in the first period institutional cohesiveness is exogenous: $I_1 = \lambda$, where (3.3.5) imposes that $\lambda < 1$. However, for the second period, the incumbent has the choice between two levels of cohesiveness, the "inherited" level or full cohesiveness: $I_2 \in \{\lambda, 1\}$.[21] The incumbent determines I_2 together with the policy vector for the first period, i.e., before the opposition decides on how much to spend on its militia. All other assumptions are unchanged.

In what follows, we assume $R > G^*(x, \lambda)$ throughout, where $G^*(x, \lambda)$ is given by equation (3.3.10). In this situation, the analysis in Subsection 3.3.2—which is not affected by the present modifications—implies that in $t = 2$ the incumbent is better off than the opposition in terms of consumption if the political institutions are not fully cohesive. As a result, setting $I_2 = I_1 = \lambda$ requires the incumbent in $t = 1$ to adopt the defense strategy described in section 3.4 to remain in power. If it does so, the corresponding analysis of section 3.4 applies and the first-period provision of public services and the incumbent's first-period consumption level are given by

$$G_1|_{I_2=\lambda} = \left\{ \frac{\alpha x(1+\lambda)}{2} \left[1 - \frac{1-\lambda}{1+\lambda} 2Zf(R, x, \lambda) \right] \right\}^{1/(1-\alpha)} \tag{3.5.1}$$

and

$$c_{1,A}^{A}\Big|_{I_2=\lambda} = \frac{2}{(1+\lambda)\alpha} \left[1 + \frac{\lambda}{1+\lambda} 2Zf(R, x, \lambda) \right]^{-1} \left[(1-\alpha) \; G_1|_{I_2=\lambda} + \alpha R \right], \tag{3.5.2}$$

respectively, where the notation highlights the levels of G_1 and $c_{1,A}^{A}$ now depend on the choice of I_2 (otherwise, equation 3.5.1 is identical to equation 3.4.11, while 3.5.2 is identical to 3.4.12).

[21] Even for the case in which I_2 can take any value in the interval $[\lambda, 1]$, numerical simulations suggest that the incumbent will either opt for the lower or the upper bound.

On the other hand, if the incumbent chooses $I_2 = 1 > I_1 = \lambda$, holding political power does not offer any privileged access to rents in $t = 2$. Hence, in this situation, there is no need for a defense strategy resting on repression and underspending. As a result, the first-period level of public services is given by $G^*(x, \lambda)$ and

$$c_{1,A}^A\Big|_{I_2=1} = \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)G^*(x,\lambda) + \alpha R\right] \tag{3.5.3}$$

A comparison of equations (3.5.2) and (3.5.3) makes immediately clear that $c_{1,A}^A\Big|_{I_2=\lambda} < c_{1,A}^A\Big|_{I_2=1}$.

3.5.2 Equilibrium

The equilibrium level of $I_2 \in \{\lambda, 1\}$ is the one that maximizes the incumbent's overall utility. Concretely, the incumbent opts for full institutional cohesiveness ($I_2 = 1$) if

$$\ln\left[c_{1,A}^A\Big|_{I_2=1}\right] + \ln\left[c_{2,A}^A(1)\right] \geq \ln\left[c_{1,A}^A\Big|_{I_2=\lambda}\right] + \ln\left[c_{2,A}^A(\lambda)\right].$$

Taking into account equations (3.3.11), (3.5.2), and (3.5.3), and remembering $R > G^*(x, \lambda)$, we obtain

$$\Delta(R) \equiv c_{2,A}^A(1)\left[1 + \frac{\lambda}{1+\lambda}2Zf(R,x,\lambda)\right] - \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)\; G_1|_{I_2=\lambda} + \alpha R\right] \geq 0, \tag{3.5.4}$$

where Δ denotes the net gain from moving to full cohesiveness in $t = 2$. The value of $c_{2,A}^A(1)$ depends on the level of public revenues. Equation (3.3.11) implies that $c_{2,A}^A(1) = xR^\alpha$ if $R \leq G^*(x, 1)$ and $c_{2,A}^A(1) = \alpha^{-1}\left[(1-\alpha)G^*(x,1) + \alpha R\right]$ otherwise. It is straightforward to check that the two levels of consumption are equal at $R = G^*(x, 1)$.

To explore when condition (3.5.4) holds, observe that the two sides of (3.5.4) are exactly equal if $R = G^*(x, \lambda)$: If R is not strictly greater than $G^*(x, \lambda)$, public revenues are in any case entirely spent on public services, implying that the choice of I_2 has no economic implications.[22] When R exceeds $G^*(x, \lambda)$, the situation changes:

Lemma 3.4. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x, \lambda)$. Then, if R is sufficiently close to $G^*(x, \lambda)$, the incumbent strictly prefers $I_2 = 1$ to $I_2 = \lambda$.*

Proof: See Appendix 3.A.1.

[22]To see this formally, note that with $R = G^*(x, \lambda)$ equations (3.4.4) and (3.5.1) imply $f(R, x, \lambda) = 0$ and $G_1|_{I_2=\lambda} = G^*(x, \lambda)$. As a result, condition (3.5.4) simplifies to $xR^\alpha \geq 2(1+\lambda)^{-1}\alpha^{-1}\left[(1-\alpha)G^*(x,\lambda) + \alpha R\right]$. Finally, taking into account $R = G^*(x, \lambda)$, we obtain that the two sides of the condition are exactly equal.

Lemma 3.4 suggests that moving to full institutional cohesiveness is the best defense against challenges from the opposition if the rents from holding office are small. However, if the rents from holding office exceed a certain threshold, this is no longer true:

Lemma 3.5. *Suppose that (3.3.5) and (3.3.8) hold. Then, there exists a finite threshold for R such that the incumbent strictly prefers $I_2 = \lambda$ to $\lambda_2 = 1$ for all R that exceed this threshold.*

Proof: See Appendix 3.A.1.

Lemmas 3.4 and 3.5 do not rule out that $\Delta(R)$, $R \in (G^*(x,\lambda), \infty)$, has more than one root. However, as we establish in the following proposition, this is not the case:

Proposition 3.4. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x,\lambda)$. Then, $\Delta(R)$ is strictly concave in R. Together with Lemmas 3.4 and 3.5, the strict concavity of $\Delta(R)$ implies that there exists a unique threshold $\overline{R} \in (G^*(x,\lambda), \infty)$ such that:*

- *If $R < \overline{R}$, the incumbent strictly prefers $I_2 = 1$ (full cohesiveness).*
- *If $R > \overline{R}$, the incumbent strictly prefers $I_2 = \lambda$ (limited cohesiveness).*

Proof: See Appendix 3.A.2.

The non-monotonic relationship between $\Delta(R)$ and R is the consequence of systematic changes to the relative gain (accruing in $t = 1$) and relative loss (accruing in $t = 2$) associated with moving to full institutional cohesiveness in the second period. As R increases, transfers become a more important source of income, implying that the relative gain (which results from that fact that no defense strategy is needed in $t = 1$) shrinks while the relative loss (resulting from a lower share of transfers in $t = 2$) rises. As a result, at some point, the incumbent changes its defense strategy, away from a commitment to more institutional cohesiveness, towards a combination of repression and under-spending on public services.

A key factor determining the threshold $\overline{R}$ is the relative productivity of the repression technology. From equations (3.5.1) and (3.5.4) we can immediately conclude that for any value of $R > G^*(x,\lambda)$ the net gain from moving to full cohesiveness, $\Delta(R)$, is increasing in Z. Because of the continuity and concavity of $\Delta(R)$, $\overline{R}$ must be increasing in Z as well:

Proposition 3.5. *Suppose that (3.3.5) and (3.3.8) hold and assume $R > G^*(x,\lambda)$. Then, a fall in the relative productivity of the repression technology (i.e., a rise in Z) raises the threshold $\bar{R}$ below which the incumbent prefers full institutional cohesiveness in $t = 2$.*

Figure 3.5.1 illustrates that a reduction in the relative productivity of the repression technology (i.e., a rise in Z from Z^L to Z^H) broadens the range over which $\Delta(R)$ is positive. If the government is relatively bad at producing military strength, it is

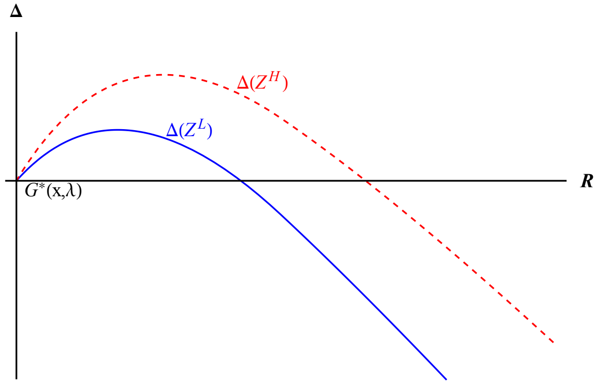

Figure 3.5.1: Public revenues (R) and preferred cohesiveness

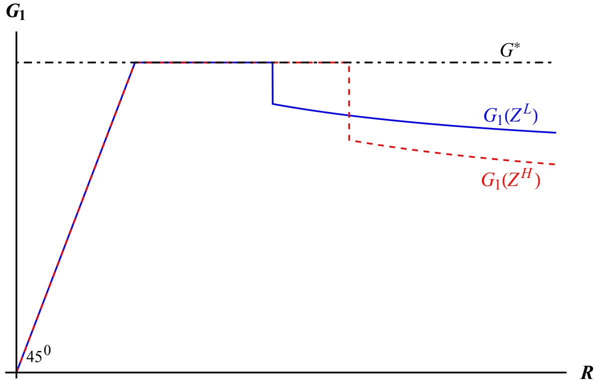

Figure 3.5.2: Public revenues (R) and the provision of public services (G) [endogenous I_2]

prepared to forgo larger amounts of rents in order to avoid adopting a defense strategy that relies on repression. Interestingly, as figure 3.5.2 illustrates, this means that a reduction in the relative productivity of the repression technology does not have an unambiguous effect on the provision of public services in $t = 1$. When the government revenues are relatively large the incumbent adopts a strategy that combines repression and under-providing public services, irrespective of the value of Z; in this case a lower relative productivity of the repression technology (a higher Z), exacerbates the under-provision of public services. However, for intermediate values of R, more precisely for $\overline{R}(Z^L) < R < \overline{R}(Z^H)$, a rise in Z from Z^L to Z^H results in a higher provision of G_1 as a consequence of the incumbent shifting from a repression and under-provision strategy to a strategy of improving institutional cohesiveness.

3.6 Discussion

A basic implication of our model is that—in countries with non-cohesive political institutions—a marginal increase in fiscal strength may produce largely different results. Other things equal, if government revenues rise from a low level, the provision of public services increases, thereby lifting the income of everyone. However, if government revenues rise from a higher level, the effect goes in the opposite direction, possibly with harmful consequences for the incomes of individuals that do not belong to the ruling group. Unlike in Oechslin (2010), where the non-monotonic relationship is driven by an increase in political instability, the impact of additional revenues turns negative because public services become a variable in the incumbent's government defense strategy. The threshold beyond which improvements in fiscal strength turn harmful depends on factors such as the degree to which the political institutions are cohesive, the productivity of private-sector technologies, or the availability of production factors.[23]

From a policy perspective, two simple conclusions follow immediately from this implication. First, international measures to improve fiscal strength (akin to the World Bank's Chad-Cameroon pipeline project or the UN's current "Financing for Development" agenda) are not a universal cure against sub-optimally low levels of public spending on health, education, and infrastructure. Such measures may be

[23]One of the assumptions of the model is that the incumbent cannot target the provision of the public services. This can be related to the specific characteristics of the public service or to those of the polity. This means that from the perspective of the incumbent, the under-provision of public services is as costly as possible. If the incumbent would have the chance to (partially) target the provision of public services, then whenever the incentives to control the government are at play, the under-provision of the public services for the opposition would be even lower than under a non-targeted provision. After all, targeting allows the incumbent to use under-provision as a defense strategy while forgoing the short run cost of a lower private income.

successful in some fiscally weak countries—but may be counterproductive in others.[24] Holding other factor constant, they are more likely to be harmful in technologically backward countries with non-cohesive political institution. Second, even in fiscally weak states where the marginal effect of such measures is positive, more is not always better. Large increases in government revenues (such as those experienced by Chad) may actually lead to worse outcomes in terms of public services than small increases.

What type of international measures could raise the provision of public services even if the marginal impact of government revenues were negative? In this situation, suitable measures would be those that raise the productivity of private-sector technologies (or the availability of production factors). While leaving total government revenues unchanged, such measures would lead to a reallocation of public resources towards public services, away from spending on repression and transfers. So there would be a double payoff: Next to the direct payoff coming from better technologies, there would be an indirect one, operating through a reorientation of public spending. Public services would further be affected by measures that lead to a change in the relative productivity of the repression technology (e.g., a weakening of an existing arms embargo so that the government could buy more effective equipment, or providing logistic support for the government forces). With exogenous political institutions, a marginal raise in the productivity of the repression technology unambiguously increases the provision of public services because of the lower need to under-provide them to secure political power.

Interestingly, when we treat cohesiveness as endogenous, there are also situations in which a discrete fall in the productivity of the repression technology leads to a discrete improvement in the provision of public services. If the government is able to commit to a more equal distribution of transfers in the future, and if public revenues are not too high, a weakening of the government's repression technology may prompt a change in its strategy to forestall an attack by the opposition. In particular, it may switch from a strategy that combines repression and under-providing public services to a strategy of improving institutional cohesiveness. Such a change in strategy would lead to a higher level of public services in the short run (because the government does not engage in the under-provision/repression defense strategy in $t = 1$) as well as the long run (because of the more cohesive institutions in $t = 2$).[25]

[24] A similar caveat applies to aid in the form of direct provision of public services by third parties. In the present framework, direct provision of public services is formally equivalent to providing resources as long as the level provided by the third party is lower than what the government would provide if it were the lone provider.

[25] A fall in the productivity of the repression technology could be, for instance, the result of the existence of an external party supporting the opposition's militia. Think for example of the existence of a diaspora helping to finance the opposition's militia.

Finally, our result that political institutions may improve in response to an exogenous raise in the resources available to the government contrasts with important approaches and arguments in the related literature. Influential contributions to the foreign aid and natural resource literature treat institutional quality as exogenous and show it to be a key factor determining whether additional revenues promote or hinder growth; there is further the argument that large increases in public revenues (due to natural resource discoveries or aid inflows) harm political institutions in the long run (see, e.g., Deaton, 2013; van der Ploeg, 2011, for overviews).[26] The present theory is not necessarily inconsistent with these approaches and arguments; it just suggests that from a theoretical perspective there is no reason to expect exogenous increases in government revenues to have an unambiguous positive or negative effect on the quality (here: cohesiveness) of political institutions. Instead, the effect of exogenous revenues on political institutions depends on how large this revenues are. In addition, our framework identifies factors (e.g., the productivity of the repression technology) that may influence whether a raise in government revenues is beneficial or harmful for the political institutions.

3.7 Conclusions

The Chad-Cameroon pipeline project is an example of how (the prospect of) huge exogenous increases in public revenues can make matters worse in fiscally weak states with non-cohesive political institutions. Our theoretical analysis suggests that there is no reason to expect that the Chadian experience would be unavoidable; it identifies circumstances under which political actors may have stronger incentives to abstain from conflict and invest additional resources productively—or may even agree on institutional reforms that foster long-run growth. At the same time, by suggesting that success is likely to depend on country-specific circumstances, it cautions against calls to indiscriminately increase the flow of resources towards fiscally weak countries. Our parsimonious framework further highlights that exogenous increases in public revenues can have dramatically better implications in environments that are more conducive to lasting institutional change than in environments where institutional change is all but impossible. This final implication prompts a number of interesting questions for future research. For instance, is it robust to obvious modifications in the setup (e.g., allowing for gradual institutional change or institutional degradation; infinite time horizon)? Or: What could be characteristics that make polities more conducive to institutional change? A further avenue for

[26]The empirical evidence on the impact of foreign aid on the quality of institutions is mixed. In a recent paper, (S. Jones & Tarp, 2016) find a small positive effect of aid on a proxy for institutional quality.

future research is the tension between the provision of productive public services and the direct provision of consumption goods. The distinction between productive services and consumption goods is a fundamental one. Allowing for the presence of both policy tools may serve to better understand whether, and in what circumstances, clientelism and repressive strategies are complements or substitutes in the incumbent's strategy to retain political power.

Appendix 3

3.A Proofs

3.A.1 Proofs of Lemmas

Proof of Lemma 3.1

Proof. The definition of $f(R, x, \lambda)$ given in equation (3.4.4) immediately implies

$$\lim_{R \to G^*} f(R, x, \lambda) = 0 \text{ and } \lim_{R \to \infty} f(R, x, \lambda) = (1 - \lambda)/2.$$

As G^* is strictly increasing in x and in λ, it is further immediately clear that $\partial f / \partial x < 0$ and $\partial f / \partial \lambda < 0$. Finally,

$$\frac{\partial f(R, x, \lambda)}{\partial R} = \frac{(1-\lambda)\alpha}{2} \frac{G^*(x, \lambda)}{[(1-\alpha)G^*(x, \lambda) + \alpha R]^2} > 0. \tag{3.A.1}$$

□

Proof of Lemma 3.2

Proof. With $D_1 = \underline{D}_1$, and using (3.4.7) the Lagrangian associated with optimization problem (3.3.9) reads

$$L = x(G_1)^\alpha + \left[\tfrac{2}{1+\lambda} + \mu_1\right] \cdot \\ \left[R - G_1 - \tfrac{Zf}{1+Zf2\lambda/(1+\lambda)} \left(x(G_1)^\alpha + 2\tfrac{\lambda}{1+\lambda}(R - G_1)\right)\right],$$

where $\mu_1 \geq 0$ denotes the Lagrange multiplier associated to the non-negativity constraint of transfers (for notational simplicity, we drop the arguments of f throughout this proof). The corresponding first-order condition (FOC) with respect to G_1 is given by,

$$\alpha x(G_1)^{\alpha-1} = \left[\frac{2}{1+\lambda} + \mu_1\right] \left[\frac{Zf}{1 + Zf2\lambda/(1+\lambda)} \left(\alpha x(G_1)^{\alpha-1} - 2\frac{\lambda}{1+\lambda}\right)\right] \tag{3.A.2}$$

Guess now that the total transfer, $R - G_1 - D_1$, is strictly positive (and hence $\mu_1 = 0$). Then, the FOC (3.A.2) turns into

$$\alpha x(G_1)^{\alpha-1} \left[1 - \frac{Zf2/(1+\lambda)}{1 + Zf2\lambda/(1+\lambda)}\right] - \frac{2}{1+\lambda} \left[1 - \frac{Zf2\lambda/(1+\lambda)}{1 + Zf2\lambda/(1+\lambda)}\right] = 0. \tag{3.A.3}$$

Equation (3.A.3) can be rearranged to obtain the expression for G_1 that is stated in the lemma (equation 3.4.11). To see that $G_1 < G^* = (\alpha x(1+\lambda)/2)^{1/(1-\alpha)}$, observe the three inequalities $(1-\lambda)/(1+\lambda) \leq 1$, $Z < 1$, and $f < 1/2$ (Lemma 3.1). $\partial G_1/\partial R < 0$, on the other hand, follows from the fact that $\partial f/\partial R > 0$ (Lemma 3.1), and $\lim_{R \to G^*} G_1 = (\alpha x(1+\lambda)/2)^{1/(1-\alpha)} = G^*$ is immediately implied by $\lim_{R \to G^*} f = 0$ (Lemma 3.1).

To derive equation (3.4.12), we use equation (3.4.8) to substitute for $D_1 = \underline{D}_1$ in equation (3.4.9):

$$c_{1,A}^A = \left[x \left(1 - \frac{1-\lambda}{1+\lambda} Z2f \right) (G_1)^\alpha + \frac{2}{1+\lambda}(R - G_1) \right] \left(1 + Zf2\frac{\lambda}{1+\lambda} \right)^{-1}. \quad (3.A.4)$$

Taking into account the functional form of G_1 given in equation (3.4.11), one can rearrange equation (3.A.4) to obtain the expression for consumption that is stated in the lemma (equation 3.4.12). To derive the limit of $c_{1,A}$ as $R \to G^*$, we take into account the corresponding limits—discussed above—of f and G_1. These two limits imply $\lim_{R \to G^*} c_{1,A}^A = 2(1+\lambda)^{-1}\alpha^{-1}G^*$, and it is straightforward to verify that $2(1+\lambda)^{-1}\alpha^{-1}G^* = x(G^*)^\alpha$.

The next step is to prove that the aggregate transfer, $R - G_1 - \underline{D}_1(G_1)$, is indeed strictly positive (so that $\mu_1 = 0$), as has been assumed so far. To do so, we note the following: Since $G_1 < G^*$, and since $c_{1,A}^A$ can be written as $x(G_1)^\alpha + 2(1+\lambda)^{-1}(R - G_1 - \underline{D}_1(G_1))$, a sufficient condition for $R - G_1 - \underline{D}_1(G_1) > 0$ is $c_{1,A} > x(G^*)^\alpha$. The rest of this poof is therefore devoted to establishing that

$$c_{1,A}^A(G_1) > x(G^*)^\alpha \quad \forall R > G^*, \quad (3.A.5)$$

where $c_{1,A}^A(G_1)$ and G_1 are given by equations (3.4.12) and (3.4.11), respectively. In this context, note that for $R \to G^*$ the two sides of inequality (3.A.5) are exactly equal. Making use of equations (3.4.12) and (3.4.11), and after some transformations, inequality (3.A.5) can be written as

$$(1-\alpha)G^* \left(1 - \frac{1-\lambda}{1+\lambda} Z2f \right)^{1/(1-\alpha)} + \alpha R > \left(1 + Zf2\frac{\lambda}{1+\lambda} \right) G^* \quad \forall R > G^*, \quad (3.A.6)$$

where—again—left-hand side (LHS) and right-hand side (RHS) are exactly equal for $R \to G^*$. To prove that (3.A.6) holds, it is sufficient to establish that the derivative of the LHS with respect to R, $\partial LHS/\partial R$, is strictly greater than $\partial RHS/\partial R$ for $\forall R \geq G^*$. The two derivatives are

$$\frac{\partial LHS}{\partial R} = -G^* \cdot \left(1 - \frac{(1-\lambda)Z2f}{1+\lambda}\right)^{\alpha/(1-\alpha)} \frac{(1-\lambda)Z2}{1+\lambda}\frac{\partial f}{\partial R} + \alpha R$$

and

$$\frac{\partial RHS}{\partial R} = G^* \cdot \frac{\lambda Z2}{1+\lambda}\frac{\partial f}{\partial R},$$

where $\partial f/\partial R$ is given by equation (3.A.1). $\partial LHS/\partial R > \partial RHS/\partial R$ for $\forall R \geq G^*$ is equivalent to

$$\alpha > G^* \cdot Z2\frac{\partial f}{\partial R}\left[\lambda + (1-\lambda)\left(1 - \frac{1-\lambda}{1+\lambda}Z2f\right)^{\alpha/(1-\alpha)}\right] \quad \forall R \geq G^*. \tag{3.A.7}$$

To see that (3.A.7) holds, note two things: (i) At $R = G^*$, (3.A.7) simplifies to $1 > Z(1-\lambda)$, a condition that holds since $Z < 1$; (ii) the right-hand side of (3.A.7) is decreasing in R because $\partial f/\partial R$ is decreasing in R (see equation 3.A.1) and f is increasing in R. So, together, (i) and (ii) imply that (3.A.7) holds, while (3.A.7) implies that (3.A.6) holds, while (3.A.6) implies that (3.A.5) holds. And, (3.A.5) implies that $R - G_1 - \underline{D}_1(G_1) > 0$ for $\forall R \geq G^*$.

As a last step, note that once the optimization problem (3.3.9) is reduced to one variable, by using $D_1 = \underline{D}_1$, one can directly see that the objective function (3.A.4) is strictly concave in G_1. This means that the G_1 that emerges as a solution of (3.A.3), i.e., equation (3.4.11), is indeed the only solution to the optimization problem (3.3.9). □

Proof of Lemma 3.3

Proof. Condition (3.4.16) can be rewritten as

$$\frac{\left[(1-\alpha)G^*\Lambda^{1/(1-\alpha)} + \alpha R\right]}{[(1-\alpha\lambda)G^* + \alpha\lambda R]} \geq 1 + Zf2\frac{\lambda}{1+\lambda}, \tag{3.A.8}$$

where Λ is defined by equation (3.4.14). The arguments of f are again dropped throughout this proof for notational simplicity. Since $\lim_{R\to G^*} \Lambda = 1$ and $\lim_{R\to G^*} f = 0$, it immediately follows that condition (3.A.8) holds with equality as $R \to G^*$. To show that (3.A.8) holds for $\forall R \geq G^*$, it is sufficient to establish that the derivative of the left-hand side (LHS) with respect to R, $\partial LHS/\partial R$, is strictly greater than $\partial RHS/\partial R$ for $\forall R \geq G^*$. The two derivatives read

$$\frac{\partial LHS}{\partial R} = \frac{\left(-G^*\Lambda^{\alpha/(1-\alpha)}\frac{1-\lambda}{1+\lambda}Z2\frac{\partial f}{\partial R}+\alpha\right)}{[(1-\alpha\lambda)G^*+\alpha\lambda R]} - \frac{\left[(1-\alpha)G^*\Lambda^{1/(1-\alpha)}+\alpha R\right]\alpha\lambda}{[(1-\alpha\lambda)G^*+\alpha\lambda R]^2}$$

and

$$\frac{\partial RHS}{\partial R} = \frac{\lambda}{1+\lambda}Z2\frac{\partial f}{\partial R},$$

where $\partial f/\partial R$ is given by equation (3.A.1). One can show that $\partial LHS/\partial R \geq \partial RHS/\partial R$ for $\forall R \geq G^*$ is equivalent to

$$(1-\alpha\lambda)-(\lambda-\alpha\lambda)\Lambda^{1/(1-\alpha)} \tag{3.A.9}$$

$$\geq Z\frac{1-\lambda}{1+\lambda}\left[\frac{(1-\alpha\lambda)G^*+\alpha\lambda R}{(1-\alpha)G^*+\alpha R}\right]^2\left[\lambda+(1-\lambda)\frac{G^*\Lambda^{\alpha/(1-\alpha)}}{(1-\alpha\lambda)G^*+\alpha\lambda R}\right] \quad \forall R \geq G^*.$$

To see that (3.A.9) holds, note two things: (i) At $R = G^*$, we have $\Lambda = 1$, so that (3.A.9) simplifies to $(1+\lambda) \geq Z$, a condition that holds since $Z < 1$; (ii) the left-hand side of (3.A.9) is increasing in R because $\partial\Lambda/\partial R < 0$, while the right-hand side is decreasing in R. So, together, (i) and (ii) imply that (3.A.9) holds, while (3.A.9) implies that (3.A.8) holds for $\forall R \geq G^*$. Since (3.A.8) and (3.4.16) are equivalent, condition (3.4.16) must—too—hold for $\forall R \geq G^*$, implying that the incumbent prefers to hold on to power. □

Proof of Lemma 3.4

Proof. We prove the lemma by showing $d\Delta/dR|_{R=G^*(x,\lambda)} > 0$. So we focus on the case $G^*(x,\lambda) < R \leq G^*(x,1)$, implying $c^A_{2,A}(1) = xR^\alpha$. As a result, (3.5.4) turns into

$$\Delta(R) = xR^\alpha\left[1+\frac{\lambda}{1+\lambda}2Zf(R,x,\lambda)\right] - \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)\left.G_1\right|_{I_2=\lambda}+\alpha R\right] \geq 0. \tag{3.A.10}$$

As noted earlier, if $G^*(x,\lambda) = R$, the two terms in condition (3.A.10) are exactly equal, implying $\Delta(R)|_{R=G^*(x,\lambda)} = 0$. Establishing $d\Delta/dR|_{R=G^*(x,\lambda)} > 0$ will therefore prove the lemma. Observing that $f(R,x,\lambda)$ and $G_1|_{I_2=\lambda}$ are given by (3.4.4) and (3.5.1), respectively, we obtain

$$\left.\frac{d\Delta}{dR}\right|_{R=G^*(x,\lambda)} = \frac{2}{1+\lambda}\left[1+\frac{\lambda(1-\lambda)}{(1+\lambda)}Z\right] - \frac{2}{1+\lambda}\left[1-\frac{(1-\lambda)^2}{(1+\lambda)}Z\right]$$

$$= \frac{2}{1+\lambda}\frac{1-\lambda}{1+\lambda}Z > 0,$$

where the sign follows from $\lambda < 1$ and $Z > 0$. □

Proof of Lemma 3.5

Proof. In what follows, it is sufficient to focus on the case $G^*(x,1) < R$. Then, $c^A_{2,A}(1) = \alpha^{-1}\left[(1-\alpha)G^*(x,1) + \alpha R\right]$, and condition (3.5.4) turns into

$$\Delta(R) = \frac{1}{\alpha}\left[(1-\alpha)G^*(x,1) + \alpha R\right]\left[1 + \frac{\lambda}{1+\lambda}2Zf(R,x,\lambda)\right] - \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)\ G_1|_{I_2=\lambda} + \alpha R\right] \geq 0, \quad (3.A.11)$$

where Δ denotes again the net gain from moving to full institutional cohesiveness in $t = 2$. To prove the lemma, we now replace in (3.A.11) the functions $f(R,x,\lambda)$ and $G_1|_{I_2=\lambda}$ by their limits $\lim_{R\to\infty} f(R,x,\lambda) = (1-\lambda)/2$ and $\lim_{R\to\infty} G_1|_{I_2=\lambda} = G^*(x,\lambda)\left[1-(1-\lambda)^2(1+\lambda)^{-1}Z\right]^{1/(1-\alpha)}$, respectively. The resulting expression is given by

$$\tilde{\Delta}(R) = \frac{1}{\alpha}\left[(1-\alpha)G^*(x,1) + \alpha R\right]\left[1 + \frac{\lambda(1-\lambda)}{1+\lambda}Z\right] - \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)G^*(x,\lambda)\left[1-(1-\lambda)^2(1+\lambda)^{-1}Z\right]^{1/(1-\alpha)} + \alpha R\right].$$

Since $f(R,x,\lambda)$ is strictly less than its limit, and since $G_1|_{I_2=\lambda}$ is strictly greater than its limit, we have $\tilde{\Delta}(R) > \Delta(R)$ for all $R \in [G^*(x,1),\infty)$. $\tilde{\Delta}(R)$ is a linear function in R with slope

$$\frac{d\tilde{\Delta}}{dR} = \frac{1}{1+\lambda}\left[1+\lambda+\lambda(1-\lambda)Z - 2\right] < 0,$$

where the sign follows from $\lambda < 1$ and $Z < 1$.

Assume now that $\tilde{\Delta}(R)\big|_{R=G^*(x,1)} > 0$. Then, there must exist a finite $\tilde{R} > G^*(x,1)$ such that $\tilde{\Delta}(\tilde{R}) = 0$ and $\tilde{\Delta}(R) < 0$ for all $R > \tilde{R}$. Since $\tilde{\Delta}(R) > \Delta(R)$, it follows that there must also be a finite $\bar{R} < \tilde{R}$ such that $\Delta(\bar{R}) = 0$ and $\Delta(\bar{R}) < 0$ for all $R > \bar{R}$. On the other hand, if $\tilde{\Delta}(R)\big|_{R=G^*(x,1)} \leq 0$, we have $\Delta(R) < 0$ for all $R \geq G^*(x,1)$. So, also in this alternative case, there exists a finite threshold for R so that $\Delta(R) < 0$ for all R that exceed this threshold. □

3.A.2 Proofs of Propositions

Proof of Proposition 3.4

Proof. We start the proof by introducing some notation. In what follows, we use $f' \equiv \partial f(R,x,\lambda)/\partial R$, an expression that is given by (3.A.1). Moreover, we obtain

$$f'' \equiv \frac{\partial^2 f}{\partial R^2} = -(1-\lambda)\,\alpha^2 \frac{G^*(x,\lambda)}{\left[(1-\alpha)\,G^*(x,\lambda)+\alpha R\right]^3} < 0. \tag{3.A.12}$$

We now distinguish the cases $R \leq G^*(x,1)$ and $R > G^*(x,1)$. In the former case, $c^A_{2,A}(1) = xR^\alpha$, implying that the net gain from moving to full cohesiveness is given by

$$\Delta(R) = xR^\alpha \left[1 + \frac{\lambda}{1+\lambda} 2Zf(R,x,\lambda)\right] - \frac{2}{(1+\lambda)\alpha}\left[(1-\alpha)\;G_1|_{I_2=\lambda} + \alpha R\right] \geq 0.$$

From (3.A.1) and (3.A.12), we can immediately infer that f is strictly concave in R. Taking into account the strict concavity of f, equation (3.5.1) suggests that $G_1|_{I_2=\lambda}$ is strictly convex in R. As a result, $-2/\left[(1+\lambda)\,\alpha\right]\left[(1-\alpha)\,G_1|_{I_2=\lambda}+\alpha R\right]$ must be strictly concave in R. Given that R^α is also strictly concave, the concavity of $R^\alpha f$ is sufficient for $\Delta(R)\,|_{R\leq G^*(x,1)}$ to be strictly concave in R. Differentiating $R^\alpha f$ twice with respect to R yields

$$\frac{d^2\left(R^\alpha f\right)}{dR^2} = -(1-\alpha)\,\alpha R^{\alpha-2} f + 2\alpha R^{\alpha-1}\left(f'\right)^\alpha f''.$$

Using (3.4.4), (3.A.1), and (3.A.12), we obtain that $d^2\left(R^\alpha f\right)/dR^2 < 0$ is equivalent to

$$\alpha^2(1-\alpha)\,RG^*\left[G^*-R\right] - \frac{(1-\alpha)\,\alpha^2}{2}\left[-G^*+R\right]\left[(1-\alpha)\,G^*+\alpha R\right]^2 < 0, \tag{3.A.13}$$

where G^* is short for $G^*(x,\lambda)$. Since $R > G^*(x,\lambda)$, equation (3.A.13) must be satisfied. We therefore conclude that $R^\alpha f$—and hence so $\Delta(R)\,|_{R\leq G^*(x,1)}$—are strictly concave in R.

Assume now $R > G^*(x,1)$. In this case, the net gain from moving to $I_2 = 1$ is given by

$$\Delta(R) = \left[\frac{(1-\alpha)\,G^*(x,1)+\alpha R}{\alpha}\right]\left[1+\frac{\lambda}{1+\lambda}2Zf\right] - \frac{2}{(1+\lambda)\,\alpha}\left[(1-\alpha)\,G_1|_{I_2=\lambda}+\alpha R\right].$$

For the first derivative with respect to R we obtain

$$\frac{d\Delta(R)}{dR} = \frac{\lambda-1}{1+\lambda} + \frac{2\lambda Zf}{1+\lambda} + \frac{2Zf'}{\alpha(1+\lambda)}\left\{\lambda\left[(1-\alpha)G^*(x,1)+\alpha R\right]+\alpha(1-\lambda)xG^{\alpha}_{1,\lambda}\right\},$$

where we have used $\partial G_{1,\lambda}/\partial R = \alpha x(1-\alpha)^{-1}G^{\alpha}_{1,\lambda}\left[-(1-\lambda)Zf'\right]$ and $G_{1,\lambda}$ is short for $G_1|_{I_2=\lambda}$. Further rewriting yields

$$\frac{d\Delta(R)}{dR} = \frac{\lambda-1}{1+\lambda} + \frac{2Z}{1+\lambda}f'\left\{\frac{\lambda}{\alpha}\left[(1-\alpha)G^*(x,1)+\alpha R\right]+(1-\lambda)xG^{\alpha}_{1,\lambda}+\lambda\frac{f}{f'}\right\},$$

where we obtain from equations (3.4.4) and (3.A.1) that

$$\frac{f}{f'} = \frac{\left[-G^*(x,\lambda)+R\right]\left[(1-\alpha)G^*(x,\lambda)+\alpha R\right]}{G^*(x,\lambda)}. \tag{3.A.14}$$

Let us now introduce for the non-constant part of $d\Delta(R)/dR$ the definition

$$U \equiv f'\left\{\frac{\lambda}{\alpha}\left[(1-\alpha)G^*(x,1)+\alpha R\right]+(1-\lambda)xG^{\alpha}_{1,\lambda}+\lambda\frac{f}{f'}\right\}.$$

Inserting expression (3.A.14) yields

$$\begin{aligned}U = {} & f'\frac{\lambda}{\alpha}\left[(1-\alpha)G^*(x,1)+\alpha R\right]+(1-\lambda)xG^{\alpha}_{1,\lambda} \\ & + f'\lambda\left[\frac{\alpha R^2}{G^*(x,\lambda)}+(1-2\alpha)R-(1-\alpha)G^*(x,\lambda)\right].\end{aligned}$$

We further obtain

$$\begin{aligned}\frac{dU}{dR} = {} & f'\left\{\lambda - \frac{\left[(1-\lambda)\alpha x\right]^2}{1-\alpha}G^{2\alpha-1}_{1,\lambda}Zf' + \lambda\left[\frac{2\alpha R}{G^*(x,\lambda)}+(1-2\alpha)\right]\right\} \\ & + f''\left\{\frac{\lambda}{\alpha}\left[(1-\alpha)G^*(x,1)+\alpha R\right]+(1-\lambda)xG^{\alpha}_{1,\lambda}\right\} \\ & + f''\lambda\left[\frac{\alpha R^2}{G^*(x,\lambda)}+(1-2\alpha)R-(1-\alpha)G^*(x,\lambda)\right].\end{aligned}$$

Note that $d^2\Delta(R)/dR^2$ and dU/dR have the same sign. The sign of dU/dR, in turn, is the same as the sign of

$$B \equiv \frac{f'}{-f''}\left[-\frac{\left[(1-\lambda)\,\alpha x\right]^2}{(1-\alpha)\,\lambda}G_{1,\lambda}^{2\alpha-1}Zf' + \frac{2\alpha R}{G^*(x,\lambda)} + 2(1-\alpha)\right]$$
$$-\left[\frac{1}{\alpha}\left[(1-\alpha)\,G^*(x,\,1)+\alpha R\right] + \frac{(1-\lambda)\,xG_{1,\lambda}^{\alpha}}{\lambda}\right]$$
$$-\left[\frac{\alpha R^2}{G^*(x,\lambda)} + (1-2\alpha)\,R - (1-\alpha)\,G^*(x,\lambda)\right].$$

From equations (3.A.1) and (3.A.12) we can derive that

$$\frac{f'}{-f''} = \frac{1}{2\alpha}\left[(1-\alpha)\,G^*(x,\,\lambda)+\alpha R\right]. \tag{3.A.15}$$

Inserting expression (3.A.15) yields

$$B = \frac{1}{\alpha}\frac{\left[(1-\alpha)\,G^*(x,\,\lambda)+\alpha R\right]^2}{G^*(x,\lambda)} + w$$
$$-\left[\frac{1}{\alpha}\left[(1-\alpha)\,G^*(x,1)+\alpha R\right] + \frac{\alpha R^2}{G^*(x,\lambda)} + (1-2\alpha)\,R - (1-\alpha)\,G^*(x,\lambda)\right],$$

where $w \equiv (f')^2(f'')^{-1}\left[(1-\lambda)\,\alpha x\right]^2\left[(1-\alpha)\,\lambda\right]^{-1}G_{1,\lambda}^{2\alpha-1}Z - (1-\lambda)\,xG_{1,\lambda}^{\alpha}\lambda^{-1} < 0$. After some further manipulations, we obtain the simple expression

$$\alpha B = (1-\alpha)\left[G^*(x,\lambda) - G^*(x,1)\right] + \alpha w < 0.$$

We therefore conclude that dU/dR—and hence $d^2\Delta(R)/dR^2$—must be strictly negative. As a result, $\Delta(R)\,|_{R>G^*(x,1)}$ is strictly concave in R.

Finally, to complete the proof of strict concavity of $\Delta(R)$, we need to show that the first derivative is non-increasing at the junction point $G^*(x,\,1)$. In formal terms, we have to establish $\lim_{R\to G^*(x,1)^-} d\Delta(R)/dR - \lim_{R\to G^*(x,1)^+} d\Delta(R)/dR \geq 0$. This difference equals

$$\lim_{R\to G^*(x,1)}\left(\left[\alpha x R^{\alpha-1}-1\right]\left[1+\frac{\lambda}{1+\lambda}2Zf\right] + \left[xR^{\alpha}-\frac{R}{\alpha}\right]\left[\frac{\lambda}{1+\lambda}2Zf'\right]\right) = 0,$$

where the last equality follows from $G^*(x,\,1) = (\alpha x)^{1/(1-\alpha)}$. We therefore conclude that the first derivative of $\Delta(R)$ is continuous in R. As a result, $\Delta(R)$ is strictly concave in R for $R > G^*(x,\,1)$. □

Chapter 4

Dynamic Resource Management Under Weak Property Rights: A Tale of Thieves and Trespassers[1]

Abstract

Using a dynamic framework with strategic interactions, we study the management of a non-renewable natural resource when property rights are generally weak. Under generally weak property rights both the resource stock and the revenues from exploiting it are imperfectly protected, due to trespassing and theft respectively. Trespassing and theft, affect the legitimate owner's extraction decision: extracting the resource today protects the stock against trespassing but exposes the revenues to theft. Our results indicate that the depletion of the resource is decreasing in the intensity of theft. In addition, when the owner and the trespassers are affected by theft, the depletion of the resource is above (below) the social optimal level if the intensity of theft is low (high).

[1]This chapter is the result of joint work with Sjak Smulders.

4.1 Introduction

Property rights ought to be adequately defined and secured for economic interactions to lead to efficient outcomes. However, in the imperfect world we live in, the problem of weak property rights is not an uncommon one. Such is the case of the management of non-renewable resources, where property rights have been for long central in the discussion of how to secure the optimal use of these resources. In this context, a weak protection of property rights is often associated with a problem of common access to the stock of the resource. That is, it is generally assumed that when property rights are weak, agents cannot be effectively excluded from accessing the pool of the resource, leading to it being over-exploited (tragedy of the commons).

Besides the problem of common access to the pool of the resource, the weakness of the property rights system can also have other manifestations. Hotte, McFerrin, and Wills (2013) rightly point out that the failure to fully appropriate the benefits from exploiting a resource, is another form of weak property rights. Put differently, when property rights are weak, the management of a non-renewable resource may not only be affected by insecure property rights over the stock of the resource, but also by imperfect property rights over the output generated from exploiting the resource.

Take for instance the anecdotes from the first major oil discovery in the U.S. (Yergin, 2008). January 10, 1901 marked the beginning of the Texas oil boom at Spindletop hill in the south of the town of Beaumont. That day, the first successful drilling in the area caused a dramatically high oil gusher, and it did not take long for the news to spread across the country. In a short period of time a mass of workers flocked into Beaumont hoping to seize a share of its underground riches. As highlighted by Yergin (2008) "[w]ithin months, there were 214 wells jammed in on the hill, owned by at least a hundred different companies" (p. 70). This seemingly indiscriminate access to oil in the ground, would soon have its consequences, "by the middle of 1902 . . . the underground pressure gave out at Spindletop because of overproduction, and specially because of all those derricks on postage-stamp sized plots, and production on the Big Hill plummeted". While the oil was being rapaciously depleted, the "fortunes" made from the oil extraction were far from protected. Beaumont was not exactly a safe haven "there were two or three murders a night . . . and there were endless frauds to make sure that money changed hands quickly" (p. 69).

A similar situation occurred half a century before the Texas oil boom, when news of the gold discoveries in California were fast to spread across America. At the outset of the California gold rush in 1848, California was yet to be admitted to the Union, meaning that rush effectively took place in a "stateless" environment. The statelessness made it difficult to solve the coordination issue inherent to the public protection of property rights (Anderson & Libecap, 2014). The absence of a state, and its coordinating role, hindered the emergence of formal institutions of property rights protection. Thus, "not only were there no institutions to enforce the laws, there were no laws" (McDowell, 2002, p. 2).[2] It has been argued that, during the rush, informal rules emerged to take the place of formal institutions regulating the access to private property, and that private efforts (partially) compensated for the absence of publicly provided enforcement of property rights (e.g., Umbeck, 1977; McDowell, 2002). However, it is unclear whether the informal rules and the private efforts actually served to deter trespassing and other property and violent crimes. Clay and Wright (2005) contend that this set of informal rules and enforcement bodies rather "gave equal attention to the rights of claim-jumpers as to claim-holders, a balance that in practice generated chronic insecurity" (p. 155). Clay and Wright (2005) go further and propose that despite the existence of these informal institutions and enforcement bodies, gold mining during the rush remained closer to an open access regime. Besides claim-jumping (trespassing), "robberies and assaults also seemed to be on the rise" (Rohrbough, 1997, p. 218), posing a direct threat on the miner's output. Moreover, the absence of a governing body coordinating law enforcement, implied that individual efforts had to be diverted into the administration of protection and justice (Owens, 2002).

A present-day counterpart of the American gold rush of the mid 1800s is the case of illegal/informal mining in the developing world (Banchirigah, 2008; Hilson, 2002; Hilson & Potter, 2003). This activity, which is by no means marginal, is a modern example of the problem of generally weak property rights. Illegal miners are trespassers of the legitimate owner's (the government's) property rights over the stock of the resource. Next to this, activities related to the transformation of the illegal mineral output into cash typically occur outside the law. In practice, this means that illegal miners are especially unprotected against property and violent crime. Illegal miners cannot turn to the government for protection, for instance, to enforce contracts without threatening their own economic activity.

These pieces of anecdotal evidence share as common theme: the exploitation of a non-renewable natural resource in an environment of weak property rights, where both the stock in the ground and the output after extraction are at risk. With this as a background, this chapter analyzes the dynamic management of a non-renewable resource when property rights are generally weak. In particular, we study whether

[2] In fact, a large fraction of first mineral discoveries in America occurred in a situation of statelessness. According to Couttenier, Grosjean, and Sangnier (2014) 35% of the counties where minerals were discovered between 1825 and WWII did not officially belong to a state or a colony at the time of the first discovery.

under generally weak property rights (i.e., in the presence of theft and trespassing), the pace of depletion of the resource is too high or too low relative to the social optimum. Furthermore, we analyze how a dynamically institutional framework, that is an evolving protection of property rights, has an effect on the resource's extraction path.

This chapter fits into a long tradition of resource economics literature dealing with resource management under insecure property rights. This literature has largely focused on the "common access to the stock" side of the weak property rights story (e.g. Copeland & Taylor, 2009; Hardin, 1968; Van Long, 2011; Ostrom, 2008). The typical result is that the failure to internalize the effect own use of the resource on the rest of the users, leads to excessive use of the resource from the social perspective. In this sense, analyzing the effects of the interaction between two embodiments of a weak property rights system (i.e., weakly protected stock and flow) in a resource management problem is relevant in itself. From a general perspective, this type of analysis, combining a set of imperfections is an application of the second best theory (Lipsey & Lancaster, 1956). Essentially by assuming that, on top of the common access to the stock problem, the revenues from extraction are imperfectly protected, a new source of inefficiency is added to an already imperfect world. Our results indicate that a world with more imperfections may be preferred from the social perspective. A straightforward reason for this is that agents may react in opposite ways to different imperfections and thus the aggregate effect is less damaging than that of the separate imperfections. Following the idea that the problem of weak property rights can go beyond the "common pool" problem, Hotte et al. (2013) study a static production problem in which both the input used to produce ("the common" in the resource literature) and the output are imperfectly protected. As an application of the second best theory, their results indicate that in the presence of both sources of imperfection, production can be too high or too low from the social perspective.

This chapter adds to the study of the inter-play between two manifestations of a generally weak property rights, by exploring its effects on the *dynamic* management of a resource. Specifically, we assume that access to the resource stock is not fully secured, and that the benefits from extracting it are imperfectly protected. Our aim is to understand the effect that the interaction between these two types of property rights imperfections, has on the rate of depletion of a non-renewable resource. More specifically, we study how the presence of these two imperfections and the dynamic evolution of the institutional quality, i.e., changes in the intensity of the imperfections, have an impact on the inter-temporal trade-offs governing the strategic interactions between the legitimate and illegitimate users of a non-renewable resource.

To the best of our knowledge, this is the first study of the interaction between these two types of imperfections in a dynamic setup. Therefore, our main contribution is to explore the effects of an environment of generally weak property rights on the dynamic extraction path of a non-renewable resource. Furthermore, our analysis is based on a rich, yet tractable, dynamic framework in which institutional quality is allowed to evolve over time. Following Hotte et al. (2013), we refer to the illegitimate extraction of the resource as trespassing, and to the appropriation of someone else's output as theft. The dynamic nature of the resource management problem creates a clear distinction between these two. Trespassing affects the stock that remains in the ground, while theft reduces the value of the extracted flow. Therefore, from the legitimate owner's perspective faster depletion serves to protect the resource against trespassing, but increases its exposure to theft. On top of the clear distinction between the two imperfections, adopting a dynamic perspective allows us to explore the effect an evolving protection of property rights. In particular, when agents anticipate changes in the strength of property rights, the inter-temporal trade-offs governing their extraction decisions are further distorted.

The depletion of a non-renewable resource is in essence a consumption-saving problem, in which the benefits and costs from extracting today are weighed against the benefits of leaving the resource in the ground for future use. Adopting a dynamic perspective generates new insights on the interaction between the two types of inefficiencies. For instance, theft not only reduces the value of what is being currently extracted, but it also reduces the value of what remains in the ground, because it is eventually going to be extracted and will potentially be exposed to theft as well. So, from the inter-temporal point of view the effect of theft on the extraction path actually depends on whether the intensity of theft changes over time. If theft is expected to remain constantly intense over time, the legitimate owner has no motive to distort her extraction path. However, if theft is expected to decrease in intensity, say because thieves are expected to be captured, the owner would adopt a more conservative position towards the extraction of the resource. Therefore, not only the current property rights strength but also its expected evolution determine the current level of depletion.

Although completely absent in a static analysis, this inter-temporal considerations remain central to understand the dynamic channels affecting the management of a non-renewable resource, specially when the institutional framework is expected to change over time. This chapter is organized in four sections including this introduction. In section 2 the theoretical model is set up and solved. In section 3 the main results are analyzed and discussed. Finally, section 4 is devoted to the concluding remarks.

4.2 Model

The model presented here examines how the use of a non-renewable resource is affected by insecure property rights, where the imperfect protection is embodied by two types of distortions. First, the stock of the resource is imperfectly protected. That is, the rightful owner/user of the resource does not have exclusive access to the stock of the resource and other agents can trespass his property and exploit the remaining stock. Second, the proceeds from extraction are unprotected, and so other agents can appropriate a fraction of the owner's revenues from extraction.

4.2.1 Setup

To illustrate the how property rights can be imperfectly protected along the two dimensions described above, we build a continuous time infinite horizon model with three agents: owner (i), trespasser (j), and thief (h). The owner is endowed with a stock $S_0 > 0$ of a non-renewable resource; the trespasser (while active) also has access to this stock and can extract from it; and, the thief can put effort into appropriating a fraction of the owner's revenues from extraction. In the following we describe the exact interactions entailed by each type of distortion.

Trespassing Initially both the owner and the trespasser have access to the stock of the resource, and they simultaneously decide how much of the resource to extract at each point in time. Instantaneous extraction is denoted by R_i and R_j respectively; by extracting R_i units the owner gets $\theta\left(\theta-1\right)^{-1} R_i^{1-\frac{1}{\theta}}$ while by extracting R_j the trespasser gets $\left(1-\Omega\right)\theta\left(\theta-1\right)^{-1} R_j^{1-\frac{1}{\theta}}$, with $\theta \in (1, 2)$.[3] $\Omega \in \{\omega, 1\}$ reflects the level of institutional strength against trespassing. If $\Omega = 1$, the trespasser has no incentives to deplete the resource and the resource is fully protected against trespassing. If $\Omega = \omega < 1$, the trespasser actively participates in the depletion of the resource. Extraction depletes the resource over time: $\dot{S}\left(t\right) = -R_i\left(t\right) - R_j\left(t\right)$; and cumulative extraction is constrained by the remaining stock of the resource $\int_t^\infty \left(R_i\left(v\right) + R_j\left(v\right)\right) dv \leq S\left(t\right)$. The assumption here is that the owner and the trespasser individually face an extraction technology constraint. That is, the interaction between the owner and the trespasser is purely of inter-temporal nature (it goes through the depletion of the stock) but, trespassing does not pose an intra-temporal externality on the owner (i.e., trespassing does not drive down the owner's marginal benefit from extraction). Instead of thinking of trespassing as a problem of a "com-

[3] The upper bound for θ guarantees the existence of an equilibrium in linear strategies in the trespassing game.

mon stock", one could in principle approach it as problem of access to a "common market". In that case, trespassing is equivalent to higher competition, which reduces the owner's marginal return to extraction. Then, the externality imposed by trespassing is fundamentally intra-temporal. Given that our main interest is to focus on the inter-temporal tradeoffs, we abstract from the "common market" interpretation in order to preserve the transparency of the dynamic mechanisms.

Theft Upon extraction, the owner gets a gross revenue flow of $\theta\left(\theta-1\right)^{-1}R_n^{1-\frac{1}{\theta}}$.[4] However, a fraction τ of this flow can be appropriated by the thief. This fraction is endogenously determined by a ratio contest success function:

$$\tau\left(e_i,\, e_h\right)=\frac{\left(1-\Lambda\right)e_h}{\Lambda e_i+\left(1-\Lambda\right)e_h}$$

where e_h is the effort that the thief puts into appropriation and e_i is the protecting effort by owner; e_h and e_i have the same exogenous unit cost of w. The relative efficiency of the protective effort depends on the theft-specific dimension of institutional quality $\Lambda\in\{\lambda,\,1\}$. This is a measure of the de facto protection against theft, with $\lambda=1$ being perfect protection.

Institutional quality The institutional space in this economy is two-dimensional: Ω determines how strong is the institutional environment against trespassing, while Λ determines the institutional strength against theft. Along these two dimensions we can define 4 different regimes of general institutional quality: *i.* generally weak institutions, $\Omega=\omega;\ \Lambda=\lambda$ (i.e., a regime with theft and trespassing); *ii.* weak protection of income, $\Omega=1;\ \Lambda=\lambda$ (i.e., a regime with only theft); *iii.* weak protection of wealth, $\Omega=1;\ \Lambda=\lambda$ (i.e., a regime with only trespassing); *iv.* strong institutions $\Omega=1;\ \Lambda=1$ (i.e., a regime without theft and trespassing).

We assume that the initial state is one of generally weak property rights, and from there institutions improve at uncertain times. An institutional improvement in this context means Ω or Λ becoming equal to one. Moreover $\Omega=1$ and $\Lambda=1$ are absorptive states, i.e., once institutions become strong in one dimension they remain strong.[5] The speed and direction of the institutional improvement is determined by

[4] The implicit assumption here is that extracted output cannot be stored. In case output can be stored, the reasonable assumption is that stored output is also imperfectly protected. Otherwise, the owner would speed-up extraction with the purpose of transforming the insecure stock in the ground into a secure stock above the ground.

[5] The assumption that institutions can only improve, is chosen to facilitate the exposition, and it is in line with the motivational anecdotes in section 1. However, one could think of empirical settings in which institutions were actually deteriorating over time, for instance after the collapse of the Soviet Union, or in which institutions follow more chaotic paths. As it is discussed in section 3, the modeling tools developed

two types of parameters: i) $\pi > 0$ determines the overall speed of change that is, how likely are institutions to improve; ii) the probabilities $p \in [0, 1]$ and $q \in [0, 1]$, determine whether this improvement occurs along the trespassing dimension or the theft dimension respectively. More specifically, the hazard of Ω shifting from ω to 1 is πp, while the hazard of Λ shifting from λ to 1 is πq. π is an economy-wide measure of how fast institutions are likely to improve, while p and q are crime-specific and can be related to the specific development path of institutions. For instance, the legal system may evolve in such a way that it initially has a bias towards the protection of wealth (property), and eventually shifts its attention to the protection of income.

We assume that all the co-movement in the institutional improvement runs through π (i.e., p and q are not related to each other). This way of connecting the likelihood of a regime shift when multiple shifts are possible follows from Sakamoto (2014). Note that regime shifts in this setup are always beneficial for the legitimate owner, as a regime shift translates into the once and for all elimination of a type of crime.

Objective and Equilibrium The three agents seek to maximize the Net Present Value of revenues, using the exogenous rate r as a discount. We look at Markovian strategies, and rely on the Feedback Nash Equilibrium as equilibrium concept. Moreover, in the trespassing game we focus on linear strategies. That is, the extraction strategy of each agent is set to be a linear function of the remaining stock.

4.2.2 Solution

As mentioned above, there are four distinct regimes that can be analyzed depending on the strength of the each of the institutional dimensions. Initially institutions are generally weak and both types of criminals are active, and eventually institutions will become strong and both types of crime will vanish (provided that p and q are > 0). We do not assume any specific sequence for the path of institutional improvement, meaning that institutions may first improve in any of the two dimensions. As a benchmark we first present the case with strong institutions, then we analyze the "weak protection of income" regime (i.e., when only the thief is active), then the "weak protection of wealth" regime (i.e., when only the trespasser is active), and finally the regime with generally weak institutions (i.e., when there is trespassing and theft).

here serve to analyze these alternative institutional dynamics.

4.2.2.1 Strong institutions — No trespassing and no theft

The problem in the perfect protection regime is a standard one. Once both types of crime have been eliminated, no further regime shifts can occur. We use the solution of this institutional environment as the social benchmark. The implicit assumption of this social benchmark is that the social planner is not constrained by the level of institutional quality and is free to distribute the rents between agents.[6]

The Hamilton-Jacobi-Bellman (HJB) equation of the owner's problem is:

$$rV_i(t) = \max_{R_i} \left\{ \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_i'(t) R_i(t) \right\}$$

Using standard techniques to solve, depletion (defined as R/S) is

$$\frac{R_i(t)}{S(t)} = \theta r$$

and the value of the remaining stock is

$$V_i(S(t)) = \frac{S(t)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(\theta r)^{\frac{1}{\theta}}} \tag{4.2.1}$$

4.2.2.2 Weak protection of income — Only theft (th)

Under this regime, the owner's problem exhibits two main differences with respect to the perfect protection benchmark: *i.* the net flow of revenues needs to be adjusted by the total cost of theft (i.e., theft itself and protecting effort); *ii.* it needs to account for the possibility of a regime shift. As mentioned above, the thief faces the risk of her activity becoming unprofitable; this means that the owner faces the "risk" of a regime shift from a theft only environment to one with strong institutions.

To address *i.* remember that the contest over the flow of revenues is characterized by $\tau(e_i e_h) = (1-\Lambda) e_h (\Lambda e_i + (1-\Lambda) e_h)^{-1}$. This is, at every point in time the owner and the thief, after observing the flow of revenues that the former gets from extraction, engage in a contest over these revenues. Specifically, the owner keeps a fraction $1-\tau$ of the flow of revenues, while τ goes to the thief. These fractions are endogenously determined by the contesting efforts (e_i and e_h) which are chosen simultaneously, after observing the flow of revenues. As for *ii.*, one can introduce

[6] Alternatively, one could think of an intermediate social benchmark in which the planner is constrained by the institutional environment (i.e., the different regimes and the hazards of a shift) and the weights of the individuals in the social welfare function. This "constrained planner" would only be able to choose the rate of depletion by the owner and the trespasser, and thus the "socially optimal" level of extraction would be different from the one derived in this section.

the effect of a regime shift taking into account that the effective hazard of a shift is constant and equal to πq, and that the continuation value for the owner is the stock's value under prefect protection and for the thief is 0. The HJB equations for the owner and the thief respectively are:

$$[i]: \ (r+\pi q)\, V_i^{th}(t) =$$

$$\max_{\{R_i, e_i\}} \left\{ (1-\tau(e_i(t), e_h(t))) \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - we_i(t) - V_i^{th'}(t) R_i(t) + \pi q V_i(t) \right\}$$

and

$$[h]: \ (r+\pi q)\, V_h^{th}(t) = \max_{\{e_h\}} \left\{ \tau(e_i(t), e_h(t)) \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - we_h(t) - V_h^{th'}(t) R_i(t) \right\}$$

Note that the superindex "th" in the value function stands for **th**eft only, and the absence of it indicates perfect protection. The FOCs with respect to the contesting efforts (e_i and e_h) reveal that this is in essence a static problem (with dynamic consequences). If $\Lambda = 1$, there is no contest and the owner retains all the revenues from extraction. If $\Lambda = \lambda$, the optimal appropriation and protection efforts are determined by the following FOCs

$$[i]: \ \frac{(1-\lambda)\lambda e_h(t)}{(\lambda e_i(t) + (1-\lambda) e_h(t))^2} \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - w = 0$$

$$[h]: \ \frac{(1-\lambda)\lambda e_i(t)}{(\lambda e_i(t) + (1-\lambda) e_h(t))^2} \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - w = 0$$

In equilibrium

$$e_i^{th}(t) = e_h^{th}(t) = (1-\lambda)\lambda \frac{R_i(t)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right) w}$$

Therefore $1-\tau^{th} = \lambda$. With $\Lambda = \lambda$ the owner and the thief effectively engage in a contest over the revenues, and in equilibrium the owner retains a fraction λ of the revenues. The owner's revenues net of theft and the cost of protection are given by

$$\left(1-\tau^{th}\right) \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - we_i^{th}(t) = \lambda \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - we_i^{th}(t) = \lambda^2 \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}$$

Using this, the owner's extraction problem is then characterized by

$$(r+\pi q)\, V_i^{th}(t) = \max_{R_i} \left\{ \lambda^2 \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_i^{th'}(R_i(t)) + \pi q\,(V_i(t)) \right\}$$

The FOC of this problem is

$$\lambda^2 R_i^{-\frac{1}{\theta}} = V_i^{th'}$$

which back into the HJB equation leads to

$$(r+\pi q)\, V_i^{th} = \lambda^{2\theta} \frac{V_i^{th'1-\theta}}{\theta-1} + \pi q\,(V_i)$$

Using

$$V_i^{th} = k_i^{th-\frac{1}{\theta}} \frac{\lambda^2 S(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} \tag{4.2.2}$$

as a guess for the value function $V_i^{th}(t)$; $V_i(t)$ comes from (4.2.1). The solution for the k_i^{th} constant, which is also the depletion rate in equilibrium R/S (see the FOC), is implicitly given by

$$z_i^{th}\left(k_i^{th}\right) = k_i^{th} + \frac{\theta \pi q}{\lambda^2 (\theta r)^{\frac{1}{\theta}}} k_i^{th\frac{1}{\theta}} = \theta(r+\pi q) \tag{4.2.3}$$

From this expression it becomes evident that (as expected) depletion is less rapacious in a more theft-prone environment: i.e., k_i^{th} is increasing in λ. This follows directly from z_i^{th} being strictly increasing in k_i^{th} and decreasing in λ. Intuitively, the lower λ the more harmful theft is, and thus the more is there to win from preserving the resource until after theft is eliminated ($\lambda = 1$). Note that with $\lambda = 1$, the depletion rate corresponds to the social optimum level θr.

Proposition 4.1. *Depletion in the theft only regime ($\Lambda = \lambda < 1$) is below the social optimum: $k_i^{th} \leq \theta r$.*

Proof: See Appendix 4.A.2.

Proposition 4.2. *The more likely is protection against theft to improve the higher the owner's incentives to preserve the resource: k_i^{th} is decreasing in πq.*

Proof: See Appendix 4.A.2.

The interpretation of these two propositions is straightforward and stems from: *i.* a regime shift is favorable from the owner's viewpoint (i.e., shifting to a world without theft is good news for the owner); and, *ii.* the problem of the owner is a typical consumption-savings trade-off. Saving the resource (not extracting today) comes at the cost of not consuming today but, has the potential advantage of leaving the resource to be extracted in a safer environment (theft will no longer be a threat at some point in the future). The intuition behind proposition 4.1 is that the owner slows down extraction while theft is a threat because it reduces marginal benefit of extraction but, this reduction is expected to have a finite end date (the thief is expected to be captured in finite time), thus the owner preserves the resource today with the objective of extracting a larger fraction of it in a potentially safer environment. As to proposition 4.2, the higher πq the less the owner expects to wait for the protection against theft to improve, and therefore the more willing the owner is to preserve the resource.

4.2.2.3 Weak protection of wealth — Only trespassing (TR)

In the presence of the trespasser two elements need to be accounted for: *i.* total extraction depends on how much both the owner and the trespasser extract; and *ii.* as with the thief, the trespasser faces the risk her activity becoming unprofitable (i.e., Ω becoming 1).

The HJB equation of the owner's problem is:

$$[i]: \; (r+\pi p)\, V_i^{TR}(t) = \max_{R_i} \left\{ \frac{R_i(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_i^{TR'}\left(R_i(t)+R_j(t)\right) + \pi p V_i(t) \right\}$$

where πp is the effective hazard that Ω becomes 1, and $V_i(t)$ is the continuation value for the owner in case this occurs (see 4.2.1). The superscript "TR" stands for **TR**espassing only.

The trespasser's HJB equation, while $\Omega = \omega$ is:

$$[j]: \; (r+\pi p)\, V_j^{TR} = \max_{R_j} \left\{ (1-\omega) \frac{R_j(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_j^{TR'}\left(R_i(t)+R_j(t)\right) \right\}$$

Note that the continuation value for the trespasser is 0 (i.e., the NPV of a shift to $\Omega = 1$ is 0).

Both agents choose their extraction simultaneously in a non-cooperative way, and they base their extraction decisions on how much of the stock remains in the ground. The FOCs with respect to extraction for the owner and the trespasser respectively are

$$R_i^{-\frac{1}{\theta}} = V_i'; \; (1-\omega)\, R_j^{-\frac{1}{\theta}} = V_j'$$

Plugging this back in the owner's value function,

$$(r+\pi p)\, V_i^{TR} = \frac{V_i^{TR'1-\theta}}{\theta-1} - (1-\omega)^{\theta}\, V_i^{TR'} V_j^{TR'-\theta} + \pi p V_i\,(t)$$

and similarly for the trespasser one gets

$$(r+\pi p)\, V_j^{TR} = (1-\omega)^{\theta}\, \frac{V_j^{TR'1-\theta}}{\theta-1} - V_j^{TR'} V_i^{TR'-\theta}$$

Now, as in the previous cases, one can guess value functions for both agents of the form

$$V_i^{TR} = k_i^{TR-\frac{1}{\theta}} \frac{S\,(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} \tag{4.2.4}$$

$$V_j^{TR} = k_j^{TR-\frac{1}{\theta}} \,(1-\omega)\, \frac{S\,(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} \tag{4.2.5}$$

where k_n^{TR} is an agent-specific constant. This specification of the value function and the FOCs imply that individual depletion (R_n/S) is given by k_n^{TR}. Using the guessed value functions and (4.2.1):

$$\theta\,(r+\pi p)\, k_i^{TR-\frac{1}{\theta}} = k_i^{TR1-\frac{1}{\theta}} - (\theta-1)\, k_i^{TR-\frac{1}{\theta}} k_j^{TR} + \frac{\theta \pi p}{(\theta r)^{\frac{1}{\theta}}}$$

and

$$\theta\,(r+\pi p)\, k_j^{TR-\frac{1}{\theta}} = k_j^{TR1-\frac{1}{\theta}} - (\theta-1)\, k_j^{TR-\frac{1}{\theta}} k_i^{TR}$$

Rearranging, the equilibrium values of k_i^{TR} and k_j^{TR} are implicitly given by

$$z_i^{TR}\left(k_i^{TR}\right) = (2-\theta)\, k_i^{TR} + \frac{\pi p}{(\theta r)^{\frac{1}{\theta}}} k_i^{TR\frac{1}{\theta}} = \theta\,(r+\pi p) \tag{4.2.6}$$

$$k_j^{TR}\left(k_i^{TR}\right) = (\theta-1)\, k_i^{TR} + \theta\,(r+\pi p) \tag{4.2.7}$$

Note that because the continuation value for the trespasser is 0, ω does not play a role in determining the speed of extraction by any of the two agents, it only affects the trespasser's valuation of the resource.[7] Moreover, $\theta > 1$ implies strategic complementarity in the extraction game. This follows from the fact that θ is a measure of the curvature of the revenue function. The higher θ the less concave the function,

[7]This result is not only the outcome of the assumption that the continuation value for the trespasser is 0, but also derives from the specific modeling choice for the revenue function. Specifically, as the revenue function is iso-elastic in R, one can separate k_j and $(1-\omega)$ in the guess for j's value function.

and thus the higher the substitution between extraction today and in the future (i.e., the lower the need to smooth individual extraction out). The presence of another agent with access to the stock of the resource lowers the "return" to preserve it, because part of what is left in the ground is going to be extracted by the other agent; in that sense extracting today protects the resource against future trespassing. When θ is relatively high the lower need for smooth extraction implies that the "return" motive dominates, therefore more rapacious depletion from one agent results also in more rapacious depletion by the other.

Lemma 4.1. *Given $\theta < 2$, there exists a unique pair of positive constants k_i^{TR}, k_j^{TR} that fulfills the FOCs of the TR problem*

Proof: See Appendix 4.A.1.

Proposition 4.3. *i) The owner depletes the resource above the socially optimal depletion rate θr; ii) before trespassing becomes unprofitable ($\Omega = 1$) the trespasser depletes the resource faster than the owner.*

Proof: See Appendix 4.A.2.

$k_j^{TR} > k_i^{TR}$ is associated to the fact that, as opposed to the owner, the trespasser faces the risk of losing access to the resource. This on the one hand makes the trespasser effectively more impatient than the owner (i.e., the regime shift is costly for the trespasser). On the other hand, it means that the owner attaches a positive probability to the emergence of a regime free of trespassing in finite time; the scrap value of the resource once the trespasser is captured is an increasing function of the remaining stock, which creates incentives for the owner to preserve the resource.

Corollary 4.1. *The competition for the non-renewable stock exacerbates the over-extraction problem pushing the trespasser to deplete the resource even faster than the rate suggested by the "inflated" effective discount (i.e., $R_j/S > \theta(r + \pi p)$).*

Proposition 4.4. *The more likely it is that trespassing becomes unprofitable the lower the owner's extraction: i.e., higher πp implies lower k_i^{TR}*

Proof: See Appendix 4.A.2.

At first glance higher πp is good news for the owner because of the better prospect of a future free of trespassing. This implies that the owner has stronger incentives to preserve the resource. However, a higher πp makes the trespasser effectively more impatient, because of the higher risk of loosing access to the resource. As a result the trespasser becomes more rapacious, which reduces the return to savings for the owner (while active the trespasser extracts a larger fraction of what is left in the ground). Thus, there are two opposing forces determining what the owner should do. On the one hand, the owner wants to preserve the resource for the "trespassing-free" future; on the other hand, the owner does not want to leave the resource exposed to more rapacious trespassing. Which one of the two dominates depends on how concave the revenue function is, and thus on how feasible is the substitution between present and future extraction. With a moderately concave revenue function (i.e., $\theta > 1$), future extraction is a good substitute for extracting today, and delaying extraction is a good strategy: more patience triumphs over lower returns (i.e., the owner prefers to wait until after the trespasser is no longer around).

4.2.2.4 Generally weak institutions — Trespassing and theft (TRth)

In the initial regime both trespassing and theft are active threats. This regime has three essential characteristics: *i.* the trespasser extracts from the owner's stock, so total extraction is the sum of the owner's and the trespasser's extraction $(R_i + R_j)$; *ii.* the thief appropriates a fraction τ of the owner's revenues, where revenues net of the total cost of theft are $\lambda^2 \frac{R_i^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}$; *iii.* the regime can shift in any of three directions namely, weak protection of revenues with hazard $\pi p\,(1-q)$, weak protection of wealth with hazard $\pi q\,(1-p)$, and strong institutions with hazardπpq. Taking these three features into account the HJB equation of the owner's problem is (the time dependency is suppressed to save notation):

$$[i]: \ (r+\pi)\, V_i^{TRth} =$$

$$\max_{R_i} \left\{ \lambda^2 \frac{R_i^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_i^{TRth'}\left(R_i + R_j\right) + \pi \Big(p\,(1-q)\, V_i^{th} \right.$$
$$\left. + q\,(1-p)\, V_i^{TR} + pqV_i + (1-p)\,(1-q)\, V_i^{TRth} \Big) \right\}$$

Using equations (4.2.1)-(4.2.6) the owner's HJB equation reduces to

$$\left(r + \pi^{TRth}\right) V_i^{TRth} = \max_{R_i} \left\{ \lambda^2 \frac{R_i^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_i^{TRth'}\left(R_i + R_j\right) + \pi\kappa_i \frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} \right\} \tag{4.2.8}$$

where $\pi^{TRth} \equiv \pi\,(p+q-pq)$ is the effective hazard of "a" regime shift; that is, the risk of a shift in any of the three potential directions in which a shift can occur. Moreover, $\kappa_i \theta\,(\theta-1)^{-1} S^{1-\frac{1}{\theta}}$ is the owner's expected continuation value of "a" regime shift, given the three potential directions in which a shift can occur, with $\kappa_i \equiv p(1-q)\lambda^2 k_i^{th-\frac{1}{\theta}} + q(1-p)k_i^{TR-\frac{1}{\theta}} + pq(\theta r)^{-\frac{1}{\theta}}$ and $\kappa'_{i\lambda} > 0$. The sign of the derivative of κ_i with respect to λ follows from the equilibrium condition for k_i^{th} (4.2.3).

Similarly, the trespasser's HJB equation is

$$[j]:\ (r+\pi)V_j^{TRth} =$$

$$\max_{R_j}\left\{(1-\omega)\frac{R_j^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_j^{TRth'}\left(R_i+R_j\right) + \pi\left(p(1-q)V_j^{th} + q(1-p)V_j^{TR} + pqV_j + (1-p)(1-q)V_j^{TRth}\right)\right\}$$

which from equations (4.2.4) and (4.2.7) and noting that the continuation value of trespassing becoming unprofitable (i.e., shifting to a regime only with theft or with perfect protection) is 0, can be rewritten as

$$\left(r+\pi^{TRth}\right)V_j^{TRth} = \max_{R_j}\left\{(1-\omega)\frac{R_j^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - V_j^{TRth'}\left(R_i+R_j\right) + \pi\kappa_j\frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}\right\} \quad (4.2.9)$$

with $\kappa_j \equiv q(1-p)(1-\omega)k_j^{TR-\frac{1}{\theta}}$ and $\pi^{TRth} \equiv \pi(p+q-pq)$ denoting the effective hazard of a regime shift (i.e., the hazard adjusted by the probability that institutions improve in at least one of the two dimensions). Using the system of HJB equations (4.2.8) and (4.2.9), it is obtained that the FOCs with respect to extraction are

$$\lambda^2 R_i^{-\frac{1}{\theta}} = V_i^{TRth'};\ (1-\omega)R_j^{-\frac{1}{\theta}} = V_j^{TRth'}$$

plugging this back into the value functions (4.2.8) and (4.2.9)

$$\left(r+\pi^{TRth}\right)V_i^{TRth} = \lambda^{2\theta}\frac{V_i^{TRth'1-\theta}}{\theta-1} - (1-\omega)^{\theta}V_i^{TRth'}V_j^{TRth'-\theta} + \pi\kappa_i\frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}$$

$$\left(r+\pi^{TRth}\right)V_j^{TRth} = (1-\omega)^{\theta}\frac{V_j^{TRth'1-\theta}}{\theta-1} - \lambda^{2\theta}V_i^{TRth'-\theta}V_j^{TRth'} + \pi\kappa_j\frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}$$

Now, to solve this system of Ordinary Differential Equations (ODEs), let us use

$$V_i^{TRth} = k_i^{TRth-\frac{1}{\theta}} \lambda^2 \frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} \text{ and } V_j^{TRth} = k_j^{TRth-\frac{1}{\theta}} (1-\omega) \frac{S^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}$$

as guesses for each of the two value functions. Then, the following system is obtained:

$$z_i^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_i^{TRth} + \frac{\theta\pi\kappa_i}{\lambda^2} k_i^{TRth\frac{1}{\theta}} - (\theta-1)\, k_j^{TRth} = \theta\left(r + \pi^{TRth}\right) \quad (4.2.10)$$

and

$$z_j^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_j^{TRth} + \frac{\theta\pi\kappa_j k_j^{TRth\frac{1}{\theta}}}{1-\omega} - (\theta-1)\, k_i^{TRth} = \theta\left(r + \pi^{TRth}\right) \quad (4.2.11)$$

The solution to this system of non-linear equations will give the equilibrium depletion by the owner and the trespasser in the TRth regime. Note that these equations clearly entail that, given that $\theta > 1$, k_i and k_j are strategic complements. That is, the owner (trespasser) would respond to an increased depletion depletion by the trespasser (owner) by accelerating depletion herself.

Lemma 4.2. *If $\theta < 2$, there exists a unique pair $\left(k_i^{TRth}, k_j^{TRth}\right) \in \mathcal{R}_+^2$ solving the $z_i^{TRth} = z_j^{TRth} = \theta\left(r + \pi^{TRth}\right)$ system. This means that the equilibrium extraction strategies exist and are unique.*

Proof: See Appendix 4.A.1.

Lemma 4.3. *When only the owner is affected by theft k_i^{TRth} and k_j^{TRth} are increasing in λ.*

Proof: See Appendix 4.A.1.

4.3 Analysis and Discussion

4.3.1 Analysis

The depletion rates under different regimes k_i^{th}, k_i^{TR}, k_j^{TR}, k_i^{TRth} and k_j^{TRth} can be obtained by solving the non-linear system (4.2.3), (4.2.6), (4.2.7), (4.2.10), and (4.2.11). Figure 4.3.1, depicts a numerical example of the depletion rate under all the possible regimes for both the owner and the trespasser, as the theft intensity λ goes from

0 to 1 (i.e., as the distortion imposed by the imperfect protection of revenue flows decreases).[8]

As expected λ has no effect on the "TR" regime depletion rates (it does not enter the problem), the "TRth" depletion rates (k_i^{TRth} and k_j^{TRth}) are increasing in λ and converge to their "TR" counterparts (k_i^{TR} and k_j^{TR}) because theft becomes less distortive as $\lambda \to 1$. With respect to the social optimum level of depletion: k_i^{TR}, k_j^{TR}, and k_j^{TRth} are always above the social optimum θr; k_i^{th} is always below; and k_i^{TRth} is below θr for low values of λ (i.e., when theft is very distortive) and it is above θr when λ is high (i.e., when theft is less distortive).

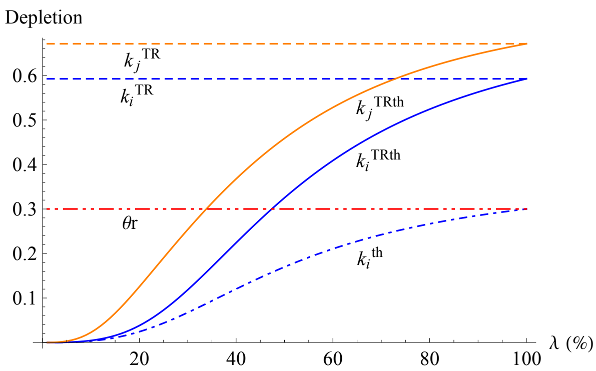

Figure 4.3.1: Individual depletion and theft intensity(λ) [Owner and Trespasser affected by theft]

4.3.1.1 Owner and Trespasser subject to theft

If both the owner and the trespasser face the threat of theft, and assuming that trespasser and thief engage in exactly the same type of contest over revenues as the owner and the thief, the ODE for the trespasser in the TRth is simply going to be symmetric to that of the owner, where the one for the owner is still given by (4.2.10) and the trespasser's becomes:

$$z_j^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_j^{TRth} + \frac{\theta \pi \kappa_j}{\lambda^2 (1-\omega)} k_j^{TRth \frac{1}{\theta}} - (\theta - 1)\, k_i^{TRth} = \theta \left(r + \pi^{TRth}\right)$$

The fundamental difference between this case, and the one in which only the owner is affected by theft is that the de facto protection against theft (λ) has a direct effect on the trespassers depletion rate (instead of running solely through the effect on the

[8] The rest of the parameters are set to: $\theta = 3/2$, $p = q = 1/2$, $r = 1/5$, and $\pi = 1/10$.

owner's depletion).

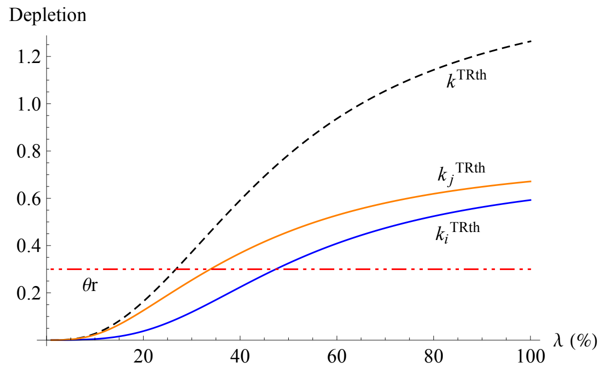

Figure 4.3.2: Total depletion and theft intensity(λ) [Owner and Trespasser affected by theft]

Figure 4.3.2 depicts k_i^{TRth}, k_j^{TRth} and the sum of the two, when theft affects both the owner and the trespasser. Evidently, when the distortion induced by theft is large (i.e., λ is low), the depletion by both the owner and the trespasser is low, in fact total depletion of the resource is below the social optimum (θr). On the contrary, if the theft distortion is mild, then the total depletion is too high from the social perspective ($> \theta r$). This means that if theft affects both the owner and the trespasser, in the presence of theft and trespassing the socially optimum level of depletion is attainable if theft occurs in the right measure (i.e., the effects of the two distortions exactly cancel out).

4.3.1.2 The illegal mining model: only the trespasser is subject to theft

The case of illegal mining seems to be better portrayed by a case in which only the trespasser is directly affected by theft. In this case λ affects only the net revenues from extraction for the trespasser. Again we end up with a system of equations from which one can solve the equilibrium levels of depletion. From the owner' s HJB one gets

$$z_i^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_i^{TRth} + \theta\pi\kappa_i k_i^{TRth\frac{1}{\theta}} - (\theta - 1)\, k_j^{TRth} = \theta\left(r + \pi^{TRth}\right)$$

where $\kappa_i \equiv q\,(1-p)\, k_i^{TR-\frac{1}{\theta}} + p\,(\theta r)^{-\frac{1}{\theta}}$. From this expression it is clear that once the trespasser is captured (which conditional on a regime shift occurs with probability p) the fate of the thief is irrelevant for the owner's problem. While from the trespasser's

HJB it is obtained that

$$z_j^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_j^{TRth} + \frac{\theta\pi\kappa_j}{\lambda^2(1-\omega)} k_j^{TRth\frac{1}{\theta}} - (\theta-1)\, k_i^{TRth} = \theta\left(r + \pi^{TRth}\right)$$

where$\kappa_j \equiv q(1-p)\, k_j^{TR-\frac{1}{\theta}}$ remains the unchanged. Once the thief is captured, the trespasser has the same valuation for the future.

Lemma 4.4. *When only the trespasser is affected by theft, $k_i^{TRth}$and k_j^{TRth} are increasing in λ irrespective of θ.*

Proof: See Appendix 4.A.1.

Interestingly, even if theft is strong enough to completely discourage trespassing (i.e., $\lambda = 0$) the owner's extraction path in the TRth regime would still be distorted. More precisely, if $\lambda = 0$ and thus $k_j^{TRth} = 0$, k_i^{TRth} is aboveθr because k_i^{TR} is above θr. From the owner's perspective, the scenario with $\lambda = 0$ can be described solely in terms of trespassing: initially during the TRth regime there is no trespassing; then if there is no theft trespassing becomes again an active threat; finally the economy would move back to a regime with inactive trespassing. Even if in the TRth regime theft is such that trespassing plays no immediate role on the owner's problem, the potential for a future regime in which trespassing is active affects current extraction. The mechanism for the distortion in the TRth regime is therefore purely dynamic, and it is actually driven by the same forces that delineate the extraction path in the TR regime. That is, as the owner responds to trespassing by engaging in over-extraction, the owner also over-extracts if there is no current trespassing but there is a potential shift towards a regime with active trespassing.

4.3.1.3 Total extraction and institutional quality

Irrespective of whether the owner, the trespasser, or both are affected by theft, total extraction is increasing in the de facto protection against theft λ. The agent(s) directly affected by theft has incentives to deplete the resource faster if theft is weaker; that is the case because the net marginal return to extraction is higher the weaker theft is; this tilts the inter-temporal trade-off towards current depletion. Due to the strategic interaction between the owner and the trespasser, the agent that is not directly affected by theft also reacts to changes in λ. Specifically, if λ increases the agent that is not directly affected by theft also accelerates depletion, therefore total depletion increases with λ.

Proposition 4.5. *Whenever the trespasser and the thief are active: i) total depletion is increasing in λ irrespective of which agent (the owner, the trespasser, or both) is subject to theft; ii) if only the owner is directly affected by theft total depletion is always above the social optimum level θr; iii) if both the owner and the trespasser are subject to theft there exists a $\lambda^* \in (0, 1)$ such that if $\lambda \gtreqless \lambda^*$ total depletion is $\gtreqless \theta r$; iv) if only the trespasser is subject to theft total depletion is $> \theta r$ for every $\lambda > 0$.*

Proof: See Appendix 4.A.2.

Thus, an improvement in terms of how prone to theft the environment is always leads to more rapacious depletion. This means that in case that only the owner is affected by theft, an improvement in the institutional environment (in terms of a higher λ) exacerbates the over-extraction problem. Actually, a necessary condition for there to be an imperfect level of λ such that depletion is optimal from the social perspective is that the trespassers is directly affected by theft. However, this does not mean that the outcome is a first best because resources are inefficiently diverted into protection and theft.

4.3.2 Discussion

As mentioned above the existence of λ^* does not imply that the first best is achievable, only that the total depletion is at its first best level if $\lambda = \lambda^*$. Because of the second best nature of the problem under the TRth regime even if total extraction is optimal, costly effort is diverted into the protection-theft contest. Taking into account the total net gain from the protection-theft contest (i.e., sum of revenues net of total effort), the contest is the least efficient when $\lambda = 1/2$ and the most efficient when λ is either 0 or 1.[9] This is the case because the more symmetric the contest the more effort each agent puts into it (i.e., the higher the stakes), but when the de facto protection is clearly favorable to one agent, both agents face little incentives to engage in the contest.

The total distortion imposed by trespassing and theft comes both in the form of a potentially distorted depletion path and of diverted effort into the protection-theft contest. The former being inter-temporal in nature and the latter intra-temporal. We know that the closer we are to λ^* the less intense the inter-temporal distortion becomes (i.e., the closer is total depletion to the optimal level θr), and the further away we are from $\lambda = 1/2$ the less intense the intra-temporal distortion is. This means that if $\lambda^* < 1/2$ ($> 1/2$), and $\lambda \in (\lambda^*, 1/2)$ a reduction (an increase) in λ is efficiency improving.

[9]If one does not take the revenues of the thief into account the contest is the less distortive when $\lambda = 1$ and the most distortive when $\lambda = 0$.

The model assumes that institutions improve over time, which is arguably what happened in the context of the California Gold Rush and the Texas Oil Boom. However, a path of improving institutions may not always be a good reflection of reality; think for instance of the collapse of the Soviet Union or the Libyan power vacuum after Gaddafi's ouster. Nevertheless, the modeling apparatus developed in this chapter is equipped to analyze alternative institutional dynamics. How alternative institutional dynamics affect the results depends on one of the fundamental mechanisms unveiled by the model: the effective discount rate used by the individuals changes by how they expect to be affected by the evolution of institutions; that is, whether they anticipate institutional changes as "good news" or as "bad news" (in expected value). For instance, in the current setup an institutional improvement in the theft dimension, when both the owner and the trespasser are affected by theft, is internalized as "good news" by the owner and the trespasser; i.e., both agents are better off in the absence of theft. This means that the prospect of this institutional improvement makes them effectively more patient. How much more patient depends on how much of an improvement the elimination of theft actually is, i.e., how intense current theft is. Now, suppose that the economy is facing an institutional collapse. This means, for instance, that from the TR regime the economy eventually shifts into the TRth regime. During the TR regime, the owner and the trespasser anticipate institutional changes to be "bad news". The prospect of theft in the future makes both i and j effectively more impatient today, when theft is not yet occurring. How much more impatient depends on how intense they anticipate theft to be in the future: the more intense future theft the more impatient they currently are. Interestingly, despite already playing a role in the TR regime, through the anticipation of a regime shift, the intensity of theft plays no role in the TRth regime (provided that this is an absorptive regime). Furthermore, if institutions are expected to deteriorate over time, i's depletion is distorted even when current institutions are strong. Specifically, in the absence of theft and trespassing, i over-extracts the resource in anticipation of an institutional collapse.

Going back to the original model, we approach trespassing as a problem of common access to the stock in the ground. However, one could also study it as a "common market" (e.g. Boyce & Vojtassak, 2008; Datta & Mirman, 1999; Salo & Tahvonen, 2001; Sandal & Steinshamn, 2004) problem. However, as opposed to the intertemporal nature of the "common stock" externality, the "common market" one is essentially intra-temporal. Arguably, the "common market" externality mechanically implies that the owner slows down extraction because of the lower instantaneous marginal return. In such case, the resource "over-use" arises as consequence of a larger number of suppliers; that is, there is no individual "over-use" but, there is "over-use" in the aggregate because of the coordination failure.

In contrast, in the "common stock" case the inter-temporal externality creates two opposing forces delineating the owner's behavior. On the one hand, it reduces the incentives to preserve the resource because the stock left in the ground would be shared with the trespasser in the future. On the other hand, for extraction-smoothing purposes the owner may act more conservatively to counter the excessively high depletion induced by trespassing. In terms of the consumption-saving tradeoff, the former means that the return to savings is lower, reducing the incentives to save, while the latter implies that the owner cannot fully appropriate her own "savings" in the future, hence there is an increased need for "savings" to finance future "consumption".

4.4 Conclusions

Weak property rights in the management of non-renewable resources can go beyond the "common access" (or "trespassing") problem typically explored in the resource economics literature. The history of resource rushes (e.g. oil and gold) provides prominent examples of cases in which the legitimate owners (users) of a resource not only had to deal with trespassing but also with the risk of theft. The interaction of these two types of property rights imperfections, one affecting the stock (wealth) in the ground and the other affecting the stream of revenues (income) from extracting it, has a significant effect on the inter-temporal trade-off governing the choice of an extraction path.

In principle, the legitimate owner of the resource needs to take into account that extracting the resource protects it from trespassing, but exposes it to theft. The dynamic model that we develop in this chapter highlights that the dynamic implications, of an environment with generally weak property rights, are rich and transcend this intuitive trade-off. These implications are rooted in the dynamic strategic interactions between agents, as well as in the possibility of shifts towards regimes with stronger property rights (i.e., regimes with no theft or no trespassing). Among the results we find that an improvement in the institutional quality in terms of a higher probability of eliminating trespassing, exacerbates the over-extraction imposed by trespassing itself. Moreover, an improvement in the institutional quality in terms of a reduction of the theft intensity, always leads to more rapacious depletion of the resource. Finally in terms of efficiency, if the trespasser is affected by theft the optimal level of extraction may be achieved. However, the waste inherent to the protection-theft contest implies that we still are in a below optimal situation. Efficiency unambiguously improves as the parameter determining the theft intensity in equilibrium moves away from the level that maximizes wasteful effort and towards the level that allows for optimal depletion. Thus in some cases, a more theft-prone environment may be more desirable in terms of efficiency.

As a potential avenue for future research using this type of dynamic framework, with a broader source of imperfect property rights and multiple regime shifts, one could think of the interaction between governments and private extraction companies, how this is affected by the different alternatives that the former can use to capture a share of the latter's revenues. In such a framework instead of trespassing, expropriation would be the source of insecure stocks; and instead of theft, revenues would be subject to taxation. An interesting feature of a setup along those lines is the dual role of the government as both "trespasser" and "thief". Such a model may shed light on the type of tools that a government should use when trying to maximize the net present revenues that it gets from the riches in the ground, once the strategic response of the firm is taken into account: when should the government pursue more or less aggressive taxation? when (if ever) is expropriation a better choice? how "expropriation-proof" should the exploitation contracts offered by the government be?

Appendix 4

4.A Proofs

4.A.1 Proofs Lemmas

Proof of Lemma 4.1

Proof. Note that the $z_i^{TR}(k_i)$ is strictly increasing in k_i; furthermore, $z_i^{TR}(0) = 0$. Thus, there is a unique value $k_i^{TR} > 0$ such that $z_i^{TR}\left(k_i^{TR}\right) = \theta(r + \pi p)$. Moreover, for each k_i^{TR} there is a unique k_j^{TR}: $k_j^{TR} = (\theta - 1)k_i^{TR} + \theta(r + \pi p)$. With $\theta > 1$, $k_i^{TR} > 0$ implies $k_j^{TR} > 0$. □

Proof of Lemma 4.2

Proof. Given $\theta > 1$:

First note that $\partial k_j/\partial k_i|_{z_i} > 0$ and $\partial k_j/\partial k_i|_{z_j} > 0$. Moreover, $z_i^{TRth}\left(0, k_j\right) \rightarrow k_j < 0$ and $z_j^{TRth}\left(0, k_j\right) \rightarrow k_j > 0$. Then, it suffices to show that $\partial k_j/\partial k_i|_{z_i} > \partial k_j/\partial k_i|_{z_j}$ always holds. Differentiating z_i^{TRth} with respect to k_i:

$$1 + \frac{\pi\kappa_i}{\lambda^2}k_i^{\frac{1}{\theta}-1} - (\theta - 1)\frac{\partial k_j}{\partial k_i} = 0$$

$$\left.\frac{\partial k_j}{\partial k_i}\right|_{z_i} = \frac{1 + \frac{\pi\kappa_i}{\lambda^2}k_i^{\frac{1}{\theta}-1}}{\theta - 1} > \frac{1}{\theta - 1};\ \forall k_i > 0$$

Differentiating z_j^{TRth} with respect to k_i:

$$\left.\frac{\partial k_j}{\partial k_i}\right|_{z_j} = \frac{\theta - 1}{1 + \frac{\pi\kappa_j k_j^{TRth\frac{1}{\theta}-1}}{1-\omega}} < \theta - 1;\ \forall k_i > -\frac{\theta\left(r + \pi^{TR}\right)}{\theta - 1}$$

Then, if $\theta < 2 \rightarrow \partial k_j/\partial k_i|_{z_i} > (\theta - 1)^{-1} > \theta - 1 > \partial k_j/\partial k_i|_{z_j}$, which implies that z_i and z_j have a single crossing in $\mathcal{R}_+^2$. □

Proof of Lemma 4.3

Proof. Taking the derivatives of z_i^{TRth} and z_j^{TRth} with respect to λ and rearranging terms:

$$[z_i]: \frac{\partial k_i^{TRth}}{\partial \lambda}\left(1+\frac{\pi\kappa_i}{\lambda^2}k_i^{TRth\frac{1}{\theta}-1}\right)-(\theta-1)\frac{\partial k_j^{TRth}}{\partial \lambda}=-\theta\pi k_i^{TRth\frac{1}{\theta}}\frac{\partial\left(\kappa_i/\lambda^2\right)}{\partial \lambda}$$

$$[z_j]: \frac{\partial k_j^{TRth}}{\partial \lambda}=\frac{\theta-1}{1+\pi\kappa_j k_j^{TRth\frac{1}{\theta}-1}}\frac{\partial k_i^{TRth}}{\partial \lambda}$$

using the latter in the former and rewriting

$$\frac{\partial k_i^{TRth}}{\partial \lambda}=\frac{-\theta\pi k_i^{TRth\frac{1}{\theta}}\frac{\partial\left(\kappa_i/\lambda^2\right)}{\partial\lambda}}{1+\frac{\pi\kappa_i}{\lambda^2}k_i^{TRth\frac{1}{\theta}-1}-\frac{(\theta-1)^2}{1+\pi\kappa_j k_j^{TRth\frac{1}{\theta}-1}}}>0$$

This expression is positive because both the numerator and the denominator are positive. From the definition of κ_i, $\frac{\kappa_i}{\lambda^2}$ is decreasing in λ, while

$$1>\frac{(\theta-1)^2}{1+\pi\kappa_i k_i^{TRth\frac{1}{\theta}-1}}$$

for any $\theta\in(1,2)$. $\partial k_j^{TRth}/\partial\lambda$ and $\theta>1$ imply $\partial k_j^{TRth}/\partial\lambda>0$. That is, as λ increases k_i^{TRth} and k_j^{TRth} increase. □

Proof of Lemma 4.4

Proof. Taking the derivatives of z_i^{TRth} and z_j^{TRth} with respect to λ and rearranging terms:

$$[z_i]: \frac{\partial k_i^{TRth}}{\partial \lambda}=\frac{\theta-1}{1+\pi\kappa_i k_i^{TRth\frac{1}{\theta}-1}}\frac{\partial k_j^{TRth}}{\partial \lambda}$$

$$[z_j]: \frac{\partial k_j^{TRth}}{\partial \lambda}\left(1+\frac{\pi\kappa_j}{\lambda^2(1-\omega)}k_j^{TRth\frac{1}{\theta}-1}\right)-(\theta-1)\frac{\partial k_i^{TRth}}{\partial \lambda}=2\frac{\theta\pi\kappa_j}{\lambda^3(1-\omega)}k_j^{TRth\frac{1}{\theta}}$$

using the former in the latter and rearranging

$$\frac{\partial k_j^{TRth}}{\partial \lambda}=\frac{2\frac{\theta\pi\kappa_j}{\lambda^3(1-\omega)}k_j^{TRth\frac{1}{\theta}}}{1+\frac{\pi\kappa_i}{\lambda^2(1-\omega)}k_j^{TRth\frac{1}{\theta}-1}-\frac{(\theta-1)^2}{1+\pi\kappa_i k_i^{TRth\frac{1}{\theta}-1}}}>0$$

This together with $\theta > 1$ implies $\partial k_i^{TRth}/\partial\lambda > 0$. That is, as λ increases both k_i^{TRth} and k_i^{TRth} increase. □

4.A.2 Proofs of Propositions

Proof of Proposition 4.1

Proof. Evaluating $z_i^{th}(.)$ at θr

$$z_i^{th}(\theta r) = \theta\left(r + \frac{\pi q}{\lambda^2}\right) \geq \theta(r + \pi q) = z_i^{th}\left(k_i^{th}\right)$$

With z_i^{th} being strictly increasing, it follows that $k_i^{th} \leq \theta r$, with strict inequality whenever theft is a relevant ($\lambda < 1$) regime with finite expected end date ($q > 0$) □

Proof of Proposition 4.2

Proof. In equilibrium

$$\frac{\partial k_i^{th}}{\partial \pi q} + \frac{\theta k_i^{th\frac{1}{\theta}}}{\lambda^2(\theta r)^{\frac{1}{\theta}}} + \frac{\pi q k_i^{th\frac{1}{\theta}-1}}{\lambda^2(\theta r)^{\frac{1}{\theta}}}\frac{\partial k_i^{th}}{\partial \pi q} = \theta$$

$$\left(1 + \frac{\pi q k_i^{th\frac{1}{\theta}-1}}{\lambda^2(\theta r)^{\frac{1}{\theta}}}\right)\frac{\partial k_i^{th}}{\partial \pi q} = \theta\left(1 - \frac{k_i^{th\frac{1}{\theta}}}{\lambda^2(\theta r)^{\frac{1}{\theta}}}\right)$$

Thus, $sign\left(\partial k/\partial \pi q\right) = sign\left(\lambda^{2\theta}\theta r - k\right)$. Evaluating $z_i^{th}(.)$ at $\lambda^{2\theta}\theta r$

$$z_i^{th}\left(\lambda^{2\theta}\theta r\right) = \lambda^{2\theta}\theta r + \theta\pi q = \theta\left(\lambda^{2\theta}r + \pi q\right) < \theta(r + \pi q) = z^{th}\left(k_i^{th}\right)$$

Given that z_i^{th} is strictly increasing, it follows that $k_i^{th} > \lambda^{2\theta}\theta r \longrightarrow \partial k_i^{th}/\partial \pi q < 0$ □

Proof of Proposition 4.3

Proof. i) Evaluate z_i^{TR} at θr: $z_i^{TR}\left(k_i^{TR}\right) \equiv \theta(r + \pi p) \gtreqless (2-\theta)\theta r + \pi p = z_i^{TR}(\theta r) \leftrightarrow \theta \gtreqless 1$. Given that $z' > 0$ then $\theta > 1$ implies $k_i^{TR} > \theta r$.

ii) $k_j^{TR}\left(k_i^{TR}\right) > k_i^{TR}$ requires $k_i^{TR} < \theta(2-\theta)^{-1}(r + \pi p)$.

Evaluating z_i^{TR} at $\theta(2-\theta)^{-1}(r + \pi p)$ it is obtained that

$$z_i^{TR}\left(\theta(2-\theta)^{-1}(r + \pi p)\right)$$

$$= \theta\left(r+\pi p\right)+\left(\theta\left(2-\theta\right)^{-1}\left(r+\pi p\right)\right)^{\frac{1}{\theta}} > \theta\left(r+\pi p\right) \equiv z_i^{TR}\left(k_i^{TR}\right)$$

Following the same argument as above $k_i^{TR} < \theta\left(2-\theta\right)^{-1}\left(r+\pi p\right)$ and so $k_j^{TR} > k_i^{TR}$. □

Proof of Proposition 4.4

Proof. From $z_i^{TR}\left(k_i^{TR}\right) = \theta\left(r+\pi p\right)$ one can obtain:

$$\frac{\partial k_i^{TR}}{\partial \pi p} = \frac{\theta - \left(\frac{k_i^{TR}}{\theta r}\right)^{\frac{1}{\theta}}}{\left(2-\theta\right)+\frac{\pi p}{k_i^{TR}}\left(\frac{k_i^{TR}}{\theta r}\right)^{\frac{1}{\theta}}}$$

Therefore, the sign of $\partial k_i^{TR}/\partial \pi p$ is equal to the sign of $\theta - \left(k_i^{TR}/\theta r\right)^{\frac{1}{\theta}}$. Using $z\left(k_i^{TR}\right)$:

$$\theta \gtreqless \left(\frac{k_i^{TR}}{\theta r}\right)^{\frac{1}{\theta}} \longleftrightarrow \theta\pi p \gtreqless \theta\left(r+\pi p\right)-\left(2-\theta\right)k_i^{TR}$$

$$\longleftrightarrow k_i^{TR} \gtreqless \frac{\theta r}{2-\theta}$$

From $z_i^{TR}\left(.\right)$ and $z' > 0$

$$k_i^{TR} \gtreqless \frac{\theta r}{2-\theta} \longleftrightarrow \theta\left(r+\pi\right) \gtreqless z_i^{TR}\left(\frac{\theta r}{2-\theta}\right) \longleftrightarrow \theta \gtreqless \frac{1}{\left(2-\theta\right)^{\frac{1}{\theta}}}$$

$\theta < \left(2-\theta\right)^{\frac{-1}{\theta}}$ for any $\theta \in (1, 2)$; therefore, $k_i^{TR} < \theta r\left(2-\theta\right)^{-1}$ and $\partial k_i^{TR}/\partial \pi p < 0.$; □

Proof of Proposition 4.5

Proof. i) Expressing the equilibrium conditions z_i^{TRth} and z_j^{TRth}more generally as [and assuming $\omega = 0$ to save notation]:

$$z_i^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_i^{TRth} + \theta\pi\mu_i\kappa_i k_i^{TRth\frac{1}{\theta}} - \left(\theta-1\right)k_j^{TRth} = \theta\left(r+\pi^{TRth}\right)$$

$$z_j^{TRth}\left(k_i^{TRth}, k_j^{TRth}\right) = k_j^{TRth} + \theta\pi\mu_j\kappa_j k_j^{TRth\frac{1}{\theta}} - \left(\theta-1\right)k_i^{TRth} = \theta\left(r+\pi^{TRth}\right)$$

Where $\mu_s = \lambda^{-2}$ if agent s is subject to theft, and $\mu_s = 1$ otherwise. Moreover, $\kappa_i \equiv p\left(1-q\right)\lambda^2 k_i^{th-\frac{1}{\theta}} + q\left(1-p\right)k_i^{TR-\frac{1}{\theta}} + pq\left(\theta r\right)^{-\frac{1}{\theta}}$ if the owner is subject to theft and $\kappa_i \equiv q\left(1-p\right)k_i^{TR-\frac{1}{\theta}} + p\left(\theta r\right)^{-\frac{1}{\theta}}$ otherwise; $\kappa_j \equiv q\left(1-p\right)k_j^{TR-\frac{1}{\theta}}$ remains the unchanged across scenarios.

Taking the derivatives of z_i^{TRth} and z_j^{TRth} with respect to λ and rearranging terms:

$$[z_i]: \; a_i \frac{\partial k_i^{TRth}}{\partial \lambda} - (\theta - 1)\frac{\partial k_j^{TRth}}{\partial \lambda} = -\theta\pi k_i^{TRth\frac{1}{\theta}} \frac{\partial\left(\mu_i \kappa_i\right)}{\partial \lambda}$$

$$\left[z_j\right]: \; a_j \frac{\partial k_j^{TRth}}{\partial \lambda} - (\theta - 1)\frac{\partial k_i^{TRth}}{\partial \lambda} = -\theta\pi k_j^{TRth\frac{1}{\theta}} \frac{\partial\left(\mu_j \kappa_j\right)}{\partial \lambda}$$

Where $a_s \equiv 1 + \pi\mu_s\kappa_s k_s^{TRth\frac{1}{\theta}-1} > 1$. Using the former in the latter and rearranging terms:

$$\frac{\partial k_i^{TRth}}{\partial \lambda} = \frac{-\theta\pi\left(k_i^{TRth\frac{1}{\theta}}\frac{\partial(\mu_i\kappa_i)}{\partial\lambda} + \frac{\theta-1}{a_j}k_j^{TRth\frac{1}{\theta}}\frac{\partial\left(\mu_j\kappa_j\right)}{\partial\lambda}\right)}{a_i - \frac{(\theta-1)^2}{a_j}}$$

by symmetry

$$\frac{\partial k_j^{TRth}}{\partial \lambda} = \frac{-\theta\pi\left(k_j^{TRth\frac{1}{\theta}}\frac{\partial\left(\mu_j\kappa_j\right)}{\partial\lambda} + \frac{\theta-1}{a_i}k_i^{TRth\frac{1}{\theta}}\frac{\partial(\mu_i\kappa_i)}{\partial\lambda}\right)}{a_j - \frac{(\theta-1)^2}{a_i}}$$

Adding the last two up

$$\frac{\partial\left(k_i^{TRth}+k_j^{TRth}\right)}{\partial\lambda} = \frac{-\theta\pi\left(\left(\left(a_j+\theta-1\right)k_i^{TRth\frac{1}{\theta}}\frac{\partial(\mu_i\kappa_i)}{\partial\lambda} + (a_i+\theta-1)k_j^{TRth\frac{1}{\theta}}\frac{\partial\left(\mu_j\kappa_j\right)}{\partial\lambda}\right)\right)}{a_ia_j-(\theta-1)^2} > 0$$

The sign follows from $\theta < 2$, and $a_s > 1$ and $\partial(\mu_s\kappa_s)/\partial\lambda < 0$ for $s \in \{i, j\}$.

ii) When **only the owner** is subject to theft:

If $\lambda = 0$ and therefore $k_i^{TRth} = 0$, k_j^{TRth} in equilibrium is given by

$$z_j^{TRth}\left(0, k_j^{TRth}\right) = k_j^{TRth} + \theta\pi\kappa_j k_j^{TRth\frac{1}{\theta}} = \theta\left(r + \pi^{TRth}\right)$$

Evaluating z_j^{TRth} in $(0, \theta r)$ and comparing with $z_j^{TRth}\left(0, k_j^{TRth}\right)$:

$$z_j^{TRth}(0, \theta r) = \theta r + \theta\pi\kappa_j(\theta r)^{\frac{1}{\theta}} \gtreqless \theta\left(r + \pi^{TRth}\right) = z_j^{TRth}\left(0, k_j^{TRth}\right)$$

using the definitions of κ_j and π^{TRth}

$$\longleftrightarrow q\,(1-p)\left(\frac{\theta r}{k_j^{TR}}\right) \gtreqless q\,(1-p)+p$$

From proposition 4.3 $k_j^{TR} > \theta r$, hence $q\,(1-p)\,\theta r\left(k_j^{TR}\right)^{-1} < q\,(1-p)+p$. Given that z_j is increasing in k_j, it is immediate that $k_j^{TRth}\Big|_{\lambda=0} > \theta r$. Given that $k_j^{TRth}\Big|_{\lambda=1} = k_j^{TR}$, it also follows from4.3 that $k_j^{TRth}\Big|_{\lambda=1} > \theta r$. As k_j^{TRth} is continuous and monotonic in λ (see lemma 4.3) and $k_j^{TRth}\Big|_{\lambda=0}, k_j^{TRth}\Big|_{\lambda=1} > \theta r$, the intermediate value theorem implies that $k_j^{TRth} > \theta r$ for any $\lambda \in [0, 1]$. Hence total depletion ($k_i^{TRth} + k_j^{TRth}$) is always above the social optimum level.

iii) When **the owner and the trespasser** are subject to theft:

If $\lambda = 0$ $k_i^{TRth}\Big|_{\lambda=0} = k_j^{TRth}\Big|_{\lambda=0} = 0$; if $\lambda = 1$ $k_j^{TRth}\Big|_{\lambda=1} + k_j^{TR}\Big|_{\lambda=1} > \theta r$, which follows from proposition 4.3. This means that total depletion in the TRth regime is below θr when $\lambda \to 0$ (it goes to 0) and it is above θr when $\lambda \to 1$. As total depletion is continuous and monotonically increasing in λ (see i), from the intermediate value theorem there is a unique $\lambda^* \in (0, 1)$ such that total depletion is $\gtreqless \theta r$ if $\lambda \gtreqless \lambda^*$.

iv) When **only the trespasser** is subject to theft:

Assuming $\lambda = 0$ (and thus $k_j^{TRth} = 0$), and evaluating z_i in θr when only the trespasser is affected by theft:

$$z_i^{TRth}(\theta r, 0) = k_i^{TRth} + \theta\pi\kappa_i k_i^{TRth\frac{1}{\theta}} \gtreqless \theta\left(r + \pi^{TRth}\right) \equiv z_i^{TRth}\left(k_i^{TRth}, 0\right) \longleftrightarrow k_i^{TR} \gtreqless \theta r$$

From proposition 4.3 we know that $k_i^{TR} > \theta r$. Using the fact that z_i is increasing in k_i^{TRth}, $k_i^{TRth} > \theta r$, and thus $k_i^{TRth} + k_j^{TRth} > \theta r$, for $\lambda = 0$. Moreover, as k_i^{TRth} is increasing in λ (see lemma *4.4*) both k_i^{TRth} and $k_i^{TRth} + k_j^{TRth}$ are above θr for any value of $\lambda > 0$ □

Chapter 5

RESOURCE MANAGEMENT UNDER ENDOGENOUS RISK OF EXPROPRIATION

Abstract

Expropriations are more likely to occur when the assets to be seized are more valuable and the cost of expropriating them is low. A direct implication of this observation is that the risk of expropriation of an asset is endogenous and can be mitigated by lowering its value. This chapter explores how the dynamic management of a non-renewable resource is affected by an endogenous (i.e., mitigable) risk of expropriation. When the risk of expropriation is internalized, in the absence of capacity constraints, the legitimate owner depletes the resource too fast from the social perspective. Moreover, an improvement in the protection of property rights cost of expropriation) exacerbates the over-extraction of the resource. In the presence of endogenous capacity constraints and when the protection of property rights is relatively weak, the resource owner over-invests in extraction capacity and depletes the resource faster than it is socially optimal. When property rights are relatively strong, yet imperfectly protected, the resource owner under-invests in extraction capacity and depletes the resource below the socially optimal rate.

5.1 Introduction

It is a well-known economic principle that the appropriate definition and enforcement of property rights is a necessary condition for efficiency. However, in many economic environments property rights fail to be adequately protected. For instance, in the oil and gas industry, the relationship between multinational firms and governments has been characterized by the persistence of weakly protected property rights. The history of this sector is rich in anecdotes of forced nationalizations, some of them even dating back to the early 1900s.

In recent years, the commodity super-cycle and the political environment in Latin America, home of about one fifth of the world's oil reserves (BP, 2015), brought expropriations in the oil and gas industry—resource nationalism—back to the headlines. Among the Latin American governments, Venezuela's is one of the most salient trespassers of private property.[1] An example of this, in the oil and gas industry, is the nationalization of ConocoPhillips and Exxon Mobil's operations, ordered by Hugo Chavez in 2007. ConocoPhillips' recount states that on June 11th, 2007—nine days before the nationalization was executed—the company declined the, allegedly unfair, compensation offered by the Venezuelan government in exchange for its local operations. Upon the company's refusal to accept this deal, the government proceeded to inform that "the nationalization process was nonnegotiable and would move forward on the government's terms, with or without ConocoPhillips" (ICSID, 2013, p. 128). The International Centre for Settlement of Investment Disputes (ICSID) tribunal arbitrating the case between ConocoPhillips and the Venezuelan government, eventually ruled that the latter "breached its obligation to negotiate in good faith for compensation for its taking of the ConocoPhillips assets" (ICSID, 2013, p. 131).

More recently, in April 2012, the Argentine government of Cristina Fernandez announced the seizure of 90% of Repsol's stake in YPF, a move to re-nationalize this oil and gas company (Forbes, April 17, 2013). At the time of the expropriation, Argentina faced an energy crisis, caused by a strict capping on energy prices, which significantly undermined the incentives to invest in the sector. Paradoxically, the government justified the expropriation of Repsol's assets on the grounds that Repsol's lack of investment was a main contributor to Argentina's trade deficit in fuel. In the midst of the energy crisis, the expropriation of Repsol's YPF stake occurred only a few months after Repsol's announcement of the discovery of the Vaca Muerta basin; "[Vaca Muerta] is estimated to hold 16 billion barrels of shale oil and 308 tril-

[1] This is well reflected in Venezuela's dismal Ease of Doing Business rank for 2016, 186 out 189 (World Bank, 2016).

lion cubic feet (8.7 trillion cubic metres) of shale gas, which would give Argentina the world's fourth-largest reserves of shale oil and second-largest of shale gas." (The Economist, June 27, 2013). The discovery of Vaca Muerta presented itself as an obvious opportunity for the cash-strapped Argentine government to reach the goal of energy independence, and put YPF's re-nationalization under a thick cloud of suspicion.

These recent Latin American expropriations not only occurred at a time of high commodity prices; these expropriations were carried out by governments with at best moderate constraints, from the legislature, to take action against private interests.[2] In the case of Venezuela, the lack of constraints on the executive occurred because the executive enjoyed special powers; while in Argentina, the parliament was largely controlled by the government's party. In other words, these expropriations occurred under what appeared to be favorable circumstances for the expropriator. Specifically, they took place in a context of: i) increased value of the assets to be seized, because of the higher oil prices and the unexpectedly large size of the newly found basin; and, ii) low cost of expropriation, because of the lack of political constraints on the executive.

These observations reveal the importance of incorporating the expropriation decisions as endogenous outcomes of a cost-benefit analysis in the study of resource management problems. The case for the economic motives behind expropriations is not only an intuitive or anecdotal one. Guriev, Kolotilin, and Sonin (2011) and Stroebel and van Benthem (2013) further substantiate this line of reasoning with evidence from nationalizations occurring after the 1960s. Both of these studies find that nationalizations in the oil sector have a higher probability of occurring when oil prices are high and in countries with low constraints on the executive.

This chapter contributes to the literature by incorporating the notion that the decision to expropriate follows a cost-benefit analysis and exploring the effect of the, resulting, endogenous risk of expropriation on the dynamic management of a non-renewable resource. The theoretical analysis presented here rests on two main elements. First, it is assumed that expropriations only occur if the benefits of doing so outweigh the cost of expropriation. This cost, which is assumed to be given, is intended to mirror the institutional hurdles that the potential expropriator needs to bypass to infringe property rights. Second, the endogenous nature of the risk of expropriation is internalized by the resource owner (or the entity with the original rights to exploit the resource). A direct implication of the combination of these el-

[2]Another common characteristic is that the compensation offers, appear to have been well below the market value of the seized assets. For example, in November 2013 the Argentine government offered $5 billion for, the reportedly $10 billion worth, Repsol's stake in YPF.

ements is that the risk of expropriation vanishes endogenously in finite time when the stock of the resource reaches a certain threshold (i.e., dry oil wells are not worth to confiscate). If the owner is aware that the resource is at risk of being expropriated her effective discount rate is higher than it would be in the absence of the risk; therefore the resource is over-exploited. If on top of recognizing that there is a risk of expropriation, the owner actually internalizes that this risk is endogenous, the over-exploitation of the resource is exacerbated: by reducing the size of the available stock the owner is protecting her property rights over the resource left in the ground.

From a broader perspective, this theoretical framework allows for a systematic analysis of the extraction of a non-renewable resource for the whole range of intermediate property rights regimes in between the two extremes commonly explored in the literature: perfectly protected property rights and fully exogenous risk of expropriation. Following this analysis one can infer the effect of the strength of property rights protection on the depletion of a non-renewable resource. When the risk of expropriation is treated as exogenous, it induces a higher effective discount rate, which in turn leads to the over-extraction of the resource relative to the social optimum, i.e., relative to what would be extracted under perfect property rights protection (e.g., Bohn & Deacon, 2000; N. V. Long, 1975; Sinn, 2008). Interestingly, when the risk of expropriation is endogenous, a marginal improvement in the protection of property rights (i.e., a marginal increase in the cost of expropriation) exacerbates the over-extraction problem. This however, does not necessarily imply that the net present value of the resource is reduced. From the viewpoint of the resource owner, an improvement in the strength of property rights protection unambiguously increases the value of the resource in the ground. Nevertheless, when calculating the social value of the resource (i.e., the net present value under perfect property rights) the effect of improved property rights protection has opposite effects: on the one hand, the extraction path is more distorted (i.e., over-extraction is more intensive) and this reduces the social value; on the other hand, the time at risk, and therefore expected duration of the distorted extraction, will be shorter and this increases the social value of the resource.

The extraction and commercialization of non-renewable resources requires complementary capital investments. For instance, before being shipped through a pipeline, oil needs to fulfill certain specifications (e.g., maximum content of water) typically not met in its natural state. As a consequence, oil extraction is often times limited by the capacity of on-site separation (demulsification) and storage facilities. This means that capital investments are needed to build-up a well's extraction capacity. Moreover, for a given stock in the ground, an underdeveloped well will generate a lower income stream than an adequately developed one.

Taking this into account, the extended version of the theoretical model presented in this chapter treats the extraction capacity as endogenous. Specifically, the extended model studies the effects of the risk of expropriation on both the extraction path and the investment in extraction capacity. Interestingly, under endogenous capacity constraints, the risk of expropriation can be (strategically) internalized in one of two opposite ways. As is the case without capacity constraints, the owner can opt for reducing the value of the well, and the incentives to confiscate it, by running down the stock; this is achieved by installing extraction capacity above the efficient level. Alternatively, the resource owner may decide to reduce the well's value by under-investing in the well's extraction capacity. Evidently, each of these two alternatives comes at a cost for the owner. Over-investing in extraction capacity is costly in the short run because installation costs may increase in the installed capacity, and in the long run because there is less of the resource in the ground. In contrast, under-investing in capacity is costly because it constrains the owner's extraction and therefore reduces the revenues while the constraint is binding. The results indicate that whether over-investing or under-investing emerges as dominant strategy depends on the strength of property rights protection. When property rights are strong (i.e., the cost of expropriation is high) the level of under-investment required to avert an expropriation is not too low; therefore, the under-investing strategy is not as costly an emerges in equilibrium. When the protection of property rights is weak, under-investing is too costly, and the owner is better off by over-investing.

The effect of weak property rights first got attention in the resource economics literature in the 1970's (e.g., N. V. Long, 1975) when the oil sector experienced a wave of nationalizations of foreign production activities (Kobrin, 1985). This early literature explores the dynamic effect of an exogenous risk of expropriation on the extraction of a non-renewable resource. By inducing a higher effective discount rate, a higher risk of expropriation leads to over-exploitation of the natural resource from the optimal perspective (e.g., Bohn & Deacon, 2000; N. V. Long, 1975; Sinn, 2008); this in turn, lowers the value of what is still in the ground.[3]

In his seminal work N. V. Long (1975) studies how the decision to exploit a non-renewable resource is affected by the risk of nationalization. In his framework the owner of the resource incorporates this as a risk of losing access to the resource. When the date of nationalization is uncertain and the probability of nationalization increases over time, the risk of nationalization is akin to a higher discount rate; thus, it causes an accelerated extraction.[4] In case the date of nationalization is known

[3]The poor definition of exploitation rights of a non-renewable resource has also been approached as a *common pool* problem: e.g., Kemp and Long (1984).

[4]See Sinn (2008) for an application of this result.

with certainty, the owner would speed-up extraction to leave as little as possible in the ground when the nationalization occurs. In a related framework, Konrad, Olsen, and Schob (1994) study how a non-renewable resource is exploited by a risk-averse dictator who can consume or invest the proceeds from extraction. The dictator, however, faces uncertainty regarding whether he can stay in power and thus accrue the benefits from exploiting the natural resource. This risk comes in the form of an exogenous probability of being expropriated. Again, in their basic setup the risk of expropriation results in over-extraction. However, they show that when the risk of losing access to the resource also means losing access to savings (say when a dictator is ousted his foreign accounts are frozen), the risk of expropriation has no effect whatsoever on the extraction path; i.e., in terms of risk, there is no difference in keeping wealth in the form of oil in the ground or transforming it into wealth in a foreign account.

More recently, Bohn and Deacon (2000) analyzed the effect of an exogenous risk of expropriation on the extraction of a natural resource, the investment in complementary physical capital, and the exploration for further sources of the resource. The find that a higher risk of expropriation has an ambiguous effect on the speed of depletion. On the one hand, a higher risk leads to over-exploitation due to the higher effective discount, and thus a lower valuation of the stock in the ground; on the other hand, because of the lower valuation of future benefits, a higher risk also entails a lower investment in extraction capacity which in turn slows down extraction. Their empirical results suggest that the former effect dominates: higher ownership security leads to more rapacious extraction.

Next to the resource economics view, the political economy of development literature offers an alternative perspective on the natural resource ownership problem. This literature commonly approaches the ownership problem assuming that the flow of extraction of the resource (or the flow of rents from exploiting it) is exogenous, while the fight over the resource rents is an endogenous process. More precisely, this literature generally highlights the effect that the availability of rents from natural resources has on the incentives to divert productive resources into unproductive activities (e.g., rent-seeking), while abstracting from the resource management problem. For instance, in weakly institutionalized polities, a high level of rents from natural resources may result in violent conflicts between rival factions, rent-seeking, or cronyism. As a consequence, more rents from natural resources may actually have a negative impact on aggregate output and welfare (see for instance, Acemoglu, Verdier, & Robinson, 2004; Hodler, 2006; Mehlum et al., 2006; Torvik, 2002).

Recently, some literature aiming directly at filling the gap between the resource economics (exogenous expropriation) and the political economy (exogenous extraction) approaches, has emerged. For example, van der Ploeg and Rohner (2012) develop a two period model of resource extraction in a political environment characterized by two rival groups, government and rebels, where the rebels may (violently) challenge the government for political power. In this setup, agents have incentives to hold political power because it grants control over the remaining stock of the resource. In the benchmark model, these authors find a combination of the traditional results: on the one hand, the larger the stock in the ground, the more intense the conflict for power; on the other hand, because the conflict for power results in uncertainty about tenure of power, the incumbent becomes effectively more impatient and over-exploits the natural resource. This framework also provides some predictions regarding the effect of allowing for private exploitation rather than nationalizing the resource. Although private exploitation is assumed to be the most efficient for extraction, it has a negative effect on the political game. In particular, the incumbent—unable to credibly commit to effectively retain power—exerts less defensive effort, which in turn leads to a more unstable political environment and thus to a less efficient extraction of the resource.[5]

The combination of endogenous extraction and endogenous fight over resources has also been framed in the context of the so-called resource wars. Using an infinite horizon model, van der Ploeg (2012) models both the extraction of a non-renewable resource and the fight to control it. Again the risk of losing the resource is endogenously determined by how much military effort the two rival factions exert. Also in the context of resource wars, but in this case motivated by international conflicts, Acemoglu, Golosov, Tsyvinski, and Yared (2012) explore a two-country model in which only one of the countries has access to a non-renewable resource. The *resource poor* country can get access to the resource either by trading or by invading the *resource rich* country. One of the main findings of Acemoglu et al. (2012) is what they call the "unraveling of peace". If the demand for the resource is relatively inelastic, the resource's value increases as it becomes scarcer, and so the incentives of the *resource poor* country to invade the *resource rich* country increase over time. In a competitive market the prospect of invasion, together with the non-internalization of the incentives to invade, accelerates extraction today. This in turn makes the resources even scarcer, which increases the current incentives to invade, and may result in an

[5]A similar issue is studied by Janus (2012). However, his setup presents some important differences; first, the rival factions have common access to the resource in the first period (i.e., both can finance the fighting effort by extracting from the common pool); second, the conflict technology requires an input (war capital) that cannot be used in the productive sectors (agriculture and extraction), and must be acquired in the international markets. The main focus of this chapter is on how different shocks and policy interventions may be reverted depending on the credit constraints faced by rival factions when purchasing their "war capital".

immediate invasion.[6, 7]

The analysis presented in this chapter belongs to the intersection of resource economics and political economy. Following the resource economics approach, this chapter's main focus is on how the extraction path of a non-renewable resource is affected by an institutional imperfection, in this case the risk of expropriation. Next to this, it adds the political economy element of explicitly modeling the source of the expropriation risk; this is done by explicitly incorporating the expropriator's cost-benefit analysis into the model. As a result, the model generates some novel elements for the study of the management of non-renewable resources in presence of expropriation risk. First, it produces a systematic analysis of the effect of ill-defined property rights on the extraction of a non-renewable resource. In particular, the model serves to explore how depletion and extraction capacity react to changes in the strength of property rights, for the complete range of intermediate property rights regimes. Second, it decomposes the expropriation risk into two sources: the risk of a political shift, which is beyond the control of the resource owner; and the strength of property rights relative to size of the resource, which can be internalized by the resource owner. Consequently, it permits us to analyze how different sources ownership risk may have different impacts on the resource's management.

The rest of this chapter is organized as follows. Section 5.2 presents the basic setup: a model of extraction of a non-renewable resource under the endogenous risk of expropriation. Section 5.3 extends the basic framework by introducing the investment in extraction capacity as an additional variable under the control of the resource owner. This section explores how this investment is affected by the strength of property rights. Section 5.4 discusses how some alternative elements that characterize the relationship between firms exploiting non-renewable natural resources and potential expropriators, can be incorporated to the model. This section also discusses the implications of these alternative formulations. Finally, section 5.5 is devoted to the concluding remarks.

[6] Also related to this literature are the contributions by Robinson et al. (2006) and Sekeris (2014). The former explicitly includes an extraction decision in a two-period political game. The latter studies a dynamic version of the tragedy of the commons, in which the common pool resource is non-renewable, and agents can engage in a one shot (destructive) conflict to define the property rights over the resource. When the remaining stock of the resource is sufficiently low, the rival groups decide to fight for the resource; anticipating that conflict will break down, when there is little of the resource left, eliminates the possibility for cooperative extraction when the remaining stock is large.

[7] For a general framework of trade in the shadow of power and the distortive effect of (potential) conflict on the comparative advantage of countries see M. Garfinkel, Skaperdas, and Syropoulos (2012).

5.2 Basic Framework

5.2.1 Setup

Endowments and technology

The economy is initially endowed with a stock S_0 of a non-renewable resource, which is perfectly observable by all agents. Time is continuous and the planning horizon is of infinite length. The evolution of the resource over time depends on extraction $R(t)$: $dS/dt \equiv \dot{S}(t) = -R(t)$. The net instantaneous income generated by extraction is a concave function of the extracted amount R. Specifically, for $R(t)$ extracted units from the ground an income flow of $\theta(\theta-1)^{-1} R(t)^{1-\frac{1}{\theta}}$ is generated, with $\theta > 1$. This assumption reflects that in the presence of geological constraints speeding-up extraction, by increasing the extractive pressure, lowers the quality and market value of the extracted resource (see Venables, 2011).

Agents and institutions

The political environment is characterized by two regimes: the incumbent's (business-friendly) regime E and the challenger's (business-hostile) regime C. By assumption the economy is initially in regime E. In this regime, the rights over the resource are granted to a third party (F). At every point in time during E's regime there is an instantaneous and exogenous risk, $\pi > 0$, of a shift in the political regime. A regime shift is defined here as a change in the identity of the group in power, from E to C. The relevance of the regime shift is that it may undermine F's property rights. Specifically, during E's regime F's property rights are secure however, upon a regime shift the new government C, by expropriating the remaining stock, has the opportunity to seize F's rights to exploit the resource.[8] Yet, C may refrain from expropriating the resource because expropriations are costly. For instance, the new regime may face institutional constraints (e.g., constitutional dispositions, limited executive powers) that make expropriations harder to execute. The expropriation cost denoted by $\chi \geq 0$, is exogenous and reflects the extent to which the protection of property rights is independent of the identity of the group in power; in other words, it reflects how resilient property rights are to shifts in the private-ownership-stance of the government. As such, $\chi \to \infty$ implies perfectly protected property rights, and a regime shift will never threaten property rights; while, $\chi = 0$ implies that expropriation is certain whenever a political regime shift occurs. By assumption at most

[8]This feature is consistent with the evidence of a positive impact of a change in government on the probability of a nationalization (Guriev et al., 2011).

one political regime shift is possible.[9] Intuitively, χ mirrors the strength of property rights and not the technological constraints faced by the expropriator. In some polities, for instance, there are constitutional provisions deeming expropriation by the executive as illegal. Thus, if the executive wants to take control of the resource, it has to go through the costly process of convincing (or over-ruling) the legislature. This interpretation of χ is further corroborated by the negative association between the likelihood of nationalizations, in the oil sector, and the strength of the constraints on the executive (see, e.g., Guriev et al., 2011; Stroebel & van Benthem, 2013). In their theoretical framework Guriev et al. (2011) and Stroebel and van Benthem (2013) also assume a fixed cost of expropriation and interpret it as institutional strength. However, in contrast to the present analysis, they do not explore the effect of this on the extraction/depletion decision.[10]

Expropriations are assumed to be permanent; that is upon expropriation F never regains access to the resource again. In this economy all agents are risk neutral, and consequently they only care about maximizing the net present value (NPV) of the income flow from exploiting the resource. Finally, the economy is small and open and therefore the interest rate r is exogenous and given by the international capital markets.

Timing

The timing of the instantaneous interactions is as follows:

1. All the agents observe whether a political regime shift occurs
2. In case of a regime shift C decides whether or not to expropriate the resource
3. If there is no regime shift, or if the resource is not expropriated, F decides how much to extract in that period; otherwise the new owner (C) decides on extraction
4. Extraction takes place and the revenues from extraction are accrued by whoever is controlling the resource

[9] This assumption just simplifies the exposition, but the results of this section remain unchanged if multiple regime changes are allowed. This is the case because under multiple regime shifts it is still true that the individual valuation of the resource is strictly increasing in the remaining stock, and that individuals discount time positively.

[10] An alternative interpretation of this cost is that upon expropriation the initial owner is nominally compensated, meaning that the compensation does not reflect to the value of what is still left in the ground. This would be in line with the anecdotal evidence from recent nationalizations in Latin America. The cost of expropriation could also reflect a reputation cost for the expropriating government. An expropriation could be, for example, punished with lower foreign investment inflows in the future or stricter conditions in the international credit markets (Stroebel & van Benthem, 2013).

5.2.2 Analysis

5.2.2.1 The Challenger's problem and the *No Expropriation Constraint*

Suppose that a regime shift occurs at time t, and that C gets a hold of the resource. The problem of C then is to maximize the NPV of the income flow generated by the extraction of the resource as of t. This is

$$V^{C}\left(S\left(t\right)\right)=\max_{R(\tau)}\int_{t}^{\infty}e^{-r\tau}\frac{R\left(\tau\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}d\tau$$

subject to the law of motion of the resource ($R\left(t\right)=-\dot{S}\left(t\right)$), the current value of the stock in the ground ($\int_{t}^{\infty}R\left(\tau\right)d\tau\leq S\left(t\right)$), and the non-negativity constraints ($S\left(t\right),R\left(t\right)\geq 0$ for all t); where $S\left(t\right)$ denotes the remaining stock of the resource in the ground, and $R\left(t\right)$ stands for the extraction of the resource at time t. This dynamic optimization problem can be solved using a simple optimal control approach. The present value Hamiltonian corresponding to this optimization is

$$\mathcal{H}^{C}=e^{-rt}\frac{R\left(\tau\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}-\lambda\left(t\right)R\left(t\right)$$

where $\lambda\left(t\right)$ is the shadow value of the stock in the ground. The FOCs of the problem are

$$[R]:\ e^{-rt}R\left(t\right)^{-\frac{1}{\theta}}-\lambda\left(t\right)=0$$

and

$$[S]:\ \dot{\lambda}\left(t\right)=0$$

which together with the transversality condition (TVC), $\lim_{t\to\infty}\lambda\left(t\right)S\left(t\right)=0$, provide the set of sufficient conditions that solve the maximization problem.[11] Combining the two FOCs, is is obtained that the growth rate of extraction is constant

$$\hat{R}\left(t\right)\equiv\frac{\dot{R}\left(t\right)}{R\left(t\right)}=-\theta r \tag{5.2.1}$$

The exact extraction path (i.e., level of $R\left(t\right)$ as a function of $S\left(t\right)$) can be pinned down by combining this growth rate and the TVC. The constant growth rate implies $R\left(\tau\right)=R\left(t\right)e^{-\theta r\left(\tau-t\right)}$, while the TVC (given that λ remains constant) calls for a full exhaustion of the resource, i.e. $\int_{t}^{\infty}R\left(\tau\right)d\tau=S\left(t\right)$. Combining these two we get:

[11] Note that the concavity of the revenue function guarantees that the necessary FOCs are also sufficient.

$$R(t) = \theta r S(t) \tag{5.2.2}$$

It is immediate from this expression that the depletion rate, defined as the extraction relative to the remaining stock (R/S), is constant at θr. Given that there are no further regime shifts after the challenger takes political power and control over the resource, C's property rights are secured. As a consequence, the extraction path described by (5.2.2) coincides with the socially optimal extraction path.

Definition 5.1. An extraction path is socially optimal if, using r as the discount rate, it maximizes the NPV of the flow of revenues from extraction

$$\int_t^\infty e^{-r\tau} \frac{R(\tau)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} d\tau$$

subject to the law of motion of the resource ($R(t) = -\dot{S}(t)$), the remaining stock in the ground ($\int_t^\infty R(\tau)\, d\tau \leq S(t)$), and the non-negativity constraints ($S(t)\,,\ R(t) \geq 0$ for all t). The socially optimal path is given by $\hat{R}(t) = -\theta r$ and $R(t)/S(t) = \theta r$.

Using $R(\tau) = R(t)\, e^{-\theta r(\tau - t)}$ and (5.2.2) one can solve for the challenger's valuation of the remaining stock $S(t)$

$$V^C(S(t)) = \Theta S(t)^{1-\frac{1}{\theta}} r^{-\frac{1}{\theta}} \tag{5.2.3}$$

with $\Theta \equiv \theta^{1-\frac{1}{\theta}} (\theta - 1)^{-1}$

According to the political economy structure of the model, expropriating is costly. As this cost is meant to reflect institutional (rather than technological) constraints, it does not depend on the size of the stock in the ground, however $V^C(S(t))$ is strictly increasing in $S(t)$. As a result, it is possible to define a threshold for the remaining stock, $\bar{S}$, below which the challenger is better off by not expropriating. In other words, as it is costly to confiscate the resource, only sufficiently valuable/large stocks are expropriated. If the new ruler expropriates the resource at t, the continuation value is

$$U^C(S(t)|\, l(t) = f(t) = 1) = V^C(S(t)) - \chi$$

where $l(t) \in \{0, 1\}$ is the state variable that takes the value of 1 if political challenger is already in power (i.e., a regime shift has occurred exactly at t or before); $f(t)$ takes the value of 1 if the challenger decides to expropriate the resource at time t, otherwise it is equal to 0. U^C stands for the challenger's (net present) valuation of the resource, net of expropriation costs. On the other hand, if the challenger decides not to expropriate, the continuation value is

$$U^C\left(S\left(t\right)|\, l\left(t\right)=1;\; f\left(t\right)=0\right)=0$$

Note that this expression uses the fact that there is no better day than today to expropriate. This follows from the assumption that the resource is non-renewable and thus the stock does not regenerate over time; hence, even in the absence of extraction C's valuation of the resource is decreasing in the time of confiscation simply because of the positive time discount. The challenger therefore decides not to expropriate the resource if

$$U^C\left(S\left(t\right)|\, l\left(t\right)=1;\; f\left(t\right)=0\right)\leq U^C\left(S\left(t\right)|\, l\left(t\right)=f\left(t\right)=1\right)$$

$$V^C\left(S\left(t\right)\right)\leq\chi \tag{5.2.4}$$

Given that $V^C\left(S\left(t\right)\right)$ strictly increasing in $S\left(t\right)$, (5.2.4) generates a threshold for $S\left(t\right)$; if the remaining stock is below this threshold, the no expropriation constraint (NEC) (5.2.4). Using (5.2.3) in (5.2.4) the NEC can be rewritten as

$$S\left(t\right)\leq\left(\chi\frac{\left(\theta r\right)^{\frac{1}{\theta}}}{\Theta}\right)^{\frac{\theta}{\theta-1}}\equiv\bar{S} \tag{5.2.5}$$

Evidently, the higher the cost of expropriation, χ, the less restrictive the NEC is.

5.2.2.2 The Owner's problem

The initially rightful owner of resource F, hereafter just *the owner*, maximizes the NPV of the resource extraction taking into account the risk of losing the resource to C. That is, the owner is fully forward looking. The risk of expropriation is composed by the combination of two elements: i) the exogenous hazard of a political regime shift (i.e., the instantaneous probability that E is replaced by C), represented by parameter $\pi>0$; and, ii) whether the NEC is fulfilled (i.e., whether $S\left(t\right)\leq\bar{S}$). Taking this into account, the expected NPV from the owner's viewpoint is

$$E\left[NPV^F\left(S_0\right)\right]=\int_0^{\infty}e^{-\left(r+\Pi\left(S\left(\tau\right)\right)\right)}R\left(\tau\right)d\tau \tag{5.2.6}$$

$$\Pi\left(S\left(t\right)\right)=\begin{cases}\pi\text{ if }S\left(t\right)>\bar{S}\\ 0\text{ otherwise}\end{cases}$$

The problem of the owner is then to maximize this expected NPV, subject to the law of motion of the resource ($R(t) = -\dot{S}(t)$), the endowment of the resource ($\int_0^\infty R(\tau)\, d\tau \le S_0$), and the non-negativity constraints ($S(t), R(t) \ge 0$) for all t.

Definition 5.2. Let $\bar{t}$ denote the time period such that if $l(\bar{t}) = 0$ (i.e., if the incumbent remains in office at least until $\bar{t}$), then $S(\bar{t}) = \bar{S}$.

In other words, $\bar{t}$ is the precise instant at which the safe stock is reached. In the absence of a regime shift, by definition 5.2 the total cumulative extraction between an arbitrary $t < \bar{t}$ and $\bar{t}$ is equal to $S(t) - \bar{S}$. That is,

$$\int_t^{\bar{t}} R(\tau)\, d\tau = S(t) - \bar{S}$$

Taking this into account the owner's problem is essentially an optimal switching time problem. When choosing how fast to extract, the owner is choosing how fast to reach the safety threshold $\bar{S}$; and this is equivalent to choosing $\bar{t}$. From the owner's perspective, running down the stock below $\bar{S}$ endogenously induces a regime shift (not to be confused with the political regime shift), in the sense that the effective discount rate jumps from $r + \pi$ to r. The objective of the owner is to maximize the expected NPV of the income flows from extraction, which is given by:[12]

$$E\left[NPV^F(S_0)\right] = \int_0^{\bar{t}} e^{-(r+\pi)\tau} \frac{R(\tau)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} d\tau + e^{-(r+\pi)\bar{t}} \int_{\bar{t}}^{\infty} e^{-r(\tau-\bar{t})} \frac{R(\tau)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} d\tau$$

The integral between 0 and $\bar{t}$ represents the sum of all the income flows, while the threat of expropriation is latent. During this time interval each flow is discounted by the interest rate and the survival probability of the incumbent's regime (i.e., $e^{-\pi t}$). The second integral is the sum of all the income flows after safety is reached ($t \ge \bar{t}$). These flows are received with certainty, conditional on the incumbent's regime surviving at least until $t = \bar{t}$; this occurs with probability $e^{-\pi \bar{t}}$, which is precisely why this term acts as an additional discount outside the second integral. Moreover, this expected NPV takes into account that expropriation is full and permanent, and therefore the owner's continuation value upon expropriation is 0.

From $\bar{t}$ onwards F's problem is simply the risk-free problem (provided that F has retained the resource until $\bar{t}$). Under the assumption that the owner F has no technological (or market access) advantages over the challenger C, the owner's valuation

[12] See the Appendix 5.B.1 for the formal derivation of this formulation.

of the resource at $\bar{t}$ must by definition be equal to χ

$$\int_{\bar{t}}^{\infty} e^{-r(\tau-\bar{t})} \frac{R(\tau)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} d\tau = \chi$$

and so the owner's NPV can be rewritten as,

$$E\left[NPV^F(S_0)\right] = \int_0^{\bar{t}} e^{-(r+\pi)\tau} \frac{R(\tau)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} d\tau + e^{-(r+\pi)\bar{t}}\chi$$

Using this objective function, the F's optimization problem between 0 and $\bar{t}$ can be represented by the following present value Hamiltonian:

$$\mathcal{H}^F(t) = e^{-(r+\pi)t} \frac{R(t)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} - \lambda(t) R(t)$$

where $\lambda(t)$ is the shadow value of the stock in the ground. The FOCs of this problem with respect to the extraction and the remaining stock respectively are:

$$[R]: \; e^{-(r+\pi)t} R(t)^{-\frac{1}{\theta}} - \lambda(t) = 0$$

and

$$[S]: \; \dot{\lambda}(t) = 0$$

Combining these two, one obtains that the growth rate of extraction is constant and equal to

$$\hat{R}(t) = -\theta(r+\pi)$$

and therefore

$$R(t_1) = e^{-\theta(r+\pi)(t_1-t_2)} R(t_2) \tag{5.2.7}$$

for any arbitrary pair $t_1 < t_2 < \bar{t}$, such that $l(t_2) = 0$.

Now, to pin down the exact extraction path between 0 and $\bar{t}$ one needs to know the value of $R(t)$ at some t in that interval. For this, one can use the TVC of the problem at $\bar{t}$. As this is an optimal control problem, with a fixed end value of the state ($S(\bar{t}) = \bar{S}$), and a free end time ($\bar{t}$), the TVC at $\bar{t}$ is given by $\mathcal{H}^F(\bar{t}) + \partial\left(e^{-(r+\pi)\bar{t}} V^F(\bar{S})\right)/\partial\bar{t} = 0$, where $e^{-(r+\pi)\bar{t}} V^F(\bar{S})$ is the net present value of reaching the safety threshold $\bar{S}$. This TVC simply establishes that at the instant when safety is reached, $\bar{t}$, the value of staying one more instant at risk ($\mathcal{H}^F(\bar{t})$) should be equal to the value of marginally bringing safety forward ($-\partial\left(e^{-(r+\pi)\bar{t}}V^F(\bar{S})\right)/\partial\bar{t}$). In the problem at hand the TVC reads:[13]

$$e^{-(r+\pi)\bar{t}}\frac{R\left(\bar{t}\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}-\lambda\left(\bar{t}\right)R\left(\bar{t}\right)=\left(r+\pi\right)e^{-(r+\pi)\bar{t}}\left(\frac{\Theta\bar{S}^{1-\frac{1}{\theta}}}{r^{\frac{1}{\theta}}}\right)$$

Using the necessary FOC with respect to R, to get the co-state λ as a function of the control R, the TVC can be rewritten as

$$R\left(\bar{t}\right)=\left(\frac{r+\pi}{r^{\frac{1}{\theta}}}\right)^{\frac{1}{1-\frac{1}{\theta}}}\theta\bar{S}=\left(1+\frac{\pi}{r}\right)^{\frac{1}{1-\frac{1}{\theta}}}\theta r\bar{S} \tag{5.2.8}$$

Definition 5.3. Let $x>0$ be such that if $l\left(\bar{t}\right)=0$, then $R\left(\bar{t}\right)\equiv x\theta r\bar{S}$.

According to this definition, $x-1$ is the adjustment in R needed at time $\bar{t}$ for $R\left(\bar{t}\right)$ to coincide with the social optimum (risk-free) level, $\theta r\bar{S}$, as a proportion of the latter. Using (5.2.8) the optimal adjustment in the presence of expropriation risk is

$$x^{*}=\left(1+\frac{\pi}{r}\right)^{\frac{1}{1-\frac{1}{\theta}}}$$

Deriving x^* from the TVC, is in fact equivalent to explicitly solving for the optimal adjustment in extraction at $\bar{t}$ (see Appendix 5.B.2 for this alternative derivation). Note that with $\theta>1$ the optimal x is strictly larger than 1 and it is increasing in π/r. Thus, whenever the risk of expropriation is latent, the owner finds it optimal to extract in such a way that in a path without a political regime shift, extraction must to be discretely downsized at $\bar{t}$. The size of this adjustment is increasing in the relative additional discount imposed by the risk of expropriation, π/r.

Note further that with $\theta>1$, x^* is decreasing in θ. Intuitively, how fast $\bar{S}$ is reached depends on how steep and how high is the extraction path. As θ increases the extraction path becomes steeper; thus, a high θ directly implies a low $\bar{t}$, and therefore the gain of inducing even more over-extraction through the jump x is lower. In other words, the steeper the extraction path the lower the marginal effect of x on $\bar{t}$. Using x^*, the maximized NPV of a given stock of the resource $S\left(t\right)$ is

$$V^F\left(S\left(t\right)\right)=\begin{cases}\dfrac{\Theta\left(S(t)-\bar{S}+\left(1+\frac{\pi}{r}\right)^{\frac{1}{\theta-1}}\bar{S}\right)}{\left((S(t)-\bar{S})(r+\pi)+\left(1+\frac{\pi}{r}\right)^{\frac{\theta}{\theta-1}}r\bar{S}\right)^{\frac{1}{\theta}}} & \text{if } S\left(t\right)>\bar{S}\\ \Theta r^{-\frac{1}{\theta}}S\left(t\right)^{1-\frac{1}{\theta}} & \text{otherwise}\end{cases} \tag{5.2.9}$$

[13] For other applications of dynamic optimization problems with regime shifts, in resource economics, see for instance Polasky, de Zeeuw, and Wagener (2011); de Zeeuw and Zemel (2012). The latter provides an explicit application of this TVC.

Lemma 5.1. *$V^F(S(t))$ is an increasing and continuous function of the remaining stock $S(t)$.*

Proof: See Appendix 5.A.1.

Furthermore, as shown by proposition 5.3 below, $V^F(S(t))$ is increasing in χ, and therefore it is increasing in $\bar{S}$. Now, it is possible to fully characterize the extraction path as a function of $S(t)$ and parameters. By combining (5.2.7), (5.2.8), and the cumulative extraction between t and $\tilde{t}$ one gets

$$R(t) = \begin{cases} \theta\left((r+\pi)\left(S(t)-\bar{S}\right)+x^{*}r\bar{S}\right) \text{ if } S(t) > \bar{S} \\ \theta r S(t) \text{ otherwise} \end{cases} \tag{5.2.10}$$

Note that as $x^{*}r > r+\pi$, when the threat of expropriation is still latent, the rate of depletion (i.e., R/S) in (5.2.10) is higher than the one obtained under fully exogenous risk of expropriation (i.e., $R(t)/S(t) > r+\pi$ if $\bar{S} > 0$); furthermore, this rate increases over time as the resource gets depleted. Overall, giving the owner the chance to protect her property rights over the resource by extracting fast enough exacerbates the over-extraction problem.

Proposition 5.1. *Under endogenous risk of expropriation there are two sources of distortion in the extraction path: 1. the exogenous risk of a regime shift (π); and, 2. the possibility of fully mitigating the risk of expropriation in finite time by reaching a safe stock of the resource. Both sources induce over-extraction of the resource when compared to the social optimum.*

Proof: See Appendix 5.A.2.

As summarized by proposition 5.1, the endogenous risk of expropriation has two reinforcing effects that lead to over-extraction. First, the hazard of a regime shift increases F's effective discount rate, and this increases the "baseline" depletion rate from θr to $\theta(r+\pi)$. Second, it pushes the owner to further accelerate depletion as this reduces the time it takes to reach the safety threshold $\bar{S}$. That is, the fact that the risk of expropriation can be endogenously mitigated, by running down the stock, exacerbates the over-extraction problem: depletion is even faster than under an exogenous risk of expropriation. As mentioned above, in this framework, the cost of expropriation (χ) and the risk of regime shift (π) is the measure of how well defined property rights are (i.e., how resilient are property rights to the identity of the group in power). In particular, $\chi = \infty$ is equivalent to perfect protection of property rights, while fully no protection is implied by $\chi = 0$. Interestingly,

Proposition 5.2. *1. When the risk of expropriation is still latent, a marginal increase in property rights protection (i.e., an increase in χ), exacerbates the over-extraction problem. 2. Only a sufficiently high (discrete) improvement in protection, i.e., an increase in χ such that*

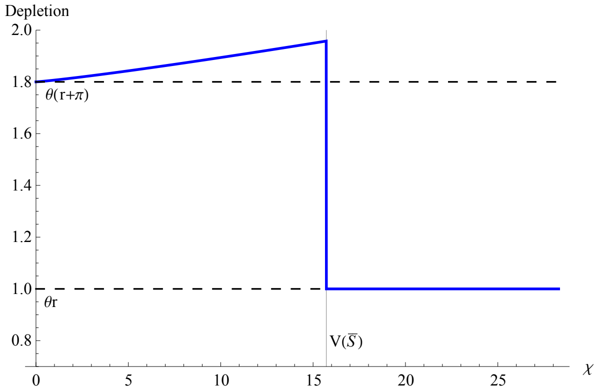

Figure 5.2.1: Depletion and cost of expropriation (χ)

$\bar{S} \geq S(t)$, leads to a lower depletion R/S. In fact, such a piecewise improvement brings R/S down to the socially optimal level θr.

Proof: See Appendix 5.A.2.

This proposition has a striking implication: if property rights are sufficiently weak, a gradual improvement in the protection of property rights leads to more over-extraction. This "perverse" effect of improving the strength of property rights follows from the interaction between the two sources of distortion: the exogenous risk of a regime shift and the possibility of endogenously avoiding expropriation. Proposition 5.2 is illustrated in figure 5.2.1:[14] when $\chi = 0$ (i.e., in a world with completely unprotected property rights) R/S is equal to $\theta(r + \pi)$ as represented by the upper horizontal line, which constitutes the baseline depletion while at risk; initially the depletion rate increases with χ, up to the point at which the NEC is met with equality (i.e., when χ is such that $\bar{S} = S(t)$), as represented by the vertical line. Note that if one interprets χ—instead of $1/\pi$—as "ownership security", these results are consistent with the (puzzling) evidence of Bohn and Deacon (2000) on the positive relationship between extraction and ownership security. In the current framework, this positive association is not due to complementary investment decisions, instead it is the outcome of using over-extraction as protection tool against expropriation. Once the NEC is fulfilled the risk of expropriation is no longer a concern; thus, R/S jumps down to the optimal level θr (depicted by the lower horizontal line), and it does not change with further improvements in property rights protection. The flip side of proposition 5.2 entails that over-extraction intensifies as $S(t)$ approaches $\bar{S}$:

Corollary 5.1. *For a given χ, such that $S_0 > \bar{S}$, in a path without a political regime shift*

[14]In this figure $S(t) = 20$, and the values of the parameters are $r = .125$, $\pi = .1$, and $\theta = 8$.

the depletion rate (R/S) increases over time as the resource gets depleted while the resource remains at risk of being expropriated; once the safety threshold $\bar{S}$ is reached, the depletion rate jumps down to the optimal level θr at remains at that level.

Proof. Follows directly from equation (5.2.10) and $x^* r > r + \pi$. □

That depletion is an increasing function of $\bar{S}$ (χ) is an outcome of the expropriation risk being mitigable. If the owner would be unable to mitigate the risk of expropriation, say if $\chi = \bar{S} = 0$, the rate of depletion would remain constant at $\theta\,(r + \pi)$, because of the higher effective discount rate. With an endogenous risk of expropriation however, the owner can fully mitigate the risk by reaching $\bar{S}$. Mitigation comes at the cost of distorting the extraction path. Taking into account that the owner's effective discount rate while at risk is $r + \pi$, the further away R/S is from $\theta\,(r + \pi)$ the more distorted the path is from the owner's point of view; nevertheless, while at risk, the baseline level to evaluate the magnitude of the distortion (i.e., $\theta\,(r + \pi)$), and so the (marginal) cost of distorting the extraction path is independent of time. Yet, the (expected) marginal benefit of running down the stock, which is reaching safety, does depend on time. Specifically, at time $t < \bar{t}$, the expected gain of marginally reducing the time at risk (marginally reducing $\bar{t} - t$) is: $(r + \pi)\, e^{-(r+\pi)(\bar{t}-t)}\, V^F\,(\bar{S})$, which is clearly decreasing in $\bar{t} - t$. That is, the closer one is to the safety threshold (i.e., the smaller $\bar{t} - t$), the more there is to gain (in expected value) from speeding-up extraction. In other words, the closer to safety the more likely is the over-extraction strategy to pay-off. This is the case because, conditional on surviving until t, the probability of a regime shift before reaching $\bar{S}$ is declining in t. Figure 5.2.2 illustrates corollary 5.1. In this figure, again the upper horizontal line is the depletion rate under exogenous risk of expropriation ($\theta\,(r + \pi)$), the lower horizontal line is the socially optimal depletion rate (θr), and the vertical line indicates the safety threshold $\bar{S}$.

Regarding the value of the resource, despite the fact that an improvement in property rights exacerbates the over-extraction problem, from the owner's perspective stronger property rights unambiguously increase the value of the resource. While it is true that an improvement in the protection of property rights induces a higher distortion in the depletion rate, this improvement also leads a shorter time at risk (i.e., a shorter time under a distorted extraction), due both to the increase in $\bar{S}$ and the acceleration of depletion. In the end, the shorter time at risk more than compensates (in expected value) for the efficiency loss from over-exploiting the resource. In sum, when it comes to the value of the resource

Proposition 5.3. *Whenever the risk of expropriation is still latent, and for a given stock of the resource, a marginal increase in property rights protection (i.e., an increase in χ),*

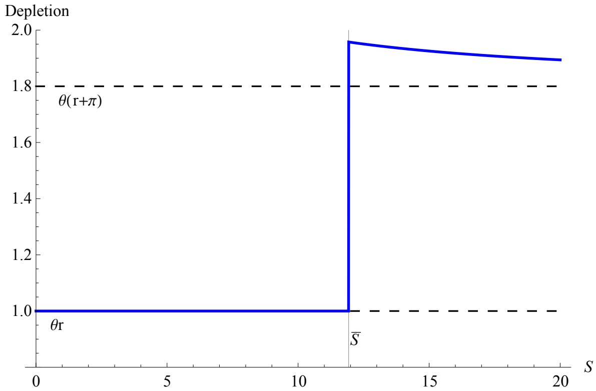

Figure 5.2.2: Depletion and remaining stock (S)

unambiguously increases the owner's expected NPV of the resource.

Proof: See Appendix 5.A.2.

5.3 Installed Capacity

Extracting and commercializing non-renewable natural resources typically requires complementary capital investments. In the case of oil for instance, extraction tends to be constrained by in-site storage and demulsification capacities, which are needed to prepare the crude before shipping it through a pipeline. Capital investments in these types of facilities can be then interpreted as investments in extraction capacity. Due to the need for these complementary investments, oil extraction from an individual well, or field, occurs in three distinct phases: build-up, plateau, and decline. The build-up period is time during which the extraction capacity of the well is installed. During the plateau phase, extraction is constrained by the well's extraction capacity and remains constant. Finally, during the decline phase, extraction smoothly decreases from the plateau level to the abandonment level, i.e., the minimum economically feasible extraction; 0 in the current setup. Taking this into account, and building on the framework developed above, this section incorporates an endogenous extraction capacity as a relevant element of the resource management problem.

To incorporate this element, it assumed that in order to be able to extract at least K units of the resource at any time, an initial investment of $c(K)$ is required. This initial investment summarizes the build-up phase, where $c(K)$ is the net value of all the investment flows necessary to build-up capacity K, calculated at the time when the capacity is fully available.[15] The installed extraction capacity of the well is then fixed over time and it determines the the maximum level that can be extracted at any t, this constraint will be binding over some interval of time akin to the plateau phase. Eventually, as the resource gets depleted and the desired extraction goes down, the capacity constraint will stop being binding, and extraction will decline over time.

This section explores how the two endogenous elements concerning the resource management, extraction and extraction capacity, are affected by the political economy uncertainty that creates to an endogenous risk of expropriation. In order to have an appropriate benchmark for this analysis, the case with no political risk (i.e., $\pi = 0$) is first presented. Then, the case with political risk is developed. The analysis under political risk first requires to obtain the owner's expected NPV of the resource, as a function of S and K. With that one can obtain the owner's preferred K under different institutional environments, i.e., different levels of χ and π and compare it to the with the "no political risk" benchmark.

5.3.1 No political risk

The case without expropriation risk is a standard exercise (e.g., Ghoddusi, 2010); yet, it constitutes an useful benchmark for analysis of the case with political risk. In fact, following definition 5.1 the results derived in this section constitute the social optimum in the presence of capacity constraints. For the moment, it is assumed that installing capacity is costless, i.e., $c(K) = 0$. In the absence of political risk, the NPV of owning the resource with an installed capacity K is given by

$$V_{NR}(S_0, K) = \max_{\{R(t), K\}} \int_0^T \frac{K^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-rt} dt + e^{-rT} \int_T^\infty \frac{\left(R(T)\, e^{-\theta r(t-T)}\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-rt} dt$$

where the subscript NR stands for "no risk" of expropriation. In this formulation, T refers to instant at which the capacity constraint is no longer binding, that is, the end of the plateau phase. T is reached when, given the remaining stock ($S(T) = S_0 - KT$), the desired extraction is exactly equal to K. We know that this is the case because in the absence of political risk and without considering the capacity constraint, the optimal extraction path implies a declining extraction. Therefore, once the capacity constraint becomes irrelevant it remains so. The relationship between K and T is given by

[15] The implicit assumption here is that during the build-up phase no extraction takes place, or alternatively that $c(K)$ is the cost of building up capacity net of the revenues from extraction during the build-up phase.

$$K = \theta r \left(S_0 - KT\right) = R\left(T\right)$$

or,

$$T = \max\left\{0,\ \frac{S_0}{K} - \frac{1}{\theta r}\right\}$$

Evidently a higher installed capacity, K, reduces the duration of the plateau phase, T; moreover, for any K greater than or equal to $\theta r S_0$, the capacity constraint is never binding and extraction will be in permanent decline over time. Using this, the NPV of the remaining stock in the ground is

$$V\left(S_0, K\right) = \frac{1}{\left(1-\frac{1}{\theta}\right) r}\left(K^{1-\frac{1}{\theta}}\left(1-e^{-rT}\right) + e^{-rT}\frac{R\left(T\right)^{1-\frac{1}{\theta}}}{\theta}\right)$$

Thus,

$$V_{NR}\left(S_0, K\right) = \begin{cases} \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)r}\left(1-e^{-rT}\left(1-\frac{1}{\theta}\right)\right) & \text{if } K \leq r\theta S_0 \\ \Theta\frac{S_0^{1-\frac{1}{\theta}}}{r^{\frac{1}{\theta}}} & \text{if } K > r\theta S_0 \end{cases} \tag{5.3.1}$$

By differentiating V_{NR} with respect to K one can obtain the effect of marginally increasing the installed capacity in NPV

$$\begin{aligned}\frac{dV_{NR}}{dK} &= \frac{K^{-\frac{1}{\theta}}}{r}\left(1-e^{-rT}\left(1-\frac{1}{\theta}\right)\right) - \frac{K^{1-\frac{1}{\theta}}}{r}\left(re^{-rT}\left(\frac{S_0}{K^2}\right)\right) \\ &= \frac{K^{-\frac{1}{\theta}}}{r}\left(1-e^{-rT}\left(1+\frac{rS_0}{K}-\frac{1}{\theta}\right)\right)\end{aligned}$$

which from T as function of K can be rewritten as

$$\frac{dV_{NR}}{dK} = \frac{K^{-\frac{1}{\theta}}}{r}\left(1-\frac{1+rT}{e^{rT}}\right) \geq 0$$

an expression that is strictly positive if $T > 0$, i.e., if the constraint is binding.[16] Next to the being increasing in K, V_{NR} is strictly concave

$$\frac{d^2V_{NR}}{dK^2} = \frac{-1}{\theta}\frac{K^{-\frac{1}{\theta}-1}}{r}\left(1-\frac{1+rT}{e^{rT}}\right) + \frac{K^{-\frac{1}{\theta}}}{r}\left(\frac{r^2T}{e^{rT}}\frac{dT}{dK}\right) < 0$$

[16] The sign follows from observing that $\left(1+b\right)e^{-b}$ reaches its global maximum when $b = 0$, and this maximum is equal to 1. This expression is therefore strictly decreasing in b if $b > 0$.

The NPV thus increases at a decreasing rate in K, reaching a maximum at $K = \theta r S_0$ (i.e $T = 0$). Once the capacity is equal to $\theta r S_0$ further investments in capacity have no impact on the NPV of the resource. Now, assume that installing capacity is costly. Specifically, in order to install capacity K the resource owner must incur a cost $c(K)$ with $c' > 0$, $c'' \geq 0$, and $c(0) = 0$. Then, the optimal level of installed capacity in the absence of political risk is

$$K^*_{NR} = \begin{cases} \theta r S_0 & \text{if } V'_K(S_0, \theta r S_0) \geq c'(\theta r S_0) \\ K_{int} & \text{otherwise} \end{cases} \tag{5.3.2}$$

where the interior solution K_{int} is implicitly given by

$$\frac{K_{int}^{-\frac{1}{\theta}}}{r}\left(1 - \frac{1 + rT_{int}}{e^{rT_{int}}}\right) = c'(K_{int})$$

Note that because of the assumed properties of $c(K)$, and given that $V(S_0, K)$ is continuous, increasing, and strictly concave in K, there is a unique K_{int} solving the condition above.

5.3.2 Political risk

The endogenous risk of expropriation creates a trade-off in the choice of the installed capacity, which may distort the owner's preferred level of K. This trade-off emerges from the possibility to mitigate the expropriation risk by reducing the value of the resource. On the one hand, a higher installed capacity allows for running down the stock at a faster pace, and so reaching the safety threshold $\bar{S}$ in less time. On the other hand, a lower installed capacity limits the ability of the challenger to extract the resource in case she captures it, so it reduces the challenger's valuation of the resource, and increases the minimum size of the stock that the challenger finds worthy to seize. Which of these two forces dominates depends, among other things, on the exogenous risk of a political regime shift and on how costly it is for the challenger to build up capacity on top of the owner's initial investment. For simplicity, I assume that once the capacity of a well is installed, no further investments are possible; however, the results of the model remain qualitatively unchanged if further investments are possible, and $c(K)$ is strictly increasing in K.[17]

[17] That is, the results follow through as long as the challenger's valuation of the well is non-increasing in K and strictly decreasing over a certain range of K, for a given remaining stock.

5.3.2.1 The Challenger's problem and the *No Expropriation Constraint*

The problem of the C depends on whether the capacity constraint is binding or not. In particular, we know that at time t the challenger decides not to expropriate the resource if

$$V\left(S\left(t\right), K\right) \leq \chi$$

The exact form of the NEC, and K's relevance for it, depend on whether the challenger is constrained by the extraction capacity at time t. Specifically,

- If the capacity constraint is irrelevant for the challenger ($K \geq \theta r S\left(t\right)$) the NEC remains as in (5.2.5)

$$\Theta \frac{S\left(t\right)^{1-\frac{1}{\theta}}}{r^{\frac{1}{\theta}}} \leq \chi \longleftrightarrow S\left(t\right) \leq \bar{S} \tag{5.3.3}$$

- If the capacity constraint is binding at t ($K < \theta r S\left(t\right)$), the NEC can be rewritten as an upper bound for K; and this upper bound is a decreasing function of S

$$\frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right) r}\left(1 - e^{-r\left(\frac{S(t)}{K}-\frac{1}{\theta r}\right)}\left(1-\frac{1}{\theta}\right)\right) \leq \chi \longleftrightarrow K \leq \bar{K}\left(S\left(t\right)\right) \tag{5.3.4}$$

When the capacity constraint is binding, the value of the resource is strictly increasing in S and K. Therefore, the upper bound $\bar{K}\left(S\left(t\right)\right)$—which is the iso-value curve at which the NEC is exactly met—is strictly decreasing in $S\left(t\right)$; the intuition for this is straightforward: if the capacity constraint is binding, both $S\left(t\right)$ and K enter positively in the challenger's valuation of the resource; thus, if the remaining stock of the resource is large, the installed capacity needs to be low to fulfill the NEC. This means that if, from the challenger's view point, the extraction capacity is binding, both extraction and extraction capacity are available tools in the owner's strategy to protect the resource against expropriation. evidently, the strategic role of K dissipates when the challenger is no longer constrained by the installed capacity. From the challenger's unconstrained extraction path (5.2.2), one obtains that $\bar{K}\left(\bar{S}\right) = \theta r \bar{S}$, and therefore $\bar{K}\left(S\left(t\right)\right) < \theta r S\left(t\right)$ for any $S\left(t\right) > \bar{S}$.

5.3.2.2 The Owner's problem

In the presence of an endogenous capacity constraint, the question is whether the owner uses a low or a high K to mitigate the risk of expropriation. To find whether the owner is willing to choose a sufficiently low K, i.e., $K = \bar{K}(S)$, in equilibrium, one needs to construct the owner's expected NPV as a function of K, $S(t)$, and parameters. A systematic way to this is by deriving the owner's expected NPV over three intervals different intervals of K. These intervals are the defined by a combination of the strategic (fulfilling the NEC) and the restricting (limiting extraction) roles of K:

1. K serves to fulfill the NEC for $S(t) \geq \bar{S}$: $K \leq \theta r \bar{S}$.

2. K does not serve to fulfill the NEC, yet it constrains the owner's extraction: $K \in (\theta r \bar{S},\, x^* \theta r \bar{S})$.

3. K is irrelevant as a capacity constraint or protection tool: $K \geq x^* \theta r \bar{S}$.

1. $K \leq \bar{K}(\bar{S}) = \theta r \bar{S}$ An installed capacity in this interval presumes that the owner uses a low extraction capacity as a tool to fulfill the NEC. That is, the risk of expropriation will be fully mitigated before reaching the safety threshold $\bar{S}$. If installing capacity is costless, $c(K) = 0$, the owner has no incentives to choose K below $\bar{K}(S_0)$. If $K = \bar{K}(S_0)$, the extraction capacity is low enough to deter the challenger from expropriating the resource at the highest possible remaining level of the stock, S_0; choosing a lower level of K would further restrict the owner's capacity to extract without generating any gains in terms of protection against expropriation. Thus, choosing $K < \bar{K}(S_0)$ is only reasonable in the presence of installation costs such that $K^*_{NR} < \bar{K}(S_0)$ holds. To get the owner's valuation for a K in this first range, it is useful to define the instant at which the NEC is first fulfilled

Definition 5.4. t_1 is such that: a) if $K > \bar{K}(S_0)$ and $l(t_1) = 0$, then $K = \bar{K}(S(t_1))$; b) if $K \leq \bar{K}(S_0)$, then $t_1 = 0$.

So, in the absence of a political regime shift, t_1 is the instant in which the NEC is first met. Part a) of the definition establishes that if $K > \bar{K}(S_0)$, there is a non-empty time interval $[0, t_1)$ during which, given K, the remaining stock of the resource is too high for the NEC to hold; thus, before t_1 the threat of expropriation remains latent. After t_1 the stock of the resource, given K, is low enough to deter the challenger from expropriating. Note however that the capacity constraint remains binding after t_1.[18] Part b) of definition 5.4, implies that if K is below $\bar{K}(S_0)$, the challenger never finds expropriation profitable; hence, the resource is never at risk of being expropriated.

[18] After t_1 the resource is safe from expropriation, thus the owner's preferred extraction rate is $R(t_1) = \theta r S(t_1)$. As $K < \theta r \bar{S} < \theta r S(t_1)$, after t_1 the capacity constrain remains binding for an interval of length T such that: $\theta r (S(t_1) - KT) = K$.

Using the definition of t_1, the owner's expected NPV for a K in this interval is

$$V_1^F(K, S_0) = \int_0^{t_1} \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)} e^{-(r+\pi)\tau} d\tau + e^{-(r+\pi)t_1} V_{NR}^F(K, S(t_1)) - c(K)$$

The integral between 0 and t_1 is the sum of all the discounted revenue flows, taking into account that the capacity constraint is binding and the threat of expropriation is latent. The former is true because in the presence of expropriation risk the owner's preferred extraction is $> \theta r S(t_1) > K$, and the latter follows from the definition of t_1. $V_{NR}^F(K, S(t_1))$ stands for the value of the resource free of expropriation risk (see equation 5.3.1); when discounting this value one needs to take into account the probability of no regime shifts before t_1, $e^{-\pi t_1}$.

In case $K \leq \bar{K}(S_0)$ the resource is always safe ($t_1 = 0$) and therefore $V_1^F(K, S_0)$ reduces to $V_{NR}(K, S_0)$.[19] If $K > \bar{K}(S_0)$, we know that the resource is at risk for some non-empty interval of time $t_1 > 0$; moreover, because both the owner and the challenger have access to the same extraction technology, their expropriation-risk-free valuation of the resource is the same: $V_{NR}^F(K, S(t_1)) = V_{NR}^C(K, S(t_1)) = V_{NR}(S_0, K)$. Using (5.3.4); this symmetry entails that when expropriation is first fully mitigated, the owner's valuation is exactly equal to the cost of expropriation: $V_{NR}^F(\bar{K}(S(t_1)), S(t_1)) = \chi$. Using this, the owner's expected NPV can be rewritten as

$$V_1^F(S_0, K, t_1) = \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-(r+\pi)t_1}\right) + e^{-(r+\pi)t_1}\chi - c(K)$$

As mentioned above, given that in this first rage K is bounded below $\theta r \bar{S}$ and that in the absence of a capacity constraint F's preferred level of extraction is $> \theta r S(t)$ for any $S(t) > \bar{S}$, the capacity constraint is necessarily binding between 0 and t_1, which means that

$$t_1 = \frac{S_0 - S(t_1)}{K}$$

Moreover, from $V_{NR}^F(K, S(t_1)) = \chi$ one can obtain $S(t_1)$ as a function of K and parameters

[19] Note that if $K \leq \bar{K}(S_0)$ then necessarily $V_{NR}(K, S_0) \leq \chi$, with strict inequality if K is below $\bar{K}(S_0)$.

$$r\frac{S(t_1)}{K} = \frac{1}{\theta} - \ln\left(\frac{1}{\left(1-\frac{1}{\theta}\right)} - \frac{r\chi}{K^{1-\frac{1}{\theta}}}\right)$$

Combining the last two expressions, the owner's expected NPV can be expressed as a function of the initial stock S_0, the installed capacity K, and parameters:

$$V_1^F(S_0, K) = \begin{cases} \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)} + e^{-(r+\pi)\left(\frac{S_0}{K}-\frac{1}{\theta r}\right)} \frac{\left(\chi - \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)}\right)}{\left(\frac{1}{1-\frac{1}{\theta}} - \frac{r\chi}{K^{1-\frac{1}{\theta}}}\right)^{1+\frac{\pi}{r}}} - c(K) \text{ if } K > \bar{K}(S_0) \\ V_{NR}(S_0, K) - c(K) \text{ if } K \leq \bar{K}(S_0) \end{cases} \tag{5.3.5}$$

2. $x^*\theta r\bar{S} > K > \theta r\bar{S}$ In this second interval, even though K can restrict the challenger's extraction (it is possible that $K < \theta r S(t)$ for some t) it is too high to deter C from expropriating the resource; that is, in this interval K has no strategic role, and so in case of a regime shift the challenger expropriates the resource if at the time of the shift $S(t) > \bar{S}$. However, K is relevant to determine the speed of extraction; while at risk the owner's preferred extraction is $\geq x^*\theta r\bar{S}$, therefore in this second interval the capacity constraint is certainly binding for as long as the resource is at risk (and may still be binding in case of expropriation). Again, defining the instant at which the NEC is first fulfilled is an useful step to get the owner's valuation

Definition 5.5. t_2 is such that if $l(t_2) = 0$, and $K \in (\theta r\bar{S}, x^*\theta r\bar{S})$, then $S(t_2) = \bar{S}$; thus, $t_2 \equiv (S_0 - \bar{S}) K^{-1} > t_1$.

Because K has no strategic role in this interval, the capacity constraint is binding and the risk of expropriation is latent between 0 and t_2, given $l(t_2) = 0$. After the safety threshold $\bar{S}$ is reached at t_2, the capacity constraint becomes irrelevant. In this case, the owner's expected NPV is given by

$$V_2^F(S_0, K, t_2) = \int_0^{t_2} \frac{K^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-(r+\pi)\tau} d\tau + e^{-(r+\pi)t_2} V^F(S(t_2)) - c(K)$$

The integral between 0 and t_2 is the expected sum of flows while the capacity constraint is binding and the risk of expropriation is latent. The second term in V_2^F does not depend on K because once $S \leq \bar{S}$, the capacity constraint becomes irrelevant from the owner's point of view. From the definition of t_2, and the symmetry between F and C: $V^F(S(t_2)) = V_{NR}^F(K, \bar{S})\big|_{K>\theta r\bar{S}} = \chi$.

Note that if the installing extraction capacity is costless, the owner has no incentives to choose a K in $(\theta r\bar{S},\, x^*\theta r\bar{S})$. A $K \in (\theta r\bar{S},\, x^*\theta r\bar{S})$ restricts the extraction capacity of the owner, without producing any gains in terms of protection against expropriation, i.e., the NEC is not met unless $S(t) \leq \bar{S}$. This is the case because in this interval K is bounded to be above, $\theta r\bar{S}$, which is the maximum K that allows for the NEC to be fulfilled at some $S(t) > \bar{S}$. Therefore, with costless installation, any K in this interval is strictly dominated by a higher K. A higher K reduces the time at risk, which is obviously beneficial to the owner, without any cost in terms increasing the incentives to capture the resource against expropriation. Using the definition of t_2, the owner's expected NPV when $K \in (\theta r\bar{S},\, x^*\theta r\bar{S})$ can be rewritten as function of S_0 and K solely

$$V_2^F(S_0, K) = \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)}\left(1 - e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\right) + e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\chi - c(K) \quad (5.3.6)$$

3. $K \geq x^*\theta r\bar{S} > \bar{K}(\bar{S})$ In this last segment, K is high enough for the owner to be unconstrained during, at least during some part of, the time at expropriation risk. Again, as in the previous case, K in this interval is too high to be relevant for the challenger's decision of whether to expropriate (i.e., if $S(t) > \bar{S}$ then $K > \bar{K}(S(t))$); consequently, the resource is expropriated unless $S(t) \leq \bar{S}$. In this case the instant at which the NEC is first met is $\bar{t}$ as in definition 5.2 in section 5.2; that is, $\bar{t}$ is the precise instant at which the remaining stock of the resource reaches the safety threshold: $S(\bar{t}) = \bar{S}$. Next to $\bar{t}$ it turns out to be useful to define the instant at which the capacity constraint is no longer binding

Definition 5.6. Let t_3 be such that if $l(t_3) = 0$, then $K = \theta\left((r+\pi)(S(t_3) - \bar{S}) + x^* r\bar{S}\right)$.

According to this definition, at t_3 the extraction capacity K is equal to the owner's preferred extraction level under expropriation risk (see 5.2.10). Using the definitions of $\bar{t}$ and t_3, one can distinguish between three extraction regimes, provided $l(\bar{t}) = 0$: i) from 0 to t_3 the installed capacity constrains the owner's extraction, and the risk of expropriation is latent; ii) between t_3 and $\bar{t}$ the capacity constraint is no longer relevant, but the threat of expropriation remains latent;[20] and, iii) at $\bar{t}$ the risk of expropriation vanishes, and from that instant onwards the owner faces the (fully) unconstrained problem.

The owner's expected NPV in this case is given by

[20] After t_3 the owner behaves as in the problem with no capacity constraint in section 5.2, and thus the value after t_3 comes directly from (5.2.9).

$$V_3^F(S_0, K, t_3, \bar{t}) =$$
$$\int_0^{t_3} \frac{K^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-(r+\pi)\tau} d\tau + e^{-(r+\pi)t_3} \int_{t_3}^{\bar{t}} \frac{\left(R(t_3)e^{-\theta(r+\pi)(t-t_3)}\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-(r+\pi)\tau} d\tau$$
$$+e^{-(r+\pi)\bar{t}} V^F(\bar{S}) - c(K)$$

$$= \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)} \left[1 - e^{-(r+\pi)t_3}\right]$$
$$+e^{-(r+\pi)t_3} \frac{\Theta\left(S(t_3)-\bar{S}+\left(1+\frac{\pi}{r}\right)^{\frac{1}{\theta-1}} \bar{S}\right)}{\left((S(t_3)-\bar{S})(r+\pi)+\left(1+\frac{\pi}{r}\right)^{\frac{1}{1-\frac{1}{\theta}}} r\bar{S}\right)^{\frac{1}{\theta}}} - c(K) \tag{5.3.7}$$

As from 0 to t_3 the capacity constraint is binding and extraction is in the plateau phase, it is true that $t_3 = (S_0 - S(t_3)) K^{-1}$. Using this and definition 5.6 one can eliminate t_3 and $\bar{t}$ in V_3^F:[21]

$$V_3^F(S_0, K) = \begin{cases} \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-\frac{((r+\pi)S_0+(x^*r-r-\pi)\bar{S})}{K}+\frac{1}{\theta}} \left(1-\frac{1}{\theta}\right)\right) - c(K) & \text{if } K \leq K_3 \\ \frac{\Theta\left(S_0-\bar{S}+\left(1+\frac{\pi}{r}\right)^{\frac{1}{\theta-1}} \bar{S}\right)}{\left((S_0-\bar{S})(r+\pi)+\left(1+\frac{\pi}{r}\right)^{\frac{1}{1-\frac{1}{\theta}}} r\bar{S}\right)^{\frac{1}{\theta}}} - c(K) & \text{otherwise} \end{cases} \tag{5.3.8}$$

Where $K_3 \equiv \theta((r+\pi)(S_0 - \bar{S}) + x^* r\bar{S})$.

Th expression for $V_3^F(S_0, K)$ is fundamentally similar to the NPV in the absence of political risk (see equation 5.3.1). The main difference is, of course, the level of K above which $V_3^F + c(K)$ becomes independent of K. Specifically, in the presence of expropriation risk $V_3^F + c(K)$ is strictly increasing and concave in K up to K_3; above this level of K, $V_3^F + c(K)$ is constant in K.

This concludes how the owner's expected valuation looks like for any value of K, given S_0. Putting the three intervals together we have that, if $S_0 < \bar{S}$, the owner's expected NPV is

$$V^F(S_0, K) = \begin{cases} V_1^F(S_0, K) & \text{if } K \leq \theta r\bar{S} \\ V_2^F(S_0, K) & \text{if } K \in (\theta r\bar{S}, x^*\theta r\bar{S}) \\ V_3^F(S_0, K) & \text{otherwise} \end{cases} \tag{5.3.9}$$

In case $S_0 \leq \bar{S}$, then $V^F(S_0, K)$ is simply given by (5.3.1).

[21] See Appendix 5.B.3 for the details of this derivation.

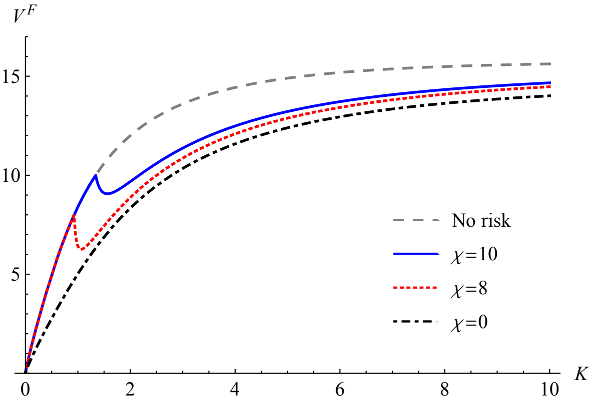

Figure 5.3.1: Expected resource value, extraction capacity, and cost of expropriation

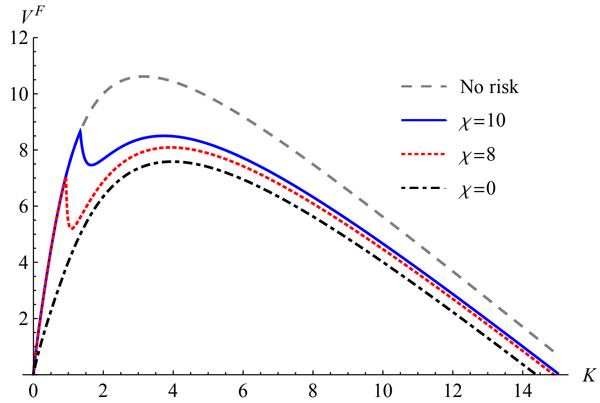

Figure 5.3.2: Expected resource value, extraction capacity, and cost of expropriation $[c(K) = K]$

Lemma 5.2. *$V^F(S_0, K)$ is continuous in K, for any $K \geq 0$, and has a continuous first derivative in K for any $K > \bar{K}(S_0)$.*

Proof: See Appendix 5.A.1.

With the explicit formulation of $V^F(S_0, K)$ it is then possible to proceed to answer if the owner prefers to under-invest in K to keep the value of the resource low and deter the challenger from expropriating it; or, if on the contrary the owner over-invests in K to run down the stock as fast as possible to avoid expropriation.

5.3.2.3 Cost of expropriation (χ) and installed capacity

Assuming $c(K) = 0$, in the absence of expropriation risk the owner's NPV is (5.3.1), with K^*_{NR} equal to any $K \geq \theta r S_0$. In the presence of expropriation risk, the owner's

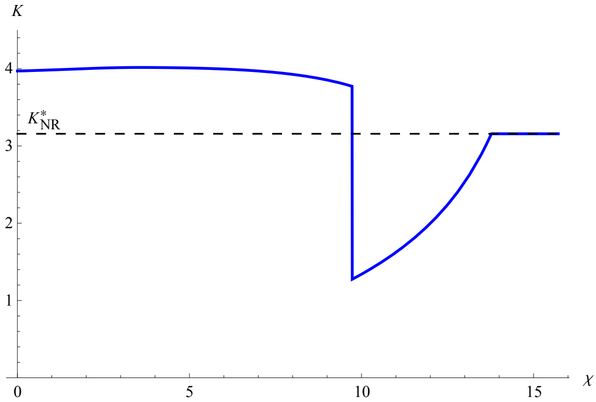

Figure 5.3.3: Owner's preferred extraction capacity [$c(K) = K$]

expected NPV, as a function of K, is (5.3.9). Figure 5.3.1 depicts the owner's valuation of the resource, as a function of K for a given $S_0 > \bar{S}$, under different regimes of property rights protection (i.e., different values of χ), under the assumption of costless installation of capacity (i.e., $c(K) = 0$).[22] The upper-most curve depicts the "no risk" benchmark, $\pi = 0$, while the lowest curve corresponds to the case with exogenous (non-mitgable) expropriation risk, $\chi = 0$. As depicted in the figure, the owner's valuation of the resource is increasing in the strength of the property rights protection, χ, for a given S_0.

As shown in the figure, for intermediate regimes of protection, the expected NPV exhibits a (fin-shaped) kink at $K = \bar{K}(S_0)$. When $K \leq \bar{K}(S_0)$ the length of the interval at expropriation risk is zero. That is why the curves with imperfect protection and the "no risk" curve overlap up to $\bar{K}(S_0)$. However, from the derivation of V_1^F we know that if K increases above $\bar{K}(S_0)$, the resource is immediately exposed to the risk of expropriation. The negative slope to the right of the kink, indicates that a marginal increase in K just above the level that allows for permanent protection against expropriation, $\bar{K}(S_0)$, has a detrimental effect on the owner's expected NPV. While a higher K has a direct positive effect on the owner's NPV through the relaxation of the capacity constraint, putting the resource at risk by marginally increasing K above $\bar{K}(S_0)$ generates a discrete increase in the effective discount rate from r to $r + \pi$, for the expected duration of the time at risk; this discrete increase, reduces the NPV of future flows. The negative impact of the higher discount rate when K increases just above $\bar{K}(S_0)$ dominates over the direct positive effect of a less demanding capacity constraint. Furthermore, with stronger institutions (higher χ)

[22] Figure 5.3.1 uses $S_0 = 20$, $r = .125$, $\theta = 8$, and $\pi = .1$ as fixed parameters. The "no risk" benchmark is obtained by setting $\pi = 0$.

$\bar{K}(S_0)$ shifts to the right and the negative slope to its right becomes less pronounced. This indicates that under stronger institutions, the net effect of putting the resource at risk is less detrimental. This result is related to one of the insights from the case with no capacity constraint: stronger property rights exacerbate the "need" for an accelerated extraction; this then increases the direct gain from relaxing the capacity constraint. Note that the kink is no longer present when the K is irrelevant for the expropriation risk, i.e., when there is no expropriation risk or when the risk is exogenous. The overall picture shows that under the assumption of costless installation, the owner strictly prefers $K = \theta\left((r+\pi)\left(S_0 - \bar{S}\right) + x^* r \bar{S}\right) > K^*_{NR}$ to any lower level of K.

When installation is costly, $K = \theta\left((r+\pi)\left(S_0 - \bar{S}\right) + x^* r \bar{S}\right)$ is not necessarily the owner's preferred level of K. In this framework this does occur not only because a high K is too costly to install, but also because K can play a role in deterring expropriation. In fact, when $c(K) > 0$, the relationship between the owner's preferred K and χ is not necessarily monotonic, as depicted in figure 5.3.1, where $c(K) = K$. The two extreme cases (i.e., no risk and exogenous risk) are hump-shaped, and have only one critical point, which in the case of no risk is K^*_{NR}. However, the owner's preferred K does not follow a monotonic pattern between the two extremes. As shown in figure 5.3.1, under intermediate protection of property rights, there are two potential candidates for a maximum: one with high installed capacity located at the top of the "hump"; and one with low installed capacity at the top of the "fin". The "hump" is located at the point at which the expected marginal benefit and the marginal cost of K equalize; while the "fin" occurs because of the discrete increase in the discount rate when K increases above $\bar{K}(S_0)$, as previously described. The figure indicates that when the protection of property rights is relatively weak (i.e., χ is relatively low), the owner prefers installs capacity above the social optimum K^*_{NR}. If the level of protection is sufficiently high, yet imperfect, the owner opts for using a limited extraction capacity to fully protect the resource against expropriation; that is, the owner's expected NPV is maximized at the "fin": $K = \bar{K}(S_0)$. Thus, when the protection of property rights is relatively strong and if $\bar{K}(S_0) < K^*_{NR}$, the owner under-invests in extraction capacity. The reason for change in investment strategy, from the "hump" to the "fin" can be explained by the relative cost of following each of these strategies. A low χ makes the under-investment strategy is too costly to pursue. Achieving full protection under a low χ requires a very restrictive extraction capacity (i.e., $\bar{K}(S_0)$ is low); this means that to avert expropriation, the well needs to be operated at a low capacity for a long period of time. On the contrary, when χ is high under-investing is not that costly; the maximum K that allows for full protection is relatively high. When the owner opts for under-investing in K, it is clear that the preferred level of K

is increasing in the strength of property rights ($\bar{K}(S_0)$ is increasing in χ), for as long as $\bar{K}(S_0) \leq K^*_{NR}$. However, when the owner opts for over-investing the relationship between χ and the owner's preferred K is potentially non-monotonic. Under $\bar{K}(S_0) \leq K^*_{NR}$, a maximum at the "hump" means that the resource is at risk, and so χ has two opposing effects on the incentives to install K. On the one hand, as shown in section 5.2 the owner's preferred depletion increases with χ, and so a higher χ increases the marginal benefits from installing capacity. On the other hand, a higher χ also reduces the time at risk, and so it reduces the length of time for which it actually pays-off to have an expanded capacity; this translates into a lower marginal benefit from further increasing K.

Figure 5.3.3 depicts the owner's preferred level of installed capacity as a function of χ. From it one can observe how χ affects the owner's choice of K through different channels. The horizontal line in the figure represents the owner's preferred K in the absence of political risk, K^*_{NR} (i.e., the social optimum level of K). As mentioned above, when the protection of property rights is weak, the owner opts for over-investing in installed capacity (i.e., owner's preferred K is above K^*_{NR}). While, for relatively high levels of χ, under-investment arises. As χ increases when the owner's preferred K is at the "fin", K approaches the social optimal level K^*_{NR}. If, given the cost of installing capacity, χ is high enough to make $\bar{K}(S_0) \geq K^*_{NR}$, the owner's preferred level of K becomes undistorted by the risk of expropriation, and consequently the level of K that maximizes the NPV does not depend χ; this is exactly why one observes a flat region in figure 5.3.3 for high levels of χ.[23]

5.3.2.4 Risk of political regime shift (π) and installed capacity

Moving to the other dimension of the expropriation risk, i.e., the risk of a political regime shift, figure 5.3.4 presents the owner's expected NPV as a function of K under different hazards of a political regime shift (i.e., different values of π).[24] In polities where shifts are more likely to occur (i.e., higher π) the valuation of the resource at risk is lower, for given values of S and K, because of the higher effective discount. As described above, when K increases just above $\bar{K}(S_0)$ the valuation of the resource decreases because the negative effect of putting the resource at risk dominates over the positive effect of a less demanding capacity constraint.

Contrary to what happens when χ changes, a change in π does not affect the position of the junction points of the value function. Formally, the intervals of K over which the owner's NPV is defined in (5.3.9) remain unchanged. However, as π increases, putting the resource at risk becomes costlier in expected value. Thus, in sce-

[23]For the particular set of parameters used here, the risk free level of K arises for $\chi < V(S_0) \approx 15.7$.
[24]Figure 5.3.4 uses $S_0 = 20$, $r = .125$, $\theta = 8$, and $\chi = 10$ as fixed parameters.

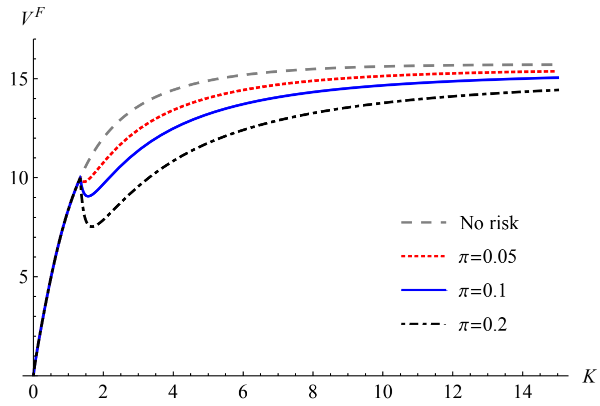

Figure 5.3.4: Expected resource value, extraction capacity, and political risk

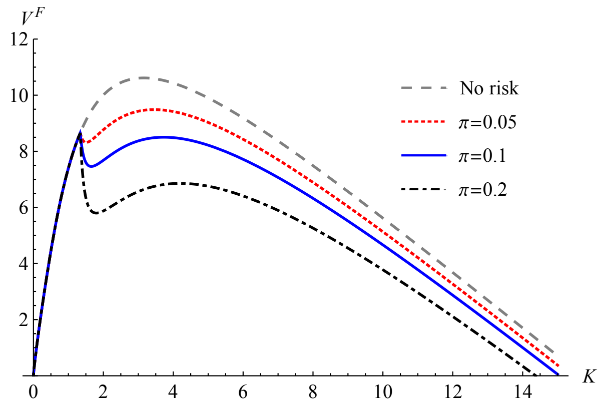

Figure 5.3.5: Expected resource value, extraction capacity, and political risk [$c(K) = K$]

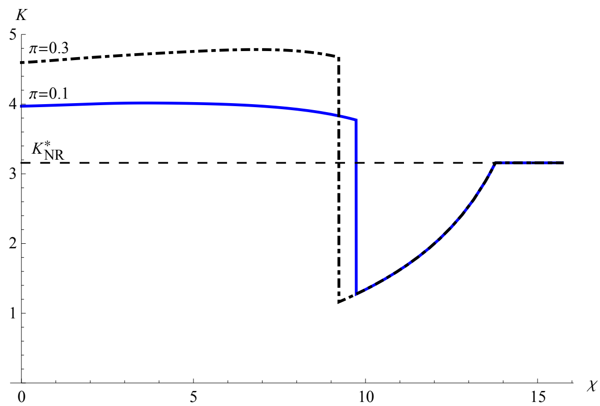

Figure 5.3.6: Owner's preferred extraction capacity [$c(K) = K$]

narios with relatively high political uncertainty, an increase in K just above $\bar{K}(S_0)$ has a more detrimental effect on the value of the resource because the discrete jump in the discount rate is higher. An immediate consequence of this property is that, given χ and $c(K) \neq 0$, a higher risk of political shift (higher π) increases the incentives of the owner to fully mitigate the risk of expropriation by choosing K equal to $\bar{K}(S_0)$; as depicted in figure 5.3.5 for high π the maximum is at the "fin". This means that, with endogenous installed capacity, higher uncertainty about the political environment results in a higher likelihood of the resource being initially under-exploited rather than over-exploited. Interestingly, the mechanism through which under-investment arises in this framework, and its exacerbation in the presence of more risk, is not the typical hold-up problem of investment in risky environments (e.g., Bohn & Deacon, 2000). Instead it follows from the strategic use of under-investment in extraction capacity as an alternative to fully mitigate the risk expropriation. And it is precisely because K plays a strategic role in the mitigation of the expropriation risk that over-investment in extraction capacity may occur in equilibrium even in the presence of political risk.

Overall, when it comes to installed capacity both over-investment and under-investment are possible outcomes. In other words, the resource owner may protect her property over the resource and the proceeds from its use, either by limiting the well's capacity or by accelerating the depletion of the resource. The numerical exercises in this section suggest that whether over-investment or under-investment arise in equilibrium depends on the specifics of the institutional environment. Figure 5.3.6 depicts the owner's preferred level of K as a function of χ for a low risk of a political regime shift (continuous curve, $\pi = 0.1$) and a high risk (dashed curve,$\pi = 0.3$). Irrespective of the level of π, under-investment is the owner's preferred strategy when the cost of expropriation is high and over-investment when it is relatively low. As mentioned above, this is the case because at high levels of χ, fully protecting the resource by under-investing is not too costly (i.e., $\bar{K}(S_0)$ is relatively high). Figure 5.3.6 also shows that whenever there is over-investment, it increases in π. After all, the reason for over-investing in K is to avoid losing the resource to the challenger by running it down fast enough; if a regime shift becomes more likely, then the motive behind over-investment is exacerbated. For intermediate levels of χ the risk of a political regime shift, π, is crucial to determine whether the owner under or over-investments. Specifically, when there is a higher risk of a regime shift, the range of χ over which under-investment arises is wider: the minimum χ under which under-investment is chosen decreases in π; when the environment is too risky in terms of a potential regime shift, full protection of the resource becomes more desirable, and so the case for under-investing is strengthened. Interestingly, from figure 5.3.6 one can also observe that when the owner opts for over-investing, a marginal increase in the protection of property rights may lead to an increase in K. Given that the social value of the resource (i.e., the value in the absence of expropriation risk) is concave in K, and that over-investment implies $K > K^*_{NR}$, further increases in K necessarily reduce the social value of the resource. In other words, when there is over-investment in extraction capacity, an improvement in the protection of property rights can reduce the social value of the resource by inducing further investment in installed capacity.

5.4 Discussion

The theory developed here focuses on the roles of the cost of expropriation and political uncertainty in the relationship between the legitimate owner of the resource and the potential expropriator. Nevertheless, the empirical and anecdotal evidence suggest that other elements, like prices and the technical knowledge by the potential expropriator, may be involved in the expropriation decision, and thus in the owner-expropriator strategic interactions (e.g., Guriev et al., 2011; Stroebel & van Benthem, 2013). This section discusses how, using the fundamental setup developed above, the model can be extended to incorporate some of these additional determinants of expropriations.

5.4.1 Price uncertainty

Prices, an important component of the valuation of natural resources, are driven by the international commodity markets and therefore are an exogenous source of uncertainty. Oil prices appear to be characterized by different regimes (i.e., regimes with high prices and regimes with low prices) and a very high persistence within these regimes (Ozdemir, Gokmenoglu, & Ekinci, 2013). Following this, price uncertainty can be incorporated in the model by assuming two different price regimes: a regime where the price of the resource is p_H and a regime where it is p_L, with $p_H > p_L$; moreover, in each of the two regimes there is an exogenous risk of shifting to the other, $\pi_p > 0$. The net flow of revenues from extraction at a particular point is then $\theta\,(\theta-1)^{-1}\,p\,(t)\,R\,(t)^{1-\frac{1}{\theta}}$, with $p\,(t) \in \{p_L, p_H\}$. Given the positive time discount, the value of the resource will be higher if the current price is p_H than if it is p_L: resource owners prefer to face high resource prices today. Again, let us assume that F is initially in control of the resource. Moreover, assume that $p_0 = p_L$, that in the absence of capacity constraints $V^C\,(S_0, p_0 = p_H) > \chi > V^C\,(S_0, p_0 = p_L)$, and for simplicity that the economy is permanently in C's regime. These assumptions translate into F initially retaining the property rights over the resource, but faces a risk of expropriation depending on the price regime. That is, under the initial price regime, p_L, C does not find it profitable to confiscate the resource; however, C would seize the resource if, given $S = S_0$, the price would be p_H. Just like in the theory developed above, the set of assumptions of this "price uncertainty setup", implies that there exist a $\bar{S}$ and a $\bar{K}(S_0)$, such that if either the stock is depleted below $\bar{S}$ (with $V^C(\bar{S}, p_{\bar{t}} = p_H) = \chi$), or the investment in extraction capacity is set at $\bar{K}(S_0)$ (with $V^C(S_0, \bar{K}(S_0), p_0 = p_H) = \chi$), the risk of expropriation is endogenously mitigated. In this alternative formulation of the model, international commodity markets, instead of the domestic political regime, are the exogenous driver of the expropriation risk. Of course, one can allow for these two sources of risk (prices and politics) to co-exist by for example having a 2-by-2 regime space combining political and price regimes. Interestingly in this alternative formulation, depending on whether the resource is at risk, the risk of shifting from the p_L to the p_H regime (π_p) will have opposite effects on the owner's effective discount (patience). If the resource is at risk of expropriation (i.e., if $V^C(S(t), K, p(t) = p_H) > \chi$), shifting from p_L to p_H entails expropriation and it is therefore "bad news" for the owner. In this case, the owner's continuation value of a price regime shift is zero, and consequently, the risk of a regime shift (i.e., the risk of losing the resource) makes the owner effectively more impatient. On the contrary, if the resource is not at risk (i.e., if $V^C(S(t), K, p(t) = p_H) \leq \chi$), shifting from p_L to p_H is "good news" for the owner. A regime shift implies a higher revenue per extracted unit. When the resource is not at risk, the risk of shifting from p_L to p_H makes the owner effectively more patient, as the owner is better off by (partially) postponing extraction to whenever p is p_H.[25]

5.4.2 Learning

The model developed above assumes that all the agents have access to the same extraction technology. Instead one can assume that F enjoys some technical advantage over the government. In particular, let us assume that per $R(t)$ extracted units, the government gets a flow of revenues of $\theta(\theta-1)^{-1} A(t) R(t)^{1-\frac{1}{\theta}}$; with $A(t) \in \{a, 1\}$, and $a < 1$. As in the price uncertainty application, suppose that there is a unique political regime, C's, and that F initially holds the property rights over the resource. Moreover, let us assume that the government's initial technical knowledge is inferior to F's, that is $A_0 = a$.[26] Furthermore, the government's learn-

[25]Rodriguez and Smulders (2016) and (Sakamoto, 2014) develop frameworks that show how, forward-looking, agents become effectively more (less) patient when they anticipate regime shifts that are, expected to be, favorable (detrimental) for them.

[26]In fact, the government's technical backwardness, can explain why is it that F holds the rights over the resource in the first place. If a is sufficiently low, C may be better off by selling the rights to exploit the resource to F, even if this implies that paying facing a cost of χ for retaking control over resource in the

ing (innovation) process entails some uncertainty: an innovation that allows C to catch-up with F arrives with a hazard of π_A. Once $A(t) = 1$, it remains at this level; that is, there is at most one technical regime shift. Let us further assume that, in the absence of capacity constraints, initially C has no incentives to expropriate: $V^C(S_0, A_0 = 1) > \chi > V^C(S_0, A_0 = a)$. As a consequence of this set of assumptions, F initially retains the property rights over the resource, there is a latent risk that the resource will be expropriated if C's innovation arrives.[27] In this setup, the owner can still mitigate the risk of expropriation by running the stock down to a certain level $\bar{S}$ or by under-investing in extraction capacity. As in the price uncertainty application, expropriation here is triggered by a sudden increase in the expropriator's valuation of the resource. Here, this sudden increase is due to an improvement in the extraction technology (or knowledge) of the expropriator.

5.4.3 Multiple political regime shifts

One of the assumptions of the model is that there is at most one regime shift. This assumption entails that C's expected tenure is of infinite length. Instead one can assume that there are multiple political regime shifts; that is, once C is in power there is a risk π that a challenger C_2 takes power, C_2 faces the same risk of being replaced by a yet new challenger C_3, and the uncertainty of the office holder continues ad infinitum. Assume that each incoming challenger is a replica of C: i.e., once they become the incumbent they must to decide whether to expropriate at a cost χ, or not to expropriate. Again, F is the original holder of the resource's property rights, which upon expropriation will pass to the expropriating incumbent, who then may lose these rights upon the next political regime shift. Note that the assumption is still that expropriations are permanent; that is, once an agent loses the resource she loses it permanently. From the perspective of the owner, the problem remains unchanged, she will lose the resource unless the remaining stock or the installed capacity are sufficiently low. The problem of C however, is slightly different. While it is the case that C only confiscates the resource if the expected NPV from exploiting it is higher than χ, C will not be free of expropriation risk unless the stock of the resource or the installed capacity are sufficiently low. This generates two fundamental changes. First, upon confiscating the resource from F, C behaves as F in the original model; this is so because C faces the risk of expropriation herself, and the risk can only be mitigated if the remaining stock is below certain level or if the installed capacity is too low. Second, being at risk of expropriation increases C's effective discount and

future.

[27] Stroebel and van Benthem (2013) provide evidence of a positive relationship between the likelihood of expropriation in the oil sector and the technical expertise (cumulative experience) of the government.

unambiguously reduces C's valuation of the resource for given S and K. This is in the end beneficial for the original owner F: a lower valuation by C makes expropriation easier to mitigate. Therefore,multiple regime shifts as described here entail higher $\bar{S}$ and $\bar{K}(S_0)$.

5.4.4 Intermediate expropriation

The model considers the expropriation decision as a dichotomous one: expropriate or not. Suppose instead that, upon coming to power, C has a third option: set a given tax rate $\tau < 1$ on extraction, at a cost of $\kappa\chi$, with $\kappa \in (0, 1)$ reflecting the cost of partially infringing F's property rights.[28] One can think of this as a situation in which the business-friendly government (E) and the firm (F) agreed on a permanent tax (royalty) rate (which for simplicity, but without loss of generality, in this analysis it has been assumed to be 0). Then, the incoming, business-hostile, office holder (C) may decide to uphold the tax rate, raise it to an intermediate level (i.e., partially expropriate), or fully expropriate the resource. The question is, given S and K, which of the three options C prefers. To determine C's preferred option, two more critical levels of S (besides $\bar{S}$) need to be defined. The first one, $\bar{S}_1$, is the level of S such that C strictly prefers full expropriation over taxation (taxation over full expropriation) if $S > \bar{S}_1$ ($S < \bar{S}_1$). The second critical level, $\bar{S}_\tau$, is such that C strictly prefers taxation over upholding F's property rights (prefers to uphold C's over the taxation option) if $S > \bar{S}_\tau$ ($S < \bar{S}_\tau$).[29] One can easily show that if $\kappa > \tau$ then $\bar{S}_1 < \bar{S} < \bar{S}_\tau$. If this is the case then C's decision making remains unchanged with respect to the dichotomous choice model, in which partial expropriation is not possible. That is, from C's point of view, for any S, the taxation alternative is strictly dominated by either full expropriation or by leaving the resource untouched and therefore partial expropriation does not arise in equilibrium. In this case the only relevant critical value is then $\bar{S}$. Instead, if $\kappa < \tau$ it is obtained that $\bar{S}_\tau < \bar{S} < \bar{S}_1$. Therefore, in the case of a political regime shift, and in the absence of capacity constraints, the resource is fully expropriated if the remaining stock is large ($S > \bar{S}_1$), it is taxed if the remaining stock is at an intermediate level ($S \in (\bar{S}_\tau, \bar{S}_1)$), and is left under F's control if the remaining stock is low ($S \leq \bar{S}_\tau$). The owner then internalizes that by running the stock down to $\bar{S}_1$ (or installing $\bar{K}_1 > \bar{K}$) mitigates the risk of full expropriation, but the risk of partial expropriation remains latent; the latter is only fully mitigated once S is below $\bar{S}_\tau$ (or if the installed extraction capacity is at most $\bar{K}_\tau$, with $\bar{K}_\tau < \bar{K}$). Nev-

[28]Note that the assumption here is that τ is given and constant. The study of a dynamic (endogenous) tax rate, albeit interesting, goes beyond the scope of this discussion.

[29]Similarly, in the presence of endogenous capacity constraints, one can define three critical levels for K given S_0:$\bar{K}$, $\bar{K}_1$ and $\bar{K}_\tau$.

ertheless, the fundamental mechanisms distorting F's dynamic management of the resource remain at play. That is, the possibility to endogenously mitigate the risk of full (and partial) expropriation by running down the stock or by limiting the extraction capacity, distorts the owner's dynamic management of the resource. However, the presence of an intermediate possibility for C, will weaken F's incentives to over-extract. In the model developed above, the reward for crossing the safety threshold $\bar{S}$ was to *fully mitigate* the risk of *full* expropriation. In the alternative discussed here, the reward from crossing the $\bar{S}_1$ is to *exchange* the risk of *full* expropriation for a risk of *partial* expropriation; while, crossing the $\bar{S}_\tau$ threshold *fully mitigates* the risk of *partial* expropriation. Whether, from the owner's perspective, a challenger with three alternatives is preferable than one with two is unclear and will depend on the values of κ and τ. The possibility of taxation by C is good for the owner when the remaining stock is in $(\bar{S}, \bar{S}_1)$, but it is detrimental if $S \in (\bar{S}_\tau, \bar{S})$.

5.5 Conclusions

Motivated by the long history of expropriations in the oil and gas sector, this chapter explores how an endogenous risk of expropriation affects the management of a non-renewable resource. The endogeneity of the expropriation risk arises from a natural mechanism. That is, the decision making of the potential expropriator is explicitly modeled as a cost-benefit analysis.

The main results of the theory put forward here are based on the response of the resource owner to the endogenous risk of expropriation. Intuitively, the owner uses the tools at hand (i.e., extraction and investment in the extraction capacity) to discourage the expropriator from seizing the remaining stock of the resource. In the absence of capacity constraints, the endogenous risk of expropriation leads the owner to engage in over-extraction, i.e., the resource is depleted too fast from the social perspective. Moreover, as long as the threat of expropriation remains latent, the depletion rate is increasing in the strength of property rights. This occurs because in a more favorable institutional framework, the owner perceives a larger expected reward from protecting the resource by running down the stock. For the same reason, while the risk of expropriation is still present, the depletion rate is decreasing in the remaining stock of the resource; i.e., less stock in the ground leads to more rapacious extraction. In the absence of capacity constraints, the only available tool to reduce the value of the resource is the rate of extraction. Thus, in order to protect the resource against expropriation, the owner depletes the resource faster than it would be optimal in the absence of imperfect institutions, and even faster than it would be the case if the risk of expropriation would be exogenous—or if the owner would fail to anticipate the endogenous nature of this risk—.

In the presence of endogenous capacity constraints, the owner can use the installed capacity as an additional tool to protect the resource against expropriation. If property rights are relatively weak, the "over-extraction motive" dominates. This means that the owner over-invests in the extraction capacity, and the resource is initially depleted at a rate that is too high from the social perspective. When the owner prefers to over-invest in extraction capacity, a marginal improvement in the strength of property rights may actually reduce the social value of the resource, by inducing an even higher investment in installed capacity. When property rights are relatively strong, the owner instead prefers to under-invest in extraction capacity. By doing so, she reduces the net present value of the resource down to a point at which the expropriator does not find it profitable to execute the expropriation.

These results add to the existing literature by providing a systematic analysis of the risk of expropriation on the dynamic management of non-renewable resources for a continuum of property rights regimes. The rich set of implications regarding the effect of different property rights regimes on the resource management decisions, speak in favor of explicitly including the political economy environment under which expropriations can occur in the models of expropriation risk. In this regard, the crossroads between resource economics and political economy is a natural starting point to analyze resource management problems in the context of imperfectly protected property rights.

Finally, the theoretical results derived in this chapter suggest potential avenues for future empirical research on the impact of imperfect property rights on the depletion of non-renewable resources. First, this framework generates implications on the marginal effect of an improvement in the protection of property rights for a continuum of property rights regimes. Second, the model is structured in such a way that the risk of expropriation is based on two different dimensions, namely the cost of expropriation and the risk of a regime shift; Therefore, the results from this analysis indicate that it may be relevant to explore how different characteristics of a polity (e.g., the constraints faced by the executive or the stability of the political regime) can have different impacts on the risk of expropriation, and ultimately on the management of non-renewable resources.

Appendix 5

5.A Proofs

5.A.1 Proofs of Lemmas

Proof of Lemma

Proof. If $S(t) > \bar{S}$:

$$V^F(S(t)) = \frac{\Theta\left(S(t) - \bar{S} + x^{*\frac{1}{\theta}}\bar{S}\right)}{\left(\left(S(t) - \bar{S}\right)(r+\pi) + x^* r\bar{S}\right)^{\frac{1}{\theta}}}$$

Taking the derivative with respect to $S(t)$:

$$\frac{\partial V^F(S(t))}{\partial S(t)} = \left(\left(S(t) - \bar{S}\right)(r+\pi) + xr\bar{S}\right)^{-\frac{1}{\theta}} - \frac{1}{\theta}\frac{\left(S(t) - \bar{S} + x^{\frac{1}{\theta}}\bar{S}\right)\left(\left(S(t)-\bar{S}\right)(r+\pi) + xr\bar{S}\right)^{-1}(r+\pi)}{\left(\left(S(t)-\bar{S}\right)(r+\pi)+xr\bar{S}\right)^{\frac{1}{\theta}}}$$

From x^* we have that $x^{\frac{1}{\theta}} = xr(r+\pi)^{-1}$, so:

$$\begin{aligned} V^F(S(t)) &= \left(\left(S(t) - \bar{S}\right)(r+\pi) + xr\bar{S}\right)^{-\frac{1}{\theta}} - \frac{1}{\theta}\frac{\left(S(t) - \bar{S} + \frac{xr\bar{S}}{r+\pi}\right)\left(\left(S(t)-\bar{S}\right)(r+\pi) + xr\bar{S}\right)^{-1}(r+\pi)}{\left(\left(S(t)-\bar{S}\right)(r+\pi)+xr\bar{S}\right)^{\frac{1}{\theta}}} \\ &= \frac{1-\frac{1}{\theta}}{\left(\left(S(t)-\bar{S}\right)(r+\pi)+xr\bar{S}\right)^{\frac{1}{\theta}}} > 0 \end{aligned}$$

From this expression is also evident that $V^F(S(t))$ is concave in $S(t)$ if $S(t) > \bar{S}$. Moreover, if one evaluates $\Theta\left(S(t) - \bar{S} + x^{*\frac{1}{\theta}}\bar{S}\right)\left(\left(S(t)-\bar{S}\right)(r+\pi) + x^* r\bar{S}\right)^{\frac{-1}{\theta}}$ at $S(t) = \bar{S}$, it is obtained that

$$\frac{\Theta\left(S(t) - \bar{S} + x^{*\frac{1}{\theta}}\bar{S}\right)}{\left(\left(S(t) - \bar{S}\right)(r+\pi) + x^* r\bar{S}\right)^{\frac{1}{\theta}}} = \Theta r^{-\frac{1}{\theta}} S(t)^{1-\frac{1}{\theta}}$$

which is exactly the definition of $V^F(S(t))$ when $S(t) \leq \bar{S}$ (this segment of the value function is also increasing and concave in $S(t)$). ☐

Proof of Lemma 5.2

Continuity of the value function in K

Proof. $V_1^F(S_0,\ K)$ **when** $K \leq \bar{K}(S_0)$**:**

From the definition of $\bar{K}(.)$ and t_1, if $K = \bar{K}(S_0)$ then $t_1 = 0$. Thus, $V_1^F(S_0,\ \bar{K}(S_0)) = V_{NR}(S_0,\ \bar{K}(S_0)) = \chi$. If $K < \bar{K}(S_0)$, $V_1^F(S_0,\ K) = V_{NR}(S_0,\ K)$, which is continuous in K (see equation 5.3.1).

$V_1^F(S_0,\ K)$ **when** $K = \bar{K}(S_0)$**:**

If $K > \bar{K}(S_0)$, V_1^F is continuous as long $K > ((1 - 1/\theta)\, r\chi)^{\frac{1}{1-\frac{1}{\theta}}}$.

Note that $((1 - 1/\theta)\, r\chi)^{\frac{1}{1-\frac{1}{\theta}}}$ is $\lim_{S_0 \to \infty} \bar{K}(S_0) \equiv \bar{K}_\infty$. As $\bar{K}(S(t))$ is decreasing in S, then $K > \bar{K}(S_0)$ entails $K > \bar{K}_\infty$.

$V_1^F(S_0,\ K)$ **&** $V_2^F(S_0,\ K)$ **when** $K = \theta r\bar{S}$**:**

Evaluating V_1 in $K = \theta r\bar{S}$:

$$V_1^F(S_0, \theta r\bar{S}) = \frac{1}{\left(1 - \frac{1}{\theta}\right)(r+\pi)} \left((\theta r\bar{S})^{1-\frac{1}{\theta}} + e^{-(r+\pi)\left(\frac{S_0}{\theta r\bar{S}} - \frac{1}{\theta r}\right)} \frac{\bar{S}^{1-\frac{1}{\theta}}}{(\theta r)^{\frac{1}{\theta}}} (r + \pi - \theta r) \right)$$

rearranging,

$$V_1^F(S_0, \theta r\bar{S}) = \frac{(\theta r\bar{S})^{1-\frac{1}{\theta}}}{\left(1 - \frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-(r+\pi)\left(\frac{S_0}{K} - \frac{1}{\theta r}\right)} \left(1 - \frac{(r+\pi)}{\theta r}\right)\right)$$

While for V_2 we have:

$$V_2^F(S_0, \theta r\bar{S}) = \frac{(\theta r\bar{S})^{1-\frac{1}{\theta}}}{\left(1 - \frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-(r+\pi)\left(\frac{S_0}{\theta r\bar{S}} - \frac{1}{\theta r}\right)} \left(1 - \frac{(r+\pi)}{\theta r}\right)\right)$$

$$= V_1^F(S_0, \theta r\bar{S})$$

$V_2^F(S_0,\ K)$ **&** $V_3^F(S_0,\ K)$ **when** $K = x^*\theta r\bar{S}$**:**

$$V_3^F(S_0, x^*\theta r\bar{S}) = \frac{(x\theta r\bar{S})^{1-\frac{1}{\theta}}}{\left(1 - \frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-\frac{((r+\pi)S_0 + (x^* r - r - \pi)\bar{S})}{x\theta r\bar{S}} + \frac{1}{\theta}} \left(1 - \frac{1}{\theta}\right)\right)$$

simplifying the power:

$$V_3^F(S_0, x^*\theta r\bar{S}) = \frac{(x^*\theta r\bar{S})^{1-\frac{1}{\theta}}}{\left(1 - \frac{1}{\theta}\right)(r+\pi)} \left(1 - e^{-(r+\pi)\frac{S_0 - \bar{S}}{x^*\theta r\bar{S}}} \left(1 - \frac{1}{\theta}\right)\right)$$

from the definition of x^*:

$$V_3^F\left(S_0,\, x^*\theta r\bar{S}\right) = \frac{\left(\theta\bar{S}\right)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right) r^{\frac{1}{\theta}}}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}\left(1-\frac{1}{\theta}\right)}\right)$$

Evaluating V_2^F :

$$V_2^F\left(S_0,\, x^*\theta r\bar{S}\right) = \frac{\left(x^*\theta r\bar{S}\right)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}}\right) + e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}}\Theta\bar{S}^{1-\frac{1}{\theta}} r^{-\frac{1}{\theta}}$$

using x^*:

$$V_2^F\left(S_0,\, x^*\theta r\bar{S}\right) = \frac{\left(\theta\bar{S}\right)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right) r^{\frac{1}{\theta}}}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}}\right) + e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}}\frac{\bar{S}^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(\theta r)^{\frac{1}{\theta}}}$$

$$= \frac{\left(\theta\bar{S}\right)^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right) r^{\frac{1}{\theta}}}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{x^*\theta r\bar{S}}\left(1-\frac{1}{\theta}\right)}\right) = V_3^F\left(S_0,\, x^*\theta r\bar{S}\right)$$

Moreover, V_1^F, is differentiable in K in the relevant domain (i.e., $K \in [\bar{K}(S_0), \theta r\bar{S}]$), the same is true for$V_2^F$ when $K \in (\theta r\bar{S},\, x^*\theta r\bar{S})$. As for V_3^F it is continuous for any $K \geq x^*\theta r\bar{S}$. This concludes the proof of the continuity of $V^F(S_0, K)$ if $S_0 > \bar{S}$. If $S_0 \leq \bar{S}$ or $K < \bar{K}(S_0)$ the continuity of the NPV in K follows immediately from the discussion in section 5.3.1. □

Continuity of the first derivative of the value function in K for $K > \bar{K}(S_0)$

Proof. $\partial V_2^F(S_0,K)/\partial K$ **&** $\partial V_3^F(S_0,K)/\partial K$ **when** $K = x^*\theta r\bar{S}$**:**

$$\frac{\partial V_1^F(S_0,K)}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{r+\pi}$$
$$+e^{-(r+\pi)\left(\frac{S_0}{K}-\frac{1}{\theta r}\right)}(r+\pi)\frac{S_0}{K^2}\left(\frac{1}{1-\frac{1}{\theta}}-\frac{r\chi}{K^{1-\frac{1}{\theta}}}\right)^{-1-\frac{\pi}{r}}\left(\chi-\frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)}\right)$$
$$+e^{-(r+\pi)\left(\frac{S_0}{K}-\frac{1}{\theta r}\right)}\frac{\left(\left(-1-\frac{\pi}{r}\right)\left(\left(1-\frac{1}{\theta}\right)\frac{r\chi}{K^{2-\frac{1}{\theta}}}\right)\left(\chi-\frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)}\right)-\left(\frac{1}{1-\frac{1}{\theta}}-\frac{r\chi}{K^{1-\frac{1}{\theta}}}\right)\frac{K^{-\frac{1}{\theta}}}{r+\pi}\right)}{\left(\frac{1}{1-\frac{1}{\theta}}-\frac{r\chi}{K^{1-\frac{1}{\theta}}}\right)^{2+\frac{\pi}{r}}}$$

Evaluating at $K = \theta r\bar{S}$ and using the definition of $\bar{S}$:

$$\frac{\partial V_1^F(S_0,\theta r\bar{S})}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{r+\pi}$$
$$+K^{-\frac{1}{\theta}}e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left((r+\pi)\frac{S_0}{K}\frac{1}{\left(1-\frac{1}{\theta}\right)}\left(\frac{1}{\theta r}-\frac{1}{r+\pi}\right)+\left(\frac{(r+\pi)\bar{S}}{\left(1-\frac{1}{\theta}\right)}\left(\frac{1}{r+\pi}-\frac{1}{\theta r}\right)-\frac{1}{r+\pi}\right)\right)$$

$$=\frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(1+(r+\pi)\frac{S_0-\bar{S}}{K}\frac{1}{\left(1-\frac{1}{\theta}\right)}\left(1-\frac{r+\pi}{\theta r}\right)\right)\right)$$

Now, the derivative of V_2^F with respect to K:

$$\frac{\partial V_2^F(S_0,K)}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\right)$$
$$+\frac{K^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}}\left(-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(\frac{S_0-\bar{S}}{K^2}\right)\right)+(r+\pi)\frac{S_0-\bar{S}}{K^2}e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\chi$$

$$=\frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(1+\frac{r+\pi}{1-\frac{1}{\theta}}\frac{S_0-\bar{S}}{K}\right)\right)+(r+\pi)\frac{S_0-\bar{S}}{K^2}e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\chi$$

Evaluating at $K=\theta r\bar{S}$ and using the definition of $\bar{S}$:

$$\frac{\partial V_2^F(S_0,\theta r\bar{S})}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(1+\frac{r+\pi}{1-\frac{1}{\theta}}\frac{S_0-\bar{S}}{K}\right)\right)$$
$$+(r+\pi)\frac{S_0-\bar{S}}{K}\frac{K^{-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)\theta r}e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}$$

$$=\frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(1+\frac{r+\pi}{1-\frac{1}{\theta}}\frac{S_0-\bar{S}}{K}\left(1-\frac{r+\pi}{\theta r}\right)\right)\right)=\frac{\partial V_1^F(S_0,\theta r\bar{S})}{\partial K}$$

$\partial V_2^F(S_0,K)/\partial K$ & $\partial V_3^F(S_0,K)/\partial K$ when $K=x^*\theta r\bar{S}$:

Evaluating $\partial V_2^F(S_0,K)/\partial K$ at $K=x^*\theta r\bar{S}$ and using the definition of $\bar{S}$:

$$\frac{\partial V_2^F(S_0,x^*\theta r\bar{S})}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{(r+\pi)}\left(1-e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\left(1+\frac{r+\pi}{1-\frac{1}{\theta}}\frac{S_0-\bar{S}}{K}\right)\right)$$
$$+e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}(r+\pi)\frac{S_0-\bar{S}}{K}\frac{K^{-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)\theta r(x^*)^{1-\frac{1}{\theta}}}$$

Using $x^*=(1+\pi/r)^{\frac{1}{1-\frac{1}{\theta}}}$

$$= \frac{K^{-\frac{1}{\theta}}}{(r+\pi)} \left(1 - e^{-(r+\pi)\frac{S_0-\bar{S}}{K}} \left(1 + \frac{r+\pi}{1-\frac{1}{\theta}} \frac{S_0-\bar{S}}{K}\right)\right) + e^{-(r+\pi)\frac{S_0-\bar{S}}{K}} \frac{S_0-\bar{S}}{K} \frac{K^{-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)\theta}$$

$$\frac{\partial V_3^F(S_0, K)}{\partial K} = \frac{K^{-\frac{1}{\theta}}}{(r+\pi)} \left(1 - e^{-\frac{((r+\pi)S_0+(x^*r-r-\pi)\bar{S})}{K}+\frac{1}{\theta}} \left(1-\frac{1}{\theta}\right)\right)$$

$$+\frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)(r+\pi)} \left(-e^{-\frac{((r+\pi)S_0+(x^*r-r-\pi)\bar{S})}{K}+\frac{1}{\theta}} \frac{((r+\pi)S_0+(x^*r-r-\pi)\bar{S})}{K^2} \left(1-\frac{1}{\theta}\right)\right)$$

Evaluating at $K = x^*\theta r\bar{S}$:

$$\begin{aligned} \tfrac{\partial V_3^F(S_0, x^*\theta r\bar{S})}{\partial K} &= \tfrac{K^{-\frac{1}{\theta}}}{(r+\pi)} \left(1 - e^{-(r+\pi)\frac{S_0-\bar{S}}{K}} \left(1-\tfrac{1}{\theta}\right)\right) \\ &+ \tfrac{K^{-\frac{1}{\theta}}}{(r+\pi)} \left(-\left((r+\pi)\tfrac{(S_0-\bar{S})}{K} + \tfrac{1}{\theta}\right) e^{-(r+\pi)\frac{S_0-\bar{S}}{K}}\right) \end{aligned}$$

$$= \frac{K^{-\frac{1}{\theta}}}{(r+\pi)} \left(1 - e^{-(r+\pi)\frac{S_0-\bar{S}}{K}} \left(1 + (r+\pi)\frac{(S_0-\bar{S})}{K}\right)\right) = \frac{\partial V_2^F(S_0, x^*\theta r\bar{S})}{\partial K}$$

This concludes the proof of continuity of the first derivative at the junction values $\theta r\bar{S}$ and $x^*\theta r\bar{S}$

Finally note that when $K = \theta((r+\pi)S_0 + (x^*r - r - \pi)\bar{S})$ then $\partial V_3^F(S_0, K)/\partial K = 0$ (i.e., V_3^F flattens smoothly as K approaches the owner's preferred level of extraction).

□

5.A.2 Proofs of Propositions

Proof of Proposition 5.2

Proof. To prove 1., one just needs to divide both sides of (5.2.10) by $S(t)$:

$$\frac{R(t)}{S(t)} = \theta\left((r+\pi) + (x^*r - (r+\pi))\frac{\bar{S}}{S(t)}\right)$$

and given that $x^*r > r + \pi$ this expression is increasing in $\bar{S}$, and thus it is increasing in χ. 2. Follows directly from the model: $\bar{S}$ increases with χ, thus there exists a sufficiently high level of χ such that $\bar{S} = S(t)$. If χ increases above this level the threat of expropriation disappears ($\Pi = 0$), and the extraction path would not be distorted. □

Proof of Proposition 5.3

Proof. From equation (5.2.9) we know that:

$$V^F(S(t)) = \frac{\Theta\left(S(t) - \bar{S} + x^{*\frac{1}{\theta}}\bar{S}\right)}{\left((S(t) - \bar{S})(r+\pi) + x^* r\bar{S}\right)^{\frac{1}{\theta}}}$$

Given that $\bar{S}$ is increasing in χ, to obtain the sign of the effect of χon the NPV, it is sufficient to check the effect of $\bar{S}$ on V^F. Taking the derivative with respect to $\bar{S}$:

$$\begin{gathered}\frac{\partial V^F(S(t))}{\partial \bar{S}} = \\ \left(x^{\frac{1}{\theta}} - 1\right)\left((S(t) - \bar{S})(r+\pi) + xr\bar{S}\right)^{-\frac{1}{\theta}} \gtreqless 0 \\ -\frac{1}{\theta}\frac{\left(S(t)-\bar{S}+x^{\frac{1}{\theta}}\bar{S}\right)(xr-r-\pi)}{\left((S(t)-\bar{S})(r+\pi)+xr\bar{S}\right)^{1+\frac{1}{\theta}}} \gtreqless 0\end{gathered}$$

$$\longleftrightarrow \left(x^{\frac{1}{\theta}} - 1\right)\left((S(t) - \bar{S})(r+\pi) + xr\bar{S}\right) \gtreqless \frac{1}{\theta}\left(S(t) - \bar{S} + x^{\frac{1}{\theta}}\bar{S}\right)(xr - r - \pi)$$

From x^* we have that $x^{\frac{1}{\theta}} = xr(r+\pi)^{-1}$, so:

$$\longleftrightarrow \left(\frac{xr}{r+\pi} - 1\right)\left((S(t) - \bar{S})(r+\pi) + xr\bar{S}\right) \gtreqless \frac{1}{\theta}\left(S(t) - \bar{S} + \frac{xr}{r+\pi}\bar{S}\right)(xr - r - \pi)$$

$$\longleftrightarrow S(t) - \bar{S} + \frac{xr}{r+\pi}\bar{S} > \frac{1}{\theta}\left(S(t) - \bar{S} + \frac{xr}{r+\pi}\bar{S}\right)$$

which holds for any $\theta > 1$. □

5.B Derivations

5.B.1 Optimal switching time formulation

Defining T as the time of the first political turbulence and $\tilde{t}$ as the instant at which safety is reached, the expected income stream of the owner is given by:

$$\begin{aligned}E\left[NPV^F\right] = &\left(1 - e^{-\pi\tilde{t}}\right)\int_0^{\tilde{t}}\left(\int_0^t f(R(m), m)\,dm + \int_t^{\infty} 0 dm\right)\frac{\pi e^{-\pi t}}{1-e^{-\pi\tilde{t}}}dt \\ &+ e^{-\pi\tilde{t}}\int_0^{\infty} f(R(m), m)\,dm\end{aligned} \tag{5.B.1}$$

Where $f(R(m), m)$ transforms extraction R into discounted revenues. The first term is the expected income stream given that a regime shift occurs before safety is reached (i.e., $T < \tilde{t}$), and it is weighted by the probability of this being the case, i.e., $1 - e^{-\pi\tilde{t}}$. The outer integral (i.e., the integral over t) is a weighted "sum" of all potential income streams given that the regime shift occurs before $\tilde{t}$, where the weight that each potential path gets is the instantaneous probability of it being the actual path (i.e., $t = T$) conditional on $T < \tilde{t}$ (i.e.$\pi e^{-\pi t}\left(1 - e^{-\pi\tilde{t}}\right)^{-1}$). Note that if turbulence occurs at some $t < \tilde{t}$, the income stream from there on is 0. The second term is the expected income stream in case the shift in power only occurs after $\tilde{t}$, multiplied by the probability of $T > \tilde{t}$ (i.e., $e^{-\pi\tilde{t}}$). Provided that $T > \tilde{t}$, the income stream does not depend on the exact realization of T. Lets focus on the expected income stream given $T < \tilde{t}$:

$$\int_0^{\tilde{t}} \left(\int_0^t f(R(m), m)\, dm + \int_t^\infty 0 dm\right) \frac{\pi e^{-\pi t}}{1 - e^{-\pi\tilde{t}}} dt$$

One can transform this expression such that instead of summing over (weighted) income streams, it sums over (weighted) income flows. The idea is simple, for example, $f(R(0), 0)$ will be received with (conditional) probability 1 (i.e., the conditional probability of $T = 0$ is 0). More generally, flow $f(R(m), m)$ will be accrued by the owner with conditional probability $\int_m^{\tilde{t}} \pi e^{-\pi t}\left(1 - e^{-\pi\tilde{t}}\right)^{-1} dt$, so:

$$\int_0^{\tilde{t}} \left(\int_0^t f(R(m), m)\, dm\right) \frac{\pi e^{-\pi t}}{1 - e^{-\pi\tilde{t}}} dt = \int_0^{\tilde{t}} f(R(m), m) \left(\int_m^{\tilde{t}} \frac{\pi e^{-\pi t}}{1 - e^{-\pi\tilde{t}}} dt\right) dm$$

$$= \int_0^{\tilde{t}} f(R(m), m) \frac{e^{-\pi m} - e^{-\pi\tilde{t}}}{1 - e^{-\pi\tilde{t}}} dm$$

Where the last term is the "sum"over all income flows $f(R(m), m)$ weighted by the probability of being received (i.e., income flow $f(R(m), m)$ is only received if the incumbent's regime survives at least until m). Plugging this back into (5.B.1):

$$E\left[NPV^F\right] = \int_0^{\tilde{t}} f(R(m), m) \left(e^{-\pi m} - e^{-\pi\tilde{t}}\right) dm + e^{-\pi\tilde{t}} \int_0^\infty f(R(m), m)\, dm$$

$$= \int_0^{\tilde{t}} f(R(m), m)\, e^{-\pi m} dm + e^{-\pi\tilde{t}} \int_{\tilde{t}}^\infty f(R(m), m)\, dm$$

5.B.2 Finding x^* explicitly

The way I proceed here is by setting R at time $\bar{t}$ as a —still to be determined— proportion of the value of R once the threshold is crossed. Albeit lengthier, this derivation also provides some useful insights. In particular, let $R(\bar{t}) = x\theta r\bar{S}$. Allowing for this adjustment presumes that extraction is not necessarily continuous in t at $\bar{t}$. Using this and the cumulative extraction between t and $\bar{t}$:

$$e^{\theta(r+\pi)(\bar{t}-t)} - 1 = \frac{(S(t) - \bar{S})(r+\pi)}{xr\bar{S}} \tag{5.B.2}$$

This expression relates the time it takes to deplete the resource up to its safe level $\bar{S}$, namely $\bar{t}$, and the extraction rate $R(\bar{t}) = x\theta r\bar{S}$. Yet, both $\bar{t}$ and x are unknown (although they are inherently tied to each other). To solve this, I proceed in three steps: i) I take $\bar{t}$ and x as given, and using the behavior R described by (5.2.7), I solve for the owner's valuation as a function of $\bar{t}$, x, and the stock still in the ground; ii), with the help of (5.2), I express the owner's expected NPV solely as a function of x and $S(t)$; and, iii) I solve for the value of x that maximizes the owner's expected NPV (i.e., the optimal adjustment at $\bar{t}$).

5.B.2.1 Owner's expected NPV as a function of the switching time $\bar{t}$ and the adjustment factor x

If $t < \bar{t}$ and $l(t) = 0$, from (5.2.7) and definitions 5.2 and 5.3:

$$R(t) = e^{\theta(r+\pi)(\bar{t}-t)} x\theta r\bar{S} \tag{5.B.3}$$

Thus, by taking $\bar{t}$ as given and following the optimal extraction path from $t = 0$ onwards, the owner expects to obtain:

$$V^F(S_0, \bar{t}, x) = e^{-(r+\pi)\bar{t}} \left(\Theta \frac{S_0 - \bar{S}}{(xr\bar{S})^{\frac{1}{\theta}}} + \chi \right)$$

where V instead of U means that I am using the owner's preferred growth rate of R to calculate the NPV, but the optimal $\bar{t}$ and x still remain to be chosen. This expression together with (5.B.2) show the trade-off faced by the owner when choosing x. On the one hand, a higher x reduces the time it takes to get to safety, increasing the present value of the reward (χ): from (5.B.2) $\bar{t}$ is decreasing in x given $S(t)$ and $\bar{S}$). On the other hand, a higher x also reduces the time over which $S_0 - \bar{S}$ is extracted; given the concavity of the revenue function, this reduces the valuation of the resource (i.e., the higher x the further away the extraction path is from the expropriation-free path).

5.B.2.2 Owner's expected NPV as a function of the adjustment factor x

Using (5.B.2) one can rewrite $e^{-(r+\pi)\bar{t}}$ as a function of x:

$$e^{-(r+\pi)\bar{t}} = (xr\bar{S})^{\frac{1}{\theta}} \left((S_0 - \bar{S})(r+\pi) + xr\bar{S} \right)^{-\frac{1}{\theta}}$$

While the NEC (5.2.5) allows to replace χ for a function of $\bar{S}$:

$$V^F(S_0, x) = \frac{\Theta \left(S_0 - \bar{S} + x^{\frac{1}{\theta}} \bar{S} \right)}{\left((S_0 - \bar{S})(r+\pi) + xr\bar{S} \right)^{\frac{1}{\theta}}}$$

5.B.2.3 Owner's preferred adjustment factor x

The final step to get a full characterization of the owner's preferred extraction path, and her valuation of the resource consists of maximizing $V^F(S_0, x)$ with respect to x. The derivative of $V^F(S_0, x)$ with respect to x is equal to:

$$\frac{\Theta \left(\left(\frac{1}{\theta} x^{\frac{1}{\theta}-1} \bar{S} \right) - \frac{1}{\theta} \left((S_0 - \bar{S})(r+\pi) + xr\bar{S} \right)^{-1} (r\bar{S}) \left(S_0 - \bar{S} + x^{\frac{1}{\theta}} \bar{S} \right) \right)}{\left((S_0 - \bar{S})(r+\pi) + xr\bar{S} \right)^{\frac{1}{\theta}}}$$

This expression is $\gtreqless 0$ if:

$$\left(x^{\frac{1}{\theta}-1} \right) \left((S_0 - \bar{S})(r+\pi) + xr\bar{S} \right) \gtreqless r \left(S_0 - \bar{S} + x^{\frac{1}{\theta}} \bar{S} \right)$$

so,

$$\frac{\partial V^F(S_0, x)}{\partial x} \gtreqless 0 \text{ if } 1 + \tfrac{\pi}{r} \gtreqless x^{1-\frac{1}{\theta}}$$

Which means that the NPV is maximized at

$$x^* = \left(1 + \frac{\pi}{r} \right)^{\frac{1}{1-\frac{1}{\theta}}}$$

5.B.3 From $V_3^F(S_0, K, t_3, \bar{t})$ to $V_3^F(S_0, K)$

To get V_3^F just as a function of S_0 and K I proceed in three steps: 1. Find t_3 as a function of S_0 and K; 2. Find the NPV of the resource after t_3 as a function of K; and, 3. combine the results from 1 and 2.

5.B.3.1 t_3 as a function of S_0 and K

From definition 5.6:

$$S(t_3) = \frac{1}{r+\pi}\left(\frac{K}{\theta} + (r+\pi - x^* r)\bar{S}\right) \tag{5.B.4}$$

Combining this with $t_3 = \frac{S_0 - S(t_3)}{K}$:

$$t_3 = \frac{S_0 - \frac{1}{r+\pi}\left(\frac{K}{\theta} + (r+\pi-x^*r)\bar{S}\right)}{K} = \frac{\theta\left((r+\pi)S_0 + (x^*r - r - \pi)\bar{S}\right) - K}{\theta(r+\pi)K}$$

5.B.3.2 NPV after t_3

Using (5.B.4) in (5.2.9):

$$\int_{t_3}^{\bar{t}} \frac{\left(R(t_3)\, e^{-\theta(r+\pi)(\tau - t_3)}\right)^{1-\frac{1}{\theta}}}{1-\frac{1}{\theta}} e^{-(r+\pi)\tau} d\tau + e^{-(r+\pi)\bar{t}} V(\bar{S})$$

$$= \frac{\Theta\left(\frac{1}{r+\pi}\left(\frac{K}{\theta} + (r+\pi-x^*r)\bar{S}\right) - \bar{S} + x^{*\frac{1}{\theta}}\bar{S}\right)}{\left(\left(\frac{1}{r+\pi}\left(\frac{K}{\theta} + (r+\pi-x^*r)\bar{S}\right) - \bar{S}\right)(r+\pi) + x^* r\bar{S}\right)^{\frac{1}{\theta}}}$$

$$= \frac{\Theta\left(\frac{K}{\theta} + \left((r+\pi)x^{*\frac{1}{\theta}} - x^* r\right)\bar{S}\right)}{(r+\pi)\left(\frac{K}{\theta}\right)^{\frac{1}{\theta}}}$$

From the value of $x^* = (1 + {}^{\pi}/_{r})^{\frac{1}{1-\frac{1}{\theta}}}$:

$$(r+\pi)x^{*\frac{1}{\theta}} - x^* r = (r+\pi)\left(1+\frac{\pi}{r}\right)^{\frac{1}{\theta-1}} - \left(1+\frac{\pi}{r}\right)^{\frac{\theta}{\theta-1}} r$$

$$= (r+\pi)(r+\pi)^{\frac{1}{\theta-1}} r^{\frac{-1}{\theta-1}} - (r+\pi)^{\frac{\theta}{\theta-1}} r^{\frac{-\theta}{\theta-1}} r$$

$$= (r+\pi)^{\frac{\theta}{\theta-1}} r^{\frac{-1}{\theta-1}} - (r+\pi)^{\frac{\theta}{\theta-1}} r^{\frac{-1}{\theta-1}} = 0$$

So,

$$\frac{\Theta\left(\frac{K}{\theta}+\left(\left(r+\pi\right)x^{*\frac{1}{\theta}}-x^{*}r\right)\bar{S}\right)}{\left(r+\pi\right)\left(\frac{K}{\theta}\right)^{\frac{1}{\theta}}}=\frac{\Theta\left(\frac{K}{\theta}\right)^{1-\frac{1}{\theta}}}{\left(r+\pi\right)}=\frac{K^{1-\frac{1}{\theta}}}{\theta\left(1-\frac{1}{\theta}\right)\left(r+\pi\right)} \tag{5.B.5}$$

Using (5.B.4) and (5.B.5) in (5.3.7):

$$\begin{aligned} V_3^F\left(S_0, K\right) = & \frac{K^{1-\frac{1}{\theta}}}{\left(1-\frac{1}{\theta}\right)\left(r+\pi\right)}\left(1-e^{-\frac{\theta\left(\left(r+\pi\right)S_0+\left(x^{*}r-r-\pi\right)\bar{S}\right)-K}{\theta K}}\right) \\ & +e^{-\frac{\theta\left(\left(r+\pi\right)S_0+\left(x^{*}r-r-\pi\right)\bar{S}\right)-K}{\theta K}}\frac{K^{1-\frac{1}{\theta}}}{\theta\left(1-\frac{1}{\theta}\right)\left(r+\pi\right)} \end{aligned}$$

Simplifying this expression leads to (5.3.8).

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