Universidade de Brasília
Faculdade de Admnistração, Economia, Contabilidade, e Gestão Pública

Land Tenure and Mining: Property Rights in Indigenous Territories in Brazil

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DISSERTAÇÃO DE MESTRADO

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Projeto Final de Mestrado submetido como requisito parcial para obtenção do grau de Mestre em Economia

Orientador: Prof. Dr. Bernardo Mueller

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To Maíra, reminding us both that new beginnings always require extra courage.
We’re perfectly balanced, sister, as all things should be.

Acknowledgements

I wish my master's were a bit different. I lived in Brasília for only a month. Then COVID-19 arrived, and I had to go back to my hometown. Doing the whole program remotely was a very frustrating experience. Every day felt the same as the one before. I felt like I was contributing to nothing. Still, I was (and am) in a very privileged position. I studied the topics I love and made one step closer to fulfilling my professional goal of working with evidence-based public policy. I must thank my parents, Eduardo and Fabiola, and my sister, Maíra. Without their support, none of my today's achievements would be possible.

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I think economists must have an interdisciplinary approach to understanding complex social phenomena. That said, I want to thank Priscilla Feller, an *indigenista* from FUNAI, for such an insightful conversation about indigenous territories in Brazil. As she said, we economists must pay attention to contexts and stories that our data may not be telling. I hope to improve this work toward that idea.

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Final thanks go to CAPES whose financial support was very appreciated and indispensable during my master's.

"O bem pode assumir inúmeras facetas."

(Mikael Blomkvist)

Abstract

Mining has been present in Brazil since the colonization period. It has influenced social and economic transformations. Indigenous people have inhabited the Amazon and other regions since before Brazil's discovery. Their territories are known to be mineral sources and have inevitably attracted miners. Does indigenous land tenure impact mining? In this paper, we follow the Institutional and Organizational Analysis framework to build our hypothesis, and use the PPTAL program to run a propensity score matching and estimate the impact of homologation on mining. We find that the indigenous territories that were treated (homologated) have, on average, fewer mining requests compared to the control (not-homologated) group after the program ended. The policy implications are that homologation not only reduces violence, as shown by Mueller (2022), but also environmental damage as mining activities are often associated with deforestation and river poisoning.

Keywords: Property Rights. Mining. Indigenous Territories. Political Economy.

Resumo

Atividades de mineração estão presentes no Brasil desde o período colonial. Elas têm influenciado transformações sociais e econômicas. Povos indígenas habitam a Amazônia e outras regiões mesmo antes da descoberta do Brasil. Seus territórios são conhecidos por serem fontes de minérios e inevitavelmente tem atraído a atenção de mineradores. A demarcação do território reduz atividades mineradoras? Nesse trabalho, nós seguimos a estrutura teórica da Análise de Instituições e Organizações para desenhar a nossa hipótese, usando o programa PPTAL para rodar um propensity score matching e estimar o impacto da homologação em mineração. Nós encontramos que territórios indígenas que foram tratados (homologados) apresentam menos processos minerários comparados ao grupo controle (não-homologado) após o fim do programa.

Palavras-chave: Direitos de Propriedade. Mineração. Territórios Indígenas. Economia Política.

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ANM	Agência Nacional de Mineração	15
FUNAI	Fundação Nacional do Índio	15
INCRA	Instituto Nacional de Colonização e Reforma Agrária	15
ISA	Instituto Socioambiental	15
MST	Movimento dos Trabalhadores Rurais Sem Terra	15
NGO	Non-Govermental Organization	15
PPTAL	Integrated Project for Protection of Indigenous People and Land in the Legal Amazon	15
PSM	Propensity Score Matching	15

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Contents

1 Introduction

Mining has been present in Brazil since the colonization period. It has influenced social and economic transformations, from social ascensions to emerging cities and market connections. It is also associated with environmental degradation. Indeed, mining was responsible for 1.2 million *ha* of deforestation in the Brazilian Amazon between 2005 and 2015 (MANZOLLI et al., 2021). Indigenous people have inhabited that area and many others since before Brazil's discovery. Their territories are known to be mining sources and have inevitably attracted miners. Mining in homologated indigenous territories is prohibited by law, but groups of politicians and miners have always tried to regulate the activity in these areas.

The regulation of mining in indigenous territories is often on the Brazilian Congress' agenda. The first project bill (*projeto de lei*) was PL 1610/1996, which was rejected in the 1990s. However, the Bolsonaro administration renewed the efforts for regulation by setting a new project bill, PL 191/2020. In the 2022 elections, 79 candidates were related to the mining industry (FOLHA, 2022). Many of them represented the small-scale mining's (*garimpo*) cause, supporting the activity's regulation in indigenous territories. Conversely, this year's elections had a record number of 181 indigenous candidates - 36% increase in four years - standing for the current institutional arrangement that aims to protect environmental and indigenous areas (GUARDIAN, 2022). In the meantime, firms and small-scale miners keep requesting mining processes (*processos minerários*) in the hope that their enterprises get regulated in indigenous territories. Moreover, small-scale miners have been associated with illegal activities inside these areas.

In this paper, we aim to measure the impact of indigenous property rights on mining. Following the literature on Institutional and Organizational Analysis (COASE, 1960; DEMSETZ, 1967; LIBECAP, 1990; ALSTON, L. J.; MUELLER, 2005; ALSTON, E. et al., 2018), we argue that these constant requests for research and mining permits, illegal activities, and mining regulation support in Congress are ways players are demanding new institutional arrangements.

In a world of zero transaction costs, Coase's (1960) theorem states that if property rights are well-defined the exchange between the parties will be efficient. However, under our context, given the heterogeneity among the parties involved, we argue that transaction costs are so high in homologated territories that a new institutional arrangement regulating mining in indigenous areas is unlikely to happen. Hence, a Coasean solution in these territories is unreachable, and there are no gains of trade. Therefore, we hypothesize that homologation reduces mining. Since the firms have no legal right to produce in these areas, all we can analyze are their expectations should the activity become regulated in the future.

Between 1996 and 2005, a World Bank initiative helped identify and recognize indigenous territories in the Amazon, the PPTAL. We use the PPTAL to build a counterfactual sample of not-homologated territories to be compared with the lands *treated* by the program. We use nearest-neighbor propensity score matching to estimate the causal effect of property rights on mining. We find that the indigenous territories treated (homologated) have, on average, fewer mining requests than the control (not-homologated) group after the program ended. We run robustness checks, and although the effect remained negative, we lose statistical significance. Nevertheless, our results indicate that homologation not only reduces violence, as shown by Mueller (2022), but it also reduces environmental damage as mining activities are often associated with deforestation and river poising (MANZOLLI et al., 2021).

This paper contributes to the literature on Brazilian indigenous land. Our work follows Mueller (2022) and continues investigating indigenous property rights' role in Brazil's development issues. The literature has consolidated the importance of establishing and enforcing property rights to spur economic development (NORTH; THOMAS, 1973; NORTH, 1981, 1990; ACEMOGLU; JOHNSON, 2005; ACEMOGLU; ROBINSON, 2012). In addition, previous research has studied the effect of property rights on violence (MUELLER, 2022; FETZER; MARDEN, 2017) and deforestation (BENYISHAY et al., 2017). The evidence shows that safer property rights reduce violence and land-related conflicts but not deforestation. We now investigate how land tenure is associated with the mining business.

The paper is structured as follows. Section 2 presents the institutional framework and motivates our discussion. Section 3 then describes the theoretical framework. Section 4 presents the multiple data sources used for our empirical strategy. Section 5 introduces our empirical exercises. In section 6, we discuss the main results of our analysis. Finally, in section 7, we conclude.

2 Institutional Background

The main issue of this paper is one of property rights. Mining activities involve multiple players, like big firms, business people, agencies, the government - the Estate itself but also congressmen and congresswomen -, and indigenous people (MANZOLLI et al., 2021). Such a distinct group inevitably implies different incentives and interests. This heterogeneity also implies higher levels of transaction costs (LIBECAP, 1990). Can property rights define the rules of the mining game? More specifically, are property rights being enforced and establishing what belongs to the indigenous people and what belongs to the mining firms? In this section, we describe the mining activity in Brazil and its relation to indigenous territories.

2.1 Mining in Brazil

Mining has always been present in Brazil. Not only because of the resources but also due to the social transformations invoked by this activity. Indeed, since the *gold cycle* in Brazil's colonization period, the search for the gemstone and the promise of social ascension encouraged thousands to migrate to the country's Southeast (CALDEIRA, 2017). New mines - usually gold - for the following centuries would still promote similar transformations in the corresponding regions. Newcomers arrive, set up their houses, and connect themselves through new roads. Around the mines, there would be new social interactions, and one could see new markets emerging.

Nowadays, mining remains an important economic activity in Brazil. In particular, in 2021 the mineral sector totaled 339.1 billion Brazilian *reais* (BRL) in revenues, a 62% increase compared to 2020 (IBRAM, 2021). Mining is active from the South to the North, including states like Pará, Minas Gerais, Bahia, and São Paulo. Iron, gold, and copper are the main substances in this matrix, substantiating almost 90% of participation in the sector's revenue. It's also an activity that involves many agents, from big firms to small-scale miners, also known as *garimpeiros*.

To start mining, these players must pass through a series of procedures. We now describe the main aspects of them. First, all mining resources are owned by Brazil's federal branch. Therefore, if a firm wants a mining area, they need to request a permit from the government to study or explore a corresponding polygon. Second, these agents must have an environmental lease that guarantees their understanding regarding the impact of the mining activity and the related measures of conservation after the exploration is finished (MANZOLLI et al., 2021).

The agency regulating the permits is the National Mining Agency (*Agência Nacional de Mineração*, ANM). The mining requests are summarized in four distinct steps (ISA, 2022c), referred to as mining processes (*processos minerários*). The first one is the **research interest** request, when the firm demands to research a specific polygon where they think there's a particular mineral resource - gold, sand, iron, copper, etc. If the area requested is free of restrictions - either of property rights of land or environmental ones - it should guarantee the interested party a research interest permit (*alvará de pesquisa*). Once the research is done and the firm decides to mine, they request a **mining solicitation**, e.g., *requerimento de lavra*. In that case, the firm needs to present an environmental lease and a project to substantiate its intentions in the mining area. In the empirical exercises discussed in sections 5 and 6, our outcome variables are related to either research or mining interest requests. We aim to capture the firms' and *garimpeiros*' expectations regarding mining in indigenous territories.

The last step is the actual mining when the firm gets the **permit** to start the extraction (*concessão de lavra*). The case for small-scale mining, *garimpo*, is a bit different and deserves special attention. The *garimpo* is a type of mining which it's supposed to be of rudimentary practices. In the *gold cycle* in Brazil's colonization period, any free man could mine - generally gold - using simple tools like pickaxes and pans. Nowadays, it still is an activity supposed to have temporary installations and less environmental impact (MANZOLLI et al., 2021). The main difference from the big-scale mining process is that *garimpeiros* don't need previous research of the mining area (MPF, 2020). The justification is that such practice is done by simple groups of men entitled to poor economic conditions and no capital to conduct large-scale mining (MPF, 2020). That way, the small-scale miners - a single person or a cooperative - request ANM for a small-scale mining permit (*requerimento de lavra garimpeira*). Once that is achieved, they get permission to mine the corresponding area (*concessão de lavra garimpeira*).

Since the constitutional law bill 7.805/1989, the image of the small-scale miner has been ambiguous. It defines the mining, but not the miner[1]. Most importantly, the law eliminated the rudimentary character that the profession had carried since the 1700s. This ambiguity has been reinforced with law 11.685/2008, the *garimpeiro*'s statute, defining the occupation as *the act* of small-scale mining substances (*substâncias garimpáveis*), such as gold, diamonds, cassiterite, etc. However, neither laws specify the techniques to be used in the activity. This juridical void has enabled groups of *garimpeiros*, their cooperatives, to utilize equipment and machinery priced between 70 thousand to 2 million BRL (MPF, 2020). The occupation's evolution, with no technological restrictions, no need for previous research, and flexible environmental rules, made way for a different kind of mining business. Nowadays, small-miners cooperatives using firm-size technology mine vaster areas and cause more ecological damage (MPF, 2020; VILLÉN-PEREZ et al., 2020). Notwithstanding,

[1] See MPF (2020) for the law articles.

in 2019 and 2020, most illegal gold extraction came from small-mining permits (MANZOLLI et al., 2021).

2.2 Indigenous Property Rights in Brazil

Indigenous rights have not always been clear in Brazil. In 1916, the Brazilian Civil Code included indigenous tutelage. The Indian Protection Service (substituted by the National Indian Foundation - FUNAI - after 1973) was responsible for dealing with indigenous affairs and sought to defend their interests. However, many judges had misinterpreted its juridical definition, understanding the tutelage as a barrier to indigenous people going to courts and claiming their rights by themselves (CUNHA, 2018). In 1973, the military regime promulgated the Indian Statute (law 6.0001/1973) that included the State's obligation to homologate all indigenous territories in five years. However, the government soon realized that this task was not feasible due to the harsh migration conditions in the Amazon area (MUELLER, 2022). Moreover, the indigenous legal capacity remained under FUNAI's tutelage.

The 1988 Brazilian Constitution overcame the tutelage issue. It explicitly recognized indigenous legal capacity as stated in article 232: "the Indians, their communities and organizations are legitimate to ingress in defense of their rights and interests". The indigenous people would now be legally treated as any other citizen. It also adequately defined indigenous territories as the ones traditionally occupied permanently and used for indigenous productive activities and environmental conservation according to indigenous customs and traditions (MUELLER, 2022). Once again, there was an effort to homologate all indigenous territories within five years (by 1993). However, there wasn't a clear strategy or procedure to handle the titling, and Mueller (2022) argues that the first lands to be titled were the more accessible ones, with fewer conflicts and controversies. As land-related disputes started to appear, the government found it challenging to homologate all the territories. As a result, it wasn't able to fulfill its objective.

In 1996, Presidential Decree 1775/96 created a set of rules to establish how indigenous territories should be identified and officially recognized. These procedures are valid until today. In summary, besides homologation, the final and most robust set of property rights of the land, an indigenous territory can be on three alternative stages (ISA, 2022a). First, the land could be regarded as **being identified** when a claim is made to FUNAI requesting a study to determine the corresponding indigenous territory. After the analysis is completed, FUNAI decides whether or not to **identify** the area. If so, the Ministry of Justice is in charge of legally **declare** the territory. Finally, the corresponding Brazilian President signs the homologation itself. Although the first two steps are considered technical, the last two are political (MUELLER, 2022). It is also a financial matter since FUNAI must compensate any firm or individual in the corresponding area being homologated. Depending on the agency's budget, this transition could take some time.

The Presidential Decree aimed to reduce uncertainty and conflicts in areas where multiple parties, such as indigenous people, miners, and farmers, claimed pieces of land for themselves. Despite the heterogeneity among these players and the constant dichotomy between environment conservation and economic progress, from 1996 to 2005, we find one of the most prosperous periods of indigenous land tenure (MUELLER, 2022). The main reason was a World Bank initiative called PPTAL - Integrated Project for Protection of Indigenous People and Land in the Legal Amazon.

2.2.1 Policy context: PPTAL

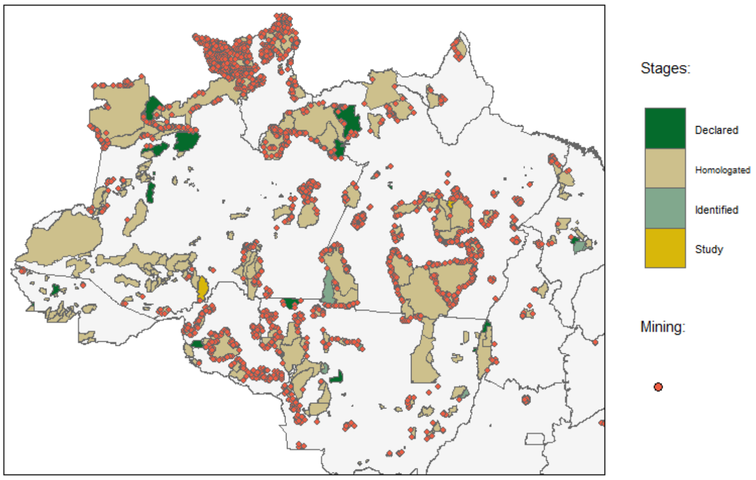
Alongside the Presidential Decree, the PPTAL helped to identify indigenous territories yet to be homologated. By 2005, the program identified 60 indigenous lands and demarcated 92, of which the President had homologated 87. PPTAL was also crucial because it involved the indigenous people in the titling process, making the program more legitimate (MUELLER, 2022). Moreover, FUNAI improved its bureaucratic and technical capabilities regarding the homologation process. We'll return to PPTAL details later in section 5, where we use the program in our empirical strategy.

2.3 Mining in indigenous territories

Any mining activity inside homologated (land-tenured) indigenous territories is prohibited. If there's an indication of it, it's necessarily illegal. The 1988 Brazilian Constitution - articles 176 and 231 - emphasizes that hydroelectric and mining activities in indigenous territories can only be operative with the Brazilian Congress and the affected indigenous people's permission (MPF, 2020). But, such a law has not been regulated yet; hence, these enterprises are considered illegal inside indigenous territories. One thing to note is that this legislation is specific to homologated indigenous territories. There is no restriction to areas that the government has not yet titled. Under this context, our goal in this paper is to measure homologation's impact on mining.

There are approximately 700 indigenous territories and more than 2000 mining requests in more than 300 of them (ISA, 2022b). The natural consequence of establishing indigenous land property rights is that most mining solicitations now occur around the area instead of inside it. That is the primary goal of the property right establishment, keeping miners legally away from the regions and protecting the environment (VILLÉN-PEREZ et al., 2020). Outside of them, anyone has the right to claim a corresponding polygon once following ANM's playbook. As for the not-homologated territories, since there's no establishment per

Figure 2.1 – Mining processes in indigenous territories in the Brazilian Amazon



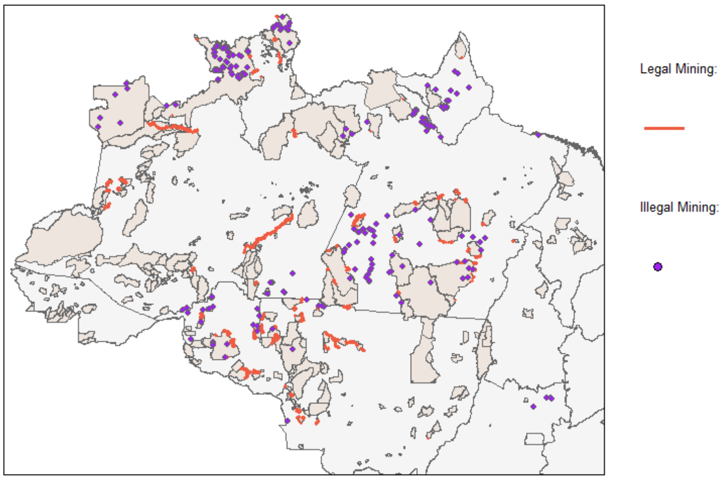
Notes: Active mining processes in indigenous territories, from 1941 to 2022. Red dots are the centroids of the mining polygons requested at ANM. Colored polygons are the indigenous territories. Each color represents one property right stage, from Study to Homologated. Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, and ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine

se, anyone can legally request a permit to mine a polygon inside the supposed indigenous area.

Figure 2.1 shows the distribution of active mining processes, from research requests to mining permits, in indigenous territories in the Brazilian Amazon. The red dots are the centroids of each mining process, and the colored polygons are the indigenous territories with their corresponding property right stage. Though most are homologated today, at least a hundred were being titled in the 1990s, with many processes already active. Indeed, as one shall see in Figure 2.3, one of the peaks of mining requests happened during that period. We explore the exogenous variation of different sets of property rights with varying mining activity levels in sections 5 and 6.

As mentioned earlier, mining in indigenous territories is yet to be regulated by Congress. The first project bill (*projeto de lei*) was PL 1610/1996, which was rejected in the 1990s. The Bolsonaro administration renewed the efforts for regulation by setting a new project bill, PL 191/2020. The proposal gathered 279 favorable deputies to discuss the bill urgently. This legislation would allow not only mining but also the construction of hydroelectric dams. In the 2022 elections, 79 candidates were related to the mining industry (FOLHA, 2022). Many of them represented the *garimpo*'s cause, supporting the activity's regulation in indigenous territories. As reported by multiple sources (MPF, 2020; MANZOLLI et al., 2021; VILLÉN-PEREZ et al., 2020; PEREIRA; PUCCI, 2021), small-scale miners have been historically associated with illegal mining in these regions. Usually, there's a pre-agreement between them and some indigenous people trading goods for entrance (MENDES, 2004). Naturally, not all indigenous groups benefit from this trade, and this

Figure 2.2 – Legal and Illegal mining spots in the Brazilian Amazon



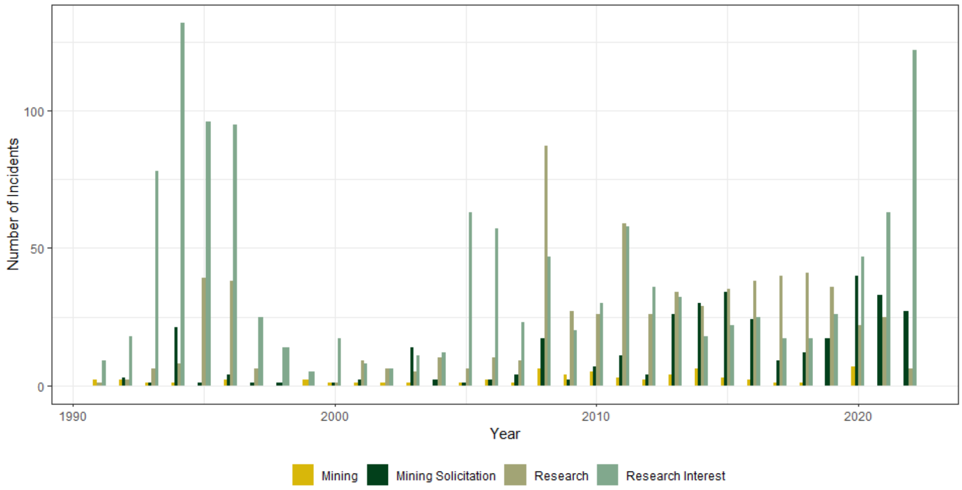
Notes: Legal and Illegal small-scale (*garimpo*) mining spots in the Brazilian Amazon. The Red lines are the active ANM's polygons borders. The purple dots are illegal mining spots from 2001 to 2017. Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine, and RAISG: https://www.raisg.org/en/maps/

distributive issue potentially causes conflicts (LIBECAP, 1990).

In the Amazon, *garimpeiros* are mainly after gold, and they take advantage of established property rights to mask the illegal character of their activity. As shown by MPF (2020) and Pereira and Pucci (2021), a common practice is to claim that gold - or any mineral able to be mined in a rudimentary way - has come from a legal polygon recognized by ANM. A recent incentive to adopt such an approach was law bill 12.844/2013. The legislation made the relationship between the small-scale miner and her first buyer more flexible. In particular, the *Good Faith* of the buyer is the guiding principle of the trade when she only needs to believe that the mineral came from legal activity. Figure 2.2 illustrates this context. The purple dots are the coordinates of illegal mining spots tracked by RAISG, an NGO associated with environmental causes in the Amazon. The red lines are either small-scale mining permits or requests issued by ANM. Their proximity makes it convenient for the miner to *laundry* her mineral and masks its true origin.

Figure 2.3 shows the distribution of mining requests in indigenous territories over the last 30 years. There are the four stages described earlier. Research interest, research (permit), mining interest, and mining (permit). Beginning in 2019, one shall see the rise of research interest in the areas. The anti-conservation discourse described above may have encouraged firms to take the first step and start the procedures to claim polygons in indigenous territories, should the practice become legal. Moreover, these processes have been around indigenous territories no matter the administration in power. Indeed, left-wing governments like Lula's and Rousseff's didn't homologate so many areas; hence, the solicitations have been around the territories ever since.

Figure 2.3 – Mining in indigenous territories (1990 - 2022)



Notes: Yearly distribution of active mining processes in indigenous territories requested at ANM (1990-2022). The requests are research interest, research permits, mining interest, and mining permits. Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, and ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine

In the next section, we argue that the constant requests for research and mining permits, illegal activities, and mining regulation support in Congress are ways players are demanding new institutional arrangments. In a world of zero transaction costs, the parties involved - indigenous people, miners, and the government - would sit down and decide the best use of a particular land. However, we highlight that our context is one of high transaction costs, and any gains of trade in indigenous territories is unlikely. Consequently, we hypothesize that homologation discourages mining requests.

3 Theoretical Framework

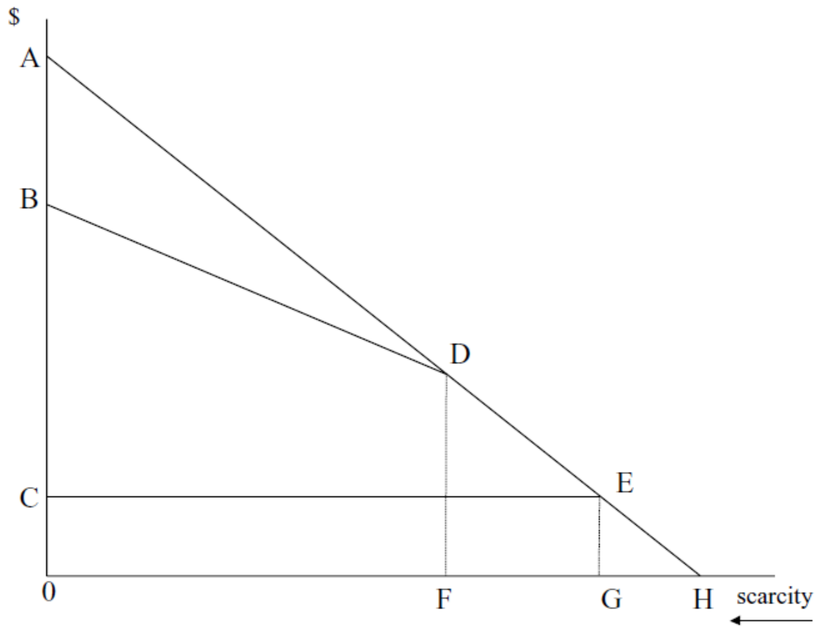
The central focus of this paper is on the impact of property rights on mining. The political economy literature has consolidated the importance of establishing and enforcing property rights to spur economic development (NORTH; THOMAS, 1973; NORTH, 1981, 1990; ACEMOGLU; JOHNSON, 2005; ACEMOGLU; ROBINSON, 2012). In addition, previous research has studied the effect of property rights on violence (MUELLER, 2022; FETZER; MARDEN, 2017) and deforestation (BENYISHAY et al., 2017). The evidence shows that safer property rights reduce violence and land-related conflicts, but not deforestation. Ultimately, in this section, we follow the Institutional and Organizational Analysis literature (COASE, 1960; DEMSETZ, 1967; LIBECAP, 1990; ALSTON, L. J.; MUELLER, 2005; ALSTON, E. et al., 2018) to build our theoretical framework and understand the relationship between property rights and mining.

We follow Mueller (2021) to analyze property rights as a bundle of rights (sticks). They represent a bundle of permissions and constraints applied to the property rights holder and the rest of society. Each stick is an asset's attribute contained in this bundle. Land use, for example, some of its attributes would be the right to conserve, plant, fence, build, or tax. Each is held by different players, like the owner, civil society, and the State. In the case of homologated indigenous lands, the indigenous people have the right to live, preserve, and practice their subsistence activities. The underground resources, however, are not available to anyone to extract and trade. The *de jure* property rights remain with the government. This attribute is in the public domain (a loose stick), meaning no one has the legal right to exercise it.

The *de facto* consequences of this loose stick are twofold. First, it enables different players to create new sets of informal property rights due to the lack of enforcement by the State. It's the case of the illegal mining markets, where indigenous people and *garimpeiros* settle agreements to extract minerals and realize gains of trade. It's also the scenario that highlights the gap between *de jure* and *de facto* property rights (ALSTON, E. et al., 2018). Second, since the big firms are less likely to engage in illegal activities like the ones related to small-scale mining, all they do is keep requesting permits to mine indigenous territories. This latter case is the focus of our empirical exercise in sections 5 and 6. They both have in common that the parties' actions in the public domain may signal their demands for new sets of *de jure* property rights.

Demsetz (1967) argues that a new set of property rights rises when it's *economical* for the parties involved to internalize the costs and benefits (externalities) of this change. It means the players are willing to incur the costs of changing property rights to realize

Figure 3.4 – The demand for and evolution of property rights



Notes: Property rights framework from AlstonMueller2005. X-axis represents resource scarcity, it increases from right to left. Y-axis is the resource net present value.

gains of trade. In the examples mentioned above, big mining firms, small-scale miners, and indigenous people would be inclined to change the *de jure* property rights to be more secure. Safer sets are associated with more economic activity and fewer conflicts (ALSTON, L. J.; LIBECAP; MUELLER, 2000; MUELLER, 2022). Another case that illustrates our point regards the landless peasants and land reform in the Amazon frontier, described by Lee J. Alston, Libecap, and Mueller (2000). The Landless Peasants Movement (MST) would choose private and *unproductive*[1] areas to invade and occupy. They would strategically pick those territories where the land reform agency, INCRA (the National Institute for Colonization and Agrarian Reform), was in the area so they could attract its attention to start an expropriation process, should the agency intervene on behalf of the squatters.

The illegal mining markets, the continuing mining requests, and the MST's invasions are examples of how players demand new property rights. Lee J. Alston and Mueller (2005) present a general and theoretical framework to analyze the demand for property rights security. In Figure 3.4 the horizontal-axis measures the relative scarcity of a given resource (from right to left), in our case, underground mineral resources, and the vertical-axis measures the net present value that the owner receives for that resource. Line *AH* shows that the net present value and the resource scarcity are negatively correlated; in other words, the resource becomes more valuable as it becomes more scarce.

Following our example, at point H, mineral resources are available to everyone, and

[1] The Brazilian Constitution states that every land must fulfill its social interest, like land use for productive reasons.

the economic return is zero. At point *G*, as these assets become more valuable, their owners begin to invest in them for productive reasons. Between points *G* and *F*, property rights are not officially established nor enforced. Instead, the parties settle informal agreements to realize the gains of trade. In our illegal markets example, it would be like a small group of *garimpeiros* compensating a small group of indigenous people for mining in their territories. As news spread and the resource becomes more scarce, more small-scale miners arrive in the area. The informal *de facto* property rights are no longer respected because there is more heterogeneity among the parties involved, and the competition results in distributive disputes among them. This scenario becomes very common at the left of point *F*.

Line *BD* represents the net present value of the resource without enforcing secure property rights. As a result, the parties involved must bear the costs of protecting their resources. The gap between lines *AD* and *BD* represents the gains derived from securing property rights. When resources become more scarce, this framework predicts that there will be a demand for well-established property rights that reduce rent dissipation, enable the owners to invest, lowering conflicts, and spur economic activity.

The Brazilian Constitution dictates that the regulation of mining activity on indigenous land would need to involve the national Congress and the indigenous people affected. In a world of zero transaction costs, Coase's (1960) theorem states that the exchange between the parties will be efficient if property rights are well defined. In our context, miners, indigenous people, Congress, and regulatory agencies, such as FUNAI, would sit down and decide the best use of the land's resources, whether mining or conservation. The corresponding players would be compensated, and there would be gains of trade as Figure 3.4 predicts. But we're not in a world of zero transaction costs.

Even if mining firms, *garimpeiros*, and indigenous people would demand this new property rights arrangement, transaction costs are too high. Libecap (1990) argues that the agreement on a new institutional structure depends, among other things, on the number and heterogeneity of the bargaining parties involved and on how the new design may affect the distribution of their wealth. The case of homologation of indigenous territories involves many parties, like the affected indigenous people, NGOs, politicians, environmentalists, members of the civil society, and even the international community. These groups are sources of great hetorogeneity in beliefs and interests. Thus a new set of property rights that would permit, for example, mining in indigenous territories is improbable. Indeed, as Eric Alston et al. (2018)) show, there are specific scenarios where transaction costs are so high that it is impossible to establish new property rights, and no economic activity is practicable.

Under this framework, we've seen that well-established property rights reduce uncertainty and transaction costs and spur economic activity. If transaction costs were low, mining firms, small-scale miners, and indigenous people could arrange a new, socially-beneficial institutional structure. But since transaction costs are high, the new arrangement seems very unlikely. What is, then, the effect of homologation on mining activities? Since the firms and garimpeiros[2] have no legal right to produce in these areas, all we can analyze are their expectations should the activity become regulated in the future.

The theory described showed two possible outcomes. On the one hand, firms would prefer to request mining permits in homologated territories because better-established property rights imply fewer conflicts and transaction costs, less uncertainty, and more economic activity. This scenario is closer to what the Coase theorem would predict. But on the other hand, since one of the homologation's main goals is to preserve the area the indigenous people inhabit, transaction costs get so high that there's no economic activity. That would make the firms request mining permits where they have more chance to produce, such as not-homologated indigenous territories.

Hence, the net effect of indigenous property rights on mining activity is an empirical matter. Since our context is one of high levels of transaction costs, a quasi-Coesean result seems very unlikely. Homologation increases transaction costs to a level where there are no gains of trade, and a new institutional arrangement among miners, indigenous people, and the government is unreachable. Hence, indigenous land tenure reduces economic activity in these territories. Under this context, we set our hypothesis:

H^1: **The homologation of indigenous territories reduces research and mining requests in these areas.**

We use the PPTAL program to identify the causal relation of homologation to legal mining requests.

The outcome can indicate what we should expect of the *de facto* indigenous land use, even if it's homologated. If homologation causes more mining requests, the firms expect that clear property rights may enable future agreements and compensations with less uncertainty and violence - a quasi-Coasean result. Although there's less violence, there's the potential to increase environmental damage in the area. If homologation causes fewer mining requests, it suggests that the policy and its enforcement may be effective against violence (as seen in Mueller (2022)) and also against environmental effects.

[2] Henceforth, whenever we say firms it also includes garimpeiros and their cooperatives. Since they also request for mining permits, we include their requests as well.

4 Data

We use different data sources to analyze the causal effect of property rights on mining in Brazilian indigenous territories (henceforth, ITs). Below we introduce them and describe the variables constructed for our analysis.

4.1 Indigenous Territories

The indigenous territories data are available at FUNAI and *Instituto Socialambiental*, ISA, an NGO related to indigenous causes. Our final data sample includes 601 ITs which 460 are homologated. FUNAI's data source has the ITs' polygons coordinates. ISA is also a rich data source. We use Mueller's (2022) data, where he compiled the ISA's information from 2006 to 2018. It includes the IT's coordinates, its population number and area extension in ha, its distance to the nearest municipality and the state's capital (both in km), and the IT's property rights situation (homologated or not-homologated). It also includes whether the IT is on the Brazilian border with another country, whether its area overlaps with an environmental conservation unit, and whether the territory is in the Amazon or Atlantic Forest. These variables are later used as time-invariant controls in sections 5 and 6.

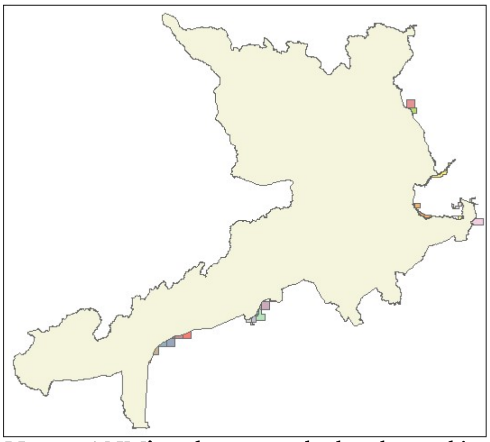
Finally, Mueller (2022) compiled information about the PPTAL program. The data includes the ITs that participated in the program - 123 -, and the ones that didn't. In sections 5 and 6, we use the PPTAL to build a control and treated groups and estimate the effect of land tenure on mining via a propensity score matching.

4.2 Mining Processes

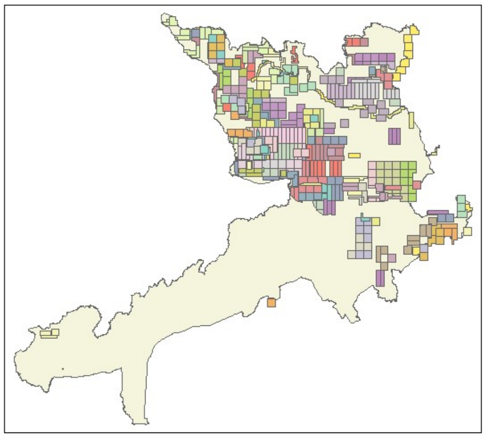
Data from ANM includes all mining processes that the agency recognizes as actives. As explained in section 3, we consider only the research and mining requests disregarding the processes already approved for production. The goal is to capture the firms expectations related to mining in ITs. The processes considered are those whose areas, or polygons, intersect with the indigenous ones. Besides the different request stages mentioned in section 2, we discriminate them by the mining solicitations that are **at the border** of the ITs and the ones that are **at the inside** of the territories. By manually checking a few of the requests and how they overlap with the ITs, we arbitrarily set an intersection cutoff of 50 ha. That way, mining requests having an intersection less or equal to 50 ha are considered to be at the IT's border. Conversely, an intersection greater than 50 ha means the mining solicitation is inside of an IT. Figures 4.5a and 4.5b show the Yanomami case, where one can see that our cutoff distinguishes both types well.

Figure 4.5 – Active mining solicitations in the Yanomami territory

(a) Solicitations at the border



(b) Solicitations at the inside



Notes: ANM's polygons at the border and inside indigenous territories. Mining requests having an intersection less or equal to 50 *ha* are considered to be at the IT's border (Figure 4.5a). Conversely, an intersection greater than 50 *ha* means the mining solicitation is inside of an IT (Figure 4.5b). Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, and ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine

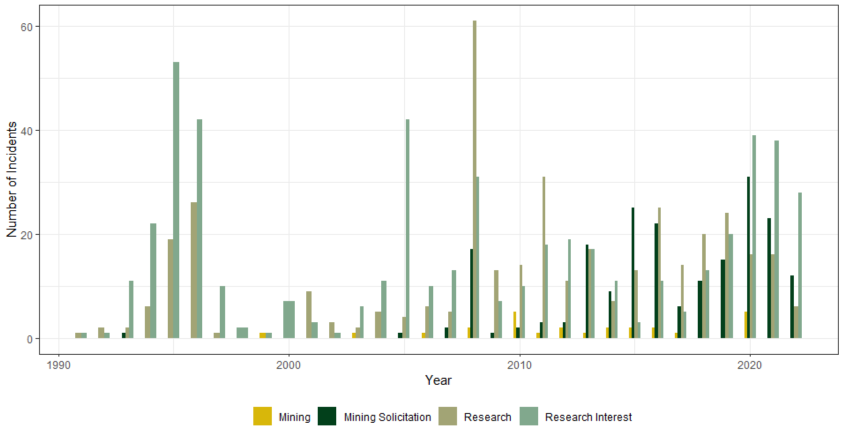
This distinction is motivated by two main reasons. First, ISA considers both types as threats to an indigenous territory. Since they are one of the most prominent NGOs related to indigenous causes, we thought it would be best to follow the exact threat definition. Also, as many illegal mining activities use legal solicitations to mask the resource's true origin (MPF, 2020), one cannot ignore the mining activities happening around an IT. Second, outside (at the border) the ITs one can find any mining request, from research interest to mining production. As Figures 4.6a and 4.7a show, there are no apparent differences in the solicitation types among territories with stronger or weaker sets of property rights.

On the inside of the ITs, however, there seems to be. Figure 4.6b shows that for the homologated territories, the majority of mining requests is the research interests permits. After homologation, there shouldn't be any mining activity. For the not-homologated ITs, Figure 4.7b shows cases of actual mining activity, like research and mining themselves. Since these territories are not indigenous ones, firms may have the property right of a specific area. Ultimately, estimating the effect of property rights on the aggregate number of mining requests, per indigenous territory, without such a distinction could be misleading.

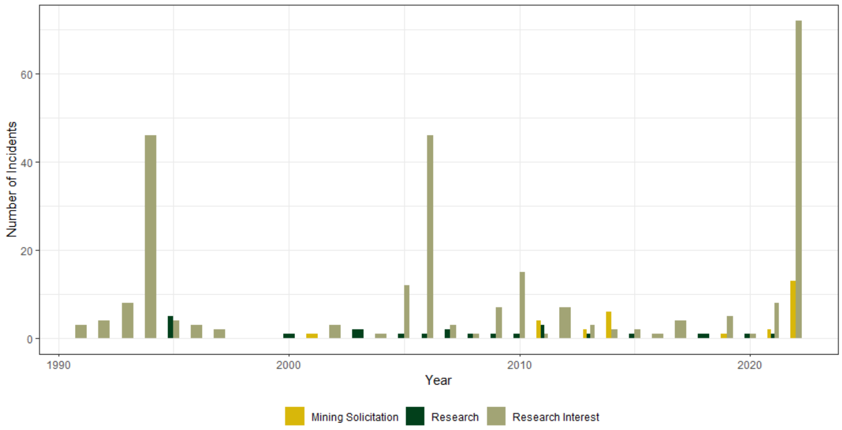
ISA also has the legal history of each indigenous territory, describing the evolution of its property rights. For the homologated ITs, only the mining permits requested after the homologation year are considered. Since any mining activity in homologated ITs is prohibited by law, keeping past solicitations, that is before the land titling, could drive us to misleading results. For instance, according to ISA (2022b) the Yanomami territory became homologated in 1989. Before that year, one will find many gold mining activities inside the corresponding area. Legally speaking, these activities are not supposed to be happening any

Figure 4.6 – Mining in homologated indigenous territories (1990 - 2022).

(a) Mining at the border of homologated ITs



(b) Mining at the inside of homologated ITs



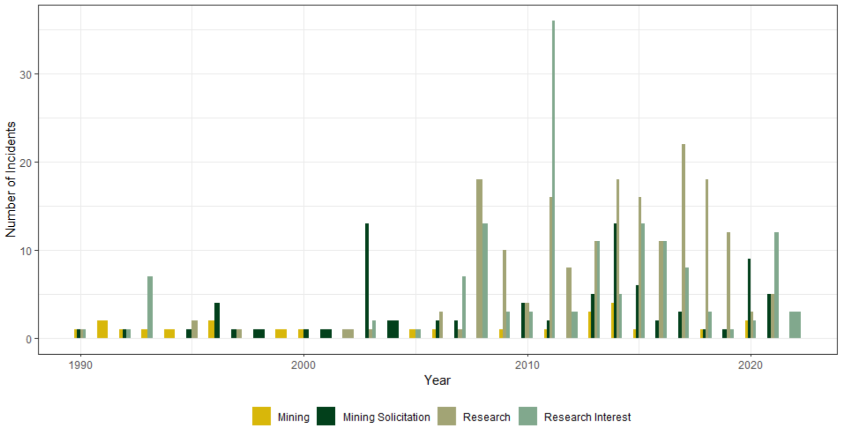
Notes: Yearly distribution of active mining processes in homologated indigenous territories requested at ANM (1990-2022). Figure 4.6a shows the polygons at the borders of the ITs. Figure 4.6b shows the polygons inside the ITs. The requests are research interest, research permits, mining interest, and mining permits. Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, and ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine

longer after homologation, so they are discarded from our analysis.

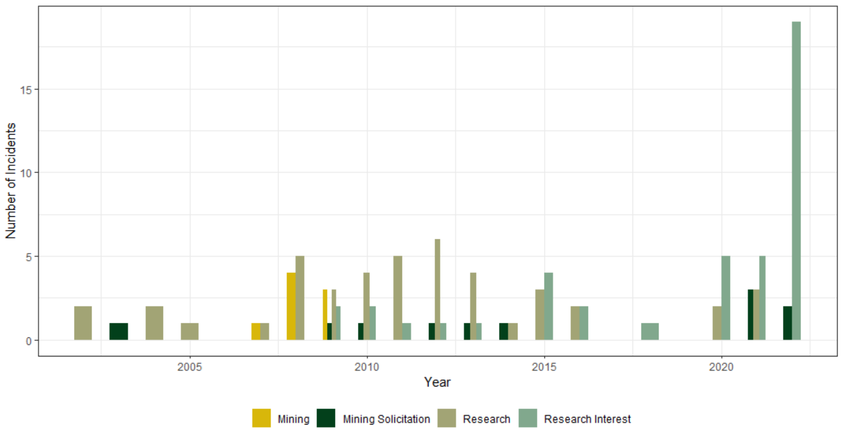
Under this context, we set three outcome variables linked to legal mining: the first *All Requests*, the number of research and mining requests without any discrimination. Then, the following two are related to the border and the inside of the ITs; *Border Requests*, for those solicitations whose intersection with the IT's polygon is less or equal to 50 ha; *Inside Requests*, for those requests whose intersection with the IT's polygon area is greater than 50 ha.

Figure 4.7 – Mining in not-homologated indigenous territories (1990-2022).

(a) Mining at the border of not-homologated ITs



(b) Mining at the inside of not-homologated ITs



Notes: Yearly distribution of active mining processes in not-homologated indigenous territories requested at ANM (1990-2022). Figure 4.7a shows the polygons at the borders of the ITs. Figure 4.7b shows the polygons inside the ITs. The requests are research interest, research permits, mining interest, and mining permits. Data sources from FUNAI: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas, and ANM: https://dados.gov.br/dataset/sistema-de-informacoes-geograficas-da-mineracao-sigmine

5 Empirical Strategy

We begin our empirical exercises with reduced form estimates to consider first the impact on mining requests of only the exogenous variables. We then present the PPTAL program and the propensity score matching strategy to estimate a causal impact of property rights on mining requests.

5.1 Reduced form estimations

We use Mueller's (2022) data set, which contains a rich set of covariates describing the ITs main characteristics. Our reduced form model is:

$$Y_{it} = \beta_0 + \beta_1 X_i + \epsilon_{it}, \quad (5.1)$$

where Y is our outcome variable, the number of research and mining requests in a particular IT, i, in a corresponding year, t. We consider the aggregate number of solicitations but also discriminate them between border and inside requests. Our covariates, X, are the IT's area (in ha) and population, its distance to the nearest municipality and the state's capital, and its coordinates. We also include a set of dummy variables equal to 1 if the IT is in the legal Amazon, if it's in the Atlantic Forest biome, if it's on the Brazilian border with other countries (variable *Frontier*), or if a territory overlaps with an official environmental conservation unit. Finally, ϵ is our error term.

We cannot use fixed effects as all variables are time-invariant. This exercise aims to highlight the possible exogenous determinants of mining in indigenous territories. For instance, one would expect that the IT's distance to a municipality may influence a firm's decision to mine the area since closer cities or counties signal more developed roads, access to services, workforce, etc. Another example is that a more populated indigenous area can make it more difficult for firms to start production due to land conflicts (MUELLER, 2022). They can also have their activities under strict scrutiny by NGOs and regulatory agencies should the IT overlap with an official environmental conservation unit.

5.2 Overcoming endogeneity: PPTAL and PSM

Titling of land is one of the few policies available to do indigenous policy in Brazil (MUELLER, 2022). It's the primary tool policymakers can use to preserve the territory and secure indigenous people's rights. Therefore, it's important to precisely measure the impact of homologation on general outcome variables like violence, environment, health, employment, and, more specifically, mining requests. As discussed in section 3, we hypothesize that official land tenure disincentivizes firms from requesting mining permits due to the high transaction costs involved in the regulation of the activity in homologated ITs.

Under our context, the simultaneity between property rights and resource use is apparent. By reading sections 2 and 3, one understands that land property rights can influence the level of mining and vice versa. Indeed, on the one hand, land tenure policy in ITs increases transaction costs and may reduce firms' mining requests (our hypothesis). Hence, property rights impact mining. On the other hand, once a new IT is identified (early stages of the demarcation process), any economic activity happening in the area (e.g. agriculture, mining, housing, etc) must be compensated to leave the region. It takes time for FUNAI to consolidate such a transition, given its restricted budget. Thus, mining incidents can influence property rights as well.

Another problem with estimating the causal effects of property rights on mining is that the historical demarcation programs didn't randomly choose which ITs to homologate. Indeed, as illustrated by Mueller (2022), between 1988 and 1995, most of the homologation happened in areas that were easy to identify and recognize as indigenous territories. Also, the policy didn't have clear criteria back then, and the titling was done in a hurry to meet a constitutional decree to homologate all ITs in five years. Hence, one cannot compare the ITs homologated in that period to those not titled. There would be backdoor paths opened, and variables potentially confounding the effect of property rights on outcomes. Therefore, the impact of homologation on the outcome variable (e.g., mining requests) would be biased.

We follow Mueller (2022) and BenYishay et al. (2017) and use the PPTAL program to overcome these issues. Alongside the Presidential decree that created clear steps for titling indigenous lands[1], between 1996 and 2005, the Integrated Project for the Protection of the Indigenous Population and Land in the Amazon (PPTAL) identified several new territories and homologated 87 other areas. The World Bank led the program, and its objective was to "improve the conservation of natural resources in indigenous areas and increase the well-being of indigenous people" (World Bank, p.4, (1995)). The program, however, didn't have the resources to title all locations, so they established a vulnerability order in which indigenous lands would be regularized. Territories would be considered vulnerable if they met two or more criteria. Some of them were: the proximity of 100 km or less to an urban center; inter-ethnic conflict cases or socio-cultural threats from external pressures; epidemics cases in the corresponding area; government projects for regional development; and easy access by road or navigable river (World Bank (1995)).

A sample of these territories met the criteria described but, for some reason, did not participate in the program. Therefore, there are two groups of lands with very similar characteristics, those that were *treated* by PPTAL and those that were not. Under this context, we use nearest neighbor propensity score matching (PSM) to find a counterfactual non-

[1] See section 2.

PPTAL territory (control group) for each one that was part of the program (treatment group). Our outcome variable is the aggregate research/mining solicitations requested by firms from 2006 to 2018 after the PPTAL program ended. Given the similarity between the two groups, except for the PPTAL participation, we expect that the average difference in mining requests between the PPTAL territories and the non-PPTAL ones is due to the program's treatment, in this case, homologation. Since one of the program's main goals was to conserve natural resources, this exercise may provide the causal impact of property rights on mining.

The matching is done on six covariates that serve as *proxies* to the criteria defined by the World Bank. They are (i) distance to the nearest town, (ii) distance to the state's capital, (iii) IT's area and (iv) population, (v) whether the territory is in the Brazilian border with other countries, and (vi) whether the territory overlaps with an environmental conservation unit. We consider only the ITs in the Amazon area since the program focused on that region. Also, we run two robustness checks. The first one is to consider only the territories with at least one mining request in the sample period, 2006-2018. Maybe some territories are not mineral sources and wouldn't have any solicitations in their area, independently of being homologated or not. That could lead to misleading estimates. Second, we disregard the territories homologated before 1996 (pre-1996 lands). If these areas were matched as counterfactuals, it could bias our estimates because they had already been homologated, not needing the PPTAL treatment in the first place. In the next section, we discuss the results of each empirical exercise. Table 5.1 provides summary statistics.

Table 5.1 – Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
All Requests	601	1.058	3.349	0	34
Border Requests	601	0.820	2.671	0	30
Inside Requests	601	0.238	1.298	0	18
PPTAL	601	0.205	0.404	0	1
Area (ha)	588	200,084.400	768,341.700	0.000	9,664,980.000
Population	601	1,036.231	2,553.468	0	26,780
Distance(capital) (km)	601	411.403	292.427	0.000	1,314.534
Distance(nearest town) (km)	601	40.506	42.974	0.000	275.800
Amazon	601	0.607	0.489	0	1
Atlantic Forest	601	0.285	0.452	0	1
Frontier	601	0.256	0.437	0	1
Overlap	601	0.175	0.521	0	3
Latitude	601	12.154	8.768	0.003	32.035
Longitude	601	54.999	9.180	34.906	73.076

Notes: There are 601 indigenous territories in our sample. The observations are at the level of indigenous lands. The time variant variables are the research and mining requests. They are also the outcome variables. They are constructed with annual data from ANM (2006-2018). We discriminate the requests by border and inside polygons, as discussed in section 4. Time invariant variables are taken from Mueller's (2022) data set. In the reduced form estimates, Area and population are in logs due to the skewed distributions. PPTAL is our variable of interest. It's a dummy that equals one if the IT participated in the program (1996-2005).

6 Main Results

In section 5, we discussed how some covariates could be associated with a firm's decision to request a research/mining permit in indigenous lands. We begin our analysis with the reduced form estimations to understand these determinants. Table 6.2 shows our results. Our outcome variable is the number of research/mining requests in an IT in a particular year. In the first column, we have the aggregate cases; in the other two, we discriminate them by border and inside incidents, respectively.

The IT's population size does not seem to be associated with new mining requests. We expected this variable to be negatively correlated with the solicitations since a bigger indigenous population could have more attention from the media, NGOs, and civil society. This raises transaction costs, and the firms may reduce the solicitations in more populated territories. The covariate negatively correlates with the aggregate mining requests, but it's not statistically significant. When we discriminate the solicitations by border and inside, the population variable remains negatively correlated with the former cases but positively correlated with the latter ones. Both remain statistically insignificant. We find evidence that larger areas are associated with more yearly mining requests. This result is expected as larger ITs may have more mineral sources grabbing more interest from the firms, especially at the border of the territories where they can legally produce. Indeed, a 10% area increase (in ha) is associated with approximately 0.2 more mining solicitations in a year. This result is significant for both *All* and *Border* cases at a 5% level. We lose significance for the *Inside* incidents, though the signal remains positive.

We find evidence of an association between the IT's distance to the nearest municipality and mining requests. The results show a positive and significant effect on the aggregate and border cases. In particular, a 100km increase in the distance is associated with a yearly rise of 0.2 and 0.1 mining requests for the *All* and *Border* variables, respectively. This goes against our discussion from section 5. We expected that firms would request more solicitations in places closer to municipalities due to public services and workforce availability. Maybe they prefer areas further away from the municipalities to avoid attention from people related to indigenous causes, or most of the mineral sources are located in more distant regions. Either way, we lose the significance when analyzing only *Inside* requests. We also find weak evidence of a correlation between the IT's distance to the state's capital covariate and our outcome variables.

Regarding the dummy variables, *Overlap* equals 1 if the indigenous territory overlaps with environmental conservation units. This covariate is positively correlated to *All* and *border* solicitations at a 10% significance level. The dummies related to the Amazon and

Atlantic Forest regions don't seem to be associated with the firm's decision to request mining permits in ITs. Indeed, what drives miners are the mineral sources' locations, no matter the biome. We find weak evidence on the correlation between *Frontier* dummy - equals 1 with the IT is on the Brazilian border with other countries - and mining requests.

Table 6.2 – Reduced form estimates

	Dependent variable:		
	All	Border	Inside
Population	−0.001	−0.009	0.008
	(0.014)	(0.012)	(0.005)
Area	0.019**	0.017**	0.002
	(0.008)	(0.007)	(0.002)
Distance to capital	−0.00005	0.00002	−0.0001***
	(0.0001)	(0.00005)	(0.00002)
Distance nearest town	0.002**	0.001**	0.0002
	(0.001)	(0.001)	(0.0002)
Amazon	−0.052	−0.042	−0.010
	(0.059)	(0.055)	(0.013)
Atlantic Forest	0.015	−0.001	0.016
	(0.040)	(0.034)	(0.014)
Frontier	0.028	−0.003	0.032***
	(0.020)	(0.017)	(0.008)
Overlap	0.085*	0.058*	0.027
	(0.046)	(0.032)	(0.021)
Latitude	−0.003*	−0.0001	−0.003***
	(0.002)	(0.001)	(0.001)
Longitude	−0.001	−0.001	0.0004
	(0.001)	(0.001)	(0.0005)
Observations	7,059	7,059	7,059
R^2	0.029	0.025	0.020
Adjusted R^2	0.028	0.023	0.018
F Statistic (df = 10; 7048)	21.160***	17.721***	14.212***

*p<0.1; **p<0.05; ***p<0.01

Notes: Standard errors in parenthesis. Robust errors. Mining data from ANM and indigenous data from Mueller's (2022) data set.

6.1 Matching results

In section 3, we used the Institutional and Organizational Analysis literature to built our theoretical framework. Our research question is: what is the effect of homologation on mining activities? In a world of zero or very few transaction costs, firms might prefer homologated ITs because there would be less uncertainty in negotiating resource (minerals) use. As a result, there would be fewer conflicts (MUELLER, 2022) and potential economic activity (a quasi-Coesean result). But, as discussed in section 2, dealing with indigenous land is far away from a Coesean world of zero transaction costs. In reality, given the high heterogeneity of the parties involved and the task of distributing the wealth among them, establishing a new, socially-beneficial institutional structure is very unlikely (LIBECAP, 1990).

We argue that transaction costs are so high in the homologated areas that any gains of trade are unlikely to happen. Moreover, since the firms have no legal right to produce in these areas, all we can analyze are their expectations should the activity become regulated in the future. Therefore, our hypothesis is:

H^1: **The homologation of indigenous territories reduces research and mining requests in these areas.**

In section 5, we discussed the endogeneity between property rights and resource use variables highlighted by Mueller (2022). To correct this issue, we used the PPTAL program to build a counterfactual sample of not homologated territories to be compared with the lands *treated* by PPTAL. We used nearest neighbor propensity score matching to estimate the causal impact of property rights on mining. The first results are shown in Table 6.3. We consider all the ITs from the Amazon sample. There are 325 indigenous territories in that region, and our matched sample has only 188. The balance test and the plot distribution are in Appendix **??**. The estimation is the average treatment effect (ATE) of the PPTAL on the mining requests.

Regarding the aggregate mining requests variable, we find that the territories treated (hence, homologated) by PPTAL have, on average, approximately 2 fewer mining solicitations compared to the control group, that is, the territories that were supposed to receive the treatment but for some reason didn't. This effect is significant at the 5% level. We find the same negative effects when discriminating the solicitations by border and inside cases, though the result is not statistically significant for the former. This was expected as we saw in section 4, the main difference between homologated and not-homologated lands were the requests inside these regions. Indeed, we find a negative and significant effect of PPTAL treatment on mining solicitations requested inside the ITs.

These results go in favor of our hypothesis, H^1. Our results indicate that homologation discourages mining requests because the firms are not expecting a new institutional

Table 6.3 – Effect of property rights on mining through matching

	Research/Mining requests:		
	All	Border	Inside
PPTAL	−1.814**	−1.301	−0.513**
	(0.791)	(0.734)	(0.216)
Observations	188	188	188

*p<0.1; **p<0.05; ***p<0.01

Notes: Nearest neighbor propensity score matching. Standard errors in parenthesis. Robust errors. 188 observations. Covariates are: distance to the nearest municipality, distance to the state's capital, area, population, frontier and overlap. Mining data from ANM and indigenous territories data from Mueller's (2022) data set.

arrangement enabling them to produce in indigenous lands. Instead, they request permits where there's a real chance of production, for example, in not-homologated ITs. Finally, the policy implications are that indigenous land titling not only reduces violence, as shown by Mueller (2022) but also provides environmental conservation as it reduces mining activities that are usually associated with deforestation and river poisoning (MANZOLLI et al., 2021).

6.1.1 Robustness checks

We present the robustness checks discussed in section 5. Both matching balance tests and distribution plots are in Appendix **??**. In the first check, we consider only the ITs with at least one mining request in the period post-PPTAL (2006-2018). Maybe the territory has zero mining requests because there's nothing in the region to be extracted. Thus, using these cases as counterfactuals may drive us to misleading results. Our sample gets reduced to 102 ITs, but only 44 are matched. Results are shown in Table 6.4.

We find that, on average, the ITs treated by PPTAL have approximately 3.5 fewer mining requests than the territories that could have been treated but, for some reason, weren't. Border solicitations remain with a similar magnitude. When we analyze only the inside cases, ITs treated have, on average, 0.16 fewer requests compared to those in the control group. Although the effects remain negative and aligned with the theoretical mechanisms discussed earlier, they are not statistically significant. It probably relates to the sample size. Ideally, we would want more than 44 matched ITs to be compared to estimate a more robust result. For future work, we may follow CPI2021 and use the Brazilian Geological Service database, which maps all the known mineral deposits in Brazil. That way, we can check which ITs are indeed mineral sources and, hopefully, expand our sample.

Our next check regards the group of ITs that were already homologated before PPTAL

Table 6.4 – Indigenous territories with at least one mining request

	Research/Mining requests:		
	All	Border	Inside
PPTAL	−3.48	−3.32	−0.16
	(2.257)	(2.094)	(0.452)
Observations	44	44	44

*p<0.1; **p<0.05; ***p<0.01

Notes: Nearest neighbor propensity score matching. Standard errors in parenthesis. Robust errors. 44 observations. Covariates are: distance to the nearest municipality, distance to the state's capital, area, population, frontier and overlap. Mining data from ANM and indigenous territories data from Mueller's (2022) data set.

Table 6.5 – Indigenous territories homologated during or after PPTAL

	Research/Mining requests:		
	All	Border	Inside
PPTAL	−0.23	−0.23	0.00
	(0.543)	(0.487)	(0.156)
Observations	150	150	150

*p<0.1; **p<0.05; ***p<0.01

Notes: Nearest neighbor propensity score matching. Standard errors in parenthesis. Robust errors. 150 observations. Covariates are: distance to the nearest municipality, distance to the state's capital, area, population, frontier and overlap. Mining data from ANM and indigenous territories data from Mueller's (2022) data set.

(1988-1995) but could potentially be part of our exercise's control group. We remove them from our analysis since they could be considered non-treated and homologated simultaneously. Our sample is reduced to 215 ITs, and 150 of them are matched. Results are shown in Table 6.5. This time, our magnitudes are generally reduced. Even though the *All* and *Border* outcome variables remain negative, the effects are not statistically significant and close to zero. Our estimation for the *Inside* variable is very close to zero at a p-value close to 1. We once again face a sample size issue. Out of the 215 ITs, less than ten have at least one mining request inside their area. Another issue is the possibility of pre1996-homologated ITs being included in the matching of Table 6.3 above since we found significant effects on the *Inside* outcome variable.

Under this context, our main challenge is to expand our sample to have more mining cases. In general, the effect of the PPTAL treatment remains negative in the three matchings discussed above, though we lose statistical significance in the last two. Our main results are not as robust as we would like, although they provide evidence of the causal impact of indigenous property rights on mining.

7 Conclusion

In this paper, we aimed to investigate the impact of property rights on mining. We followed the literature on Institutional and Organizational Analysis to build our hypothesis. In a world of zero transaction costs, miners, indigenous people, and the government would define the best land use, either conservation or production. We argued that due to the parties' heterogeneity and the wealth distributive conflicts, transaction costs in homologated territories get so high that economic activity seems very unlikely in these areas. Under this context, we hypothesized that land tenure in these regions reduces mining activities.

To test our hypothesis, we used PPTAL to build a control group that we could use as counterfactual to the sample of ITs participating in the program. We used propensity score matching to estimate the causal impact of homologation on mining requests. We found that the treated group has, on average, approximately two fewer mining processes regarding research and mining interests compared to the control group. We ran two robustness checks, and although the estimates remained negative, we lost statistical significance. That implies that our results are not as robust as we would like.

Land titling is the most critical policy in indigenous territories. Our results indicate that homologation not only reduces violence, as shown by Mueller (2022), but it also reduces environmental damage as mining activities are often associated with deforestation and river poising (MANZOLLI et al., 2021).

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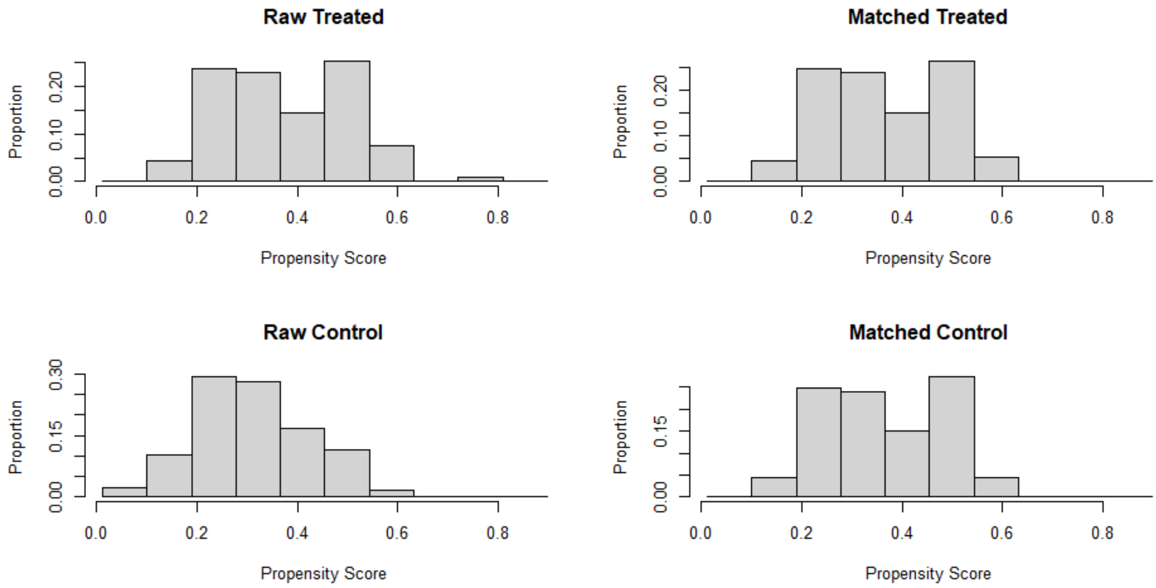
Appendix

Appendix A – Balance Tests

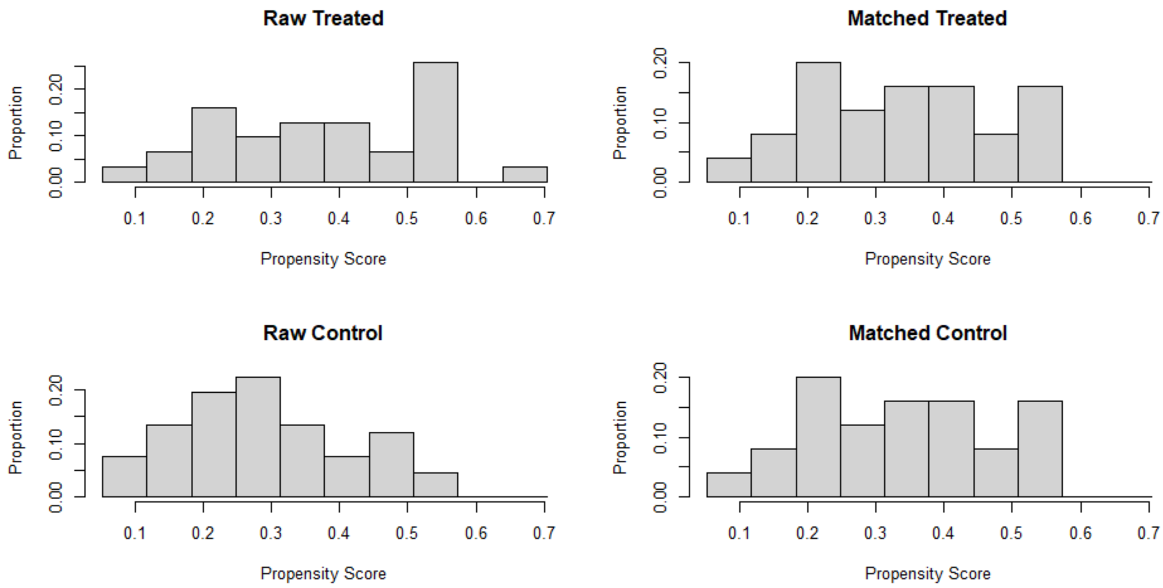
In this Appendix we provide balance tests and distribution plots of our PSM exercises. We performed t-tests of mean differences before and after the matching is done. The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups. The distribution plots illustrate the balances.

Figure A.8 – Matching distribution from Table 6.3



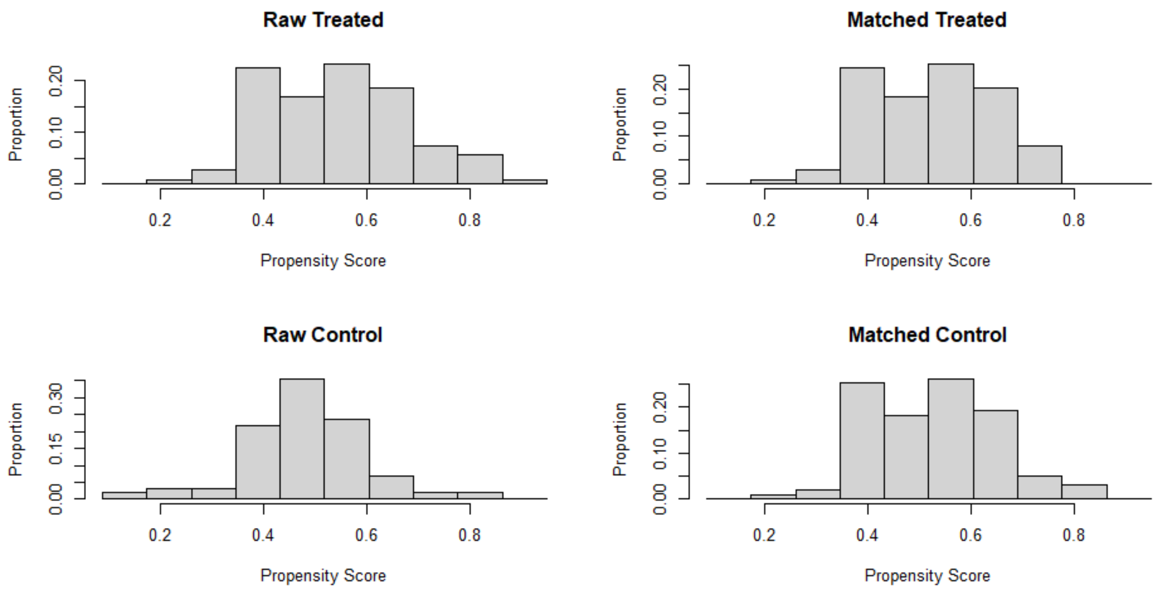
Notes: Nearest neighbor propensity score matching. Plot distribution from matching in Table 6.3. The plots present the raw treated and control groups (before the matching), and the matched samples (after the matching).

Figure A.9 – Robustness check: mining requests matching distribution



Notes: Nearest neighbor propensity score matching. Plot distribution from matching in Table 6.4. The robustness check considered only ITs with at least one mining request in the period (2006-2018). The plots present the raw treated and control groups (before the matching), and the matched samples (after the matching).

Figure A.10 – Robustness check: pre-1996 homologated ITs matching distribution



Notes: Nearest neighbor propensity score matching. Plot distribution from matching in Table 6.5. The robustness check disregarded the ITs homologated before PPTAL started (1988-1995). The plots present the raw treated and control groups (before the matching), and the matched samples (after the matching).

Table A.6 – Unmatched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	359.227	597.234	-238.007	<0.001	Reject H0 at 5%
Distnearmun	33.189	61.237	-28.048	<0.001	Reject H0 at 5%
Area	146723.683	412622.729	-265899.046	<0.001	Reject H0 at 5%
Population	1101.706	752.085	349.622	0.186	Do not reject H0 at 5%
Frontier	0.260	0.263	-0.003	0.945	Do not reject H0 at 5%
Overlap	0.200	0.085	0.115	0.033	Reject H0 at 5%

Notes: Nearest neighbor propensity score matching. t-tests for unmatched sample in Table 6.3. The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Table A.7 – Matched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	515.617	575.242	-59.625	0.330	Do not reject H0 at 5%
Distnearmun	61.410	57.841	3.569	0.760	Do not reject H0 at 5%
Area	546222.602	278288.602	267934.000	0.269	Do not reject H0 at 5%
Population	705.354	723.460	-18.106	0.953	Do not reject H0 at 5%
Frontier	0.301	0.248	0.053	0.525	Do not reject H0 at 5%
Overlap	0.044	0.088	-0.044	0.313	Do not reject H0 at 5%

Notes: Nearest neighbor propensity score matching. t-tests for matched sample in Table 6.3. The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Table A.8 – Robustness check mining requests: unmatched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	479.413	643.135	-163.721	0.016	Reject H0 at 5%
Distnearmun	61.251	66.877	-5.626	0.580	Do not reject H0 at 5%
Area	539015.284	616737.677	-77722.394	0.797	Do not reject H0 at 5%
Population	1460.627	1425.065	35.562	0.969	Do not reject H0 at 5%
Frontier	0.284	0.258	0.026	0.795	Do not reject H0 at 5%
Overlap	0.254	0.097	0.157	0.224	Do not reject H0 at 5%

Notes: Nearest neighbor propensity score matching.t-tests for unmatched sample in Table 6.4. Robustness check considered only ITs with at least one mining request in the period (2006-2018). The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Table A.9 – Robustness check mining requests: matched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	512.263	549.430	-37.167	0.713	Do not reject H0 at 5%
Distnearmun	60.079	62.480	-2.400	0.896	Do not reject H0 at 5%
Area	454309.800	293447.920	160861.880	0.437	Do not reject H0 at 5%
Population	762.200	606.640	155.560	0.576	Do not reject H0 at 5%
Frontier	0.160	0.240	-0.080	0.504	Do not reject H0 at 5%
Overlap	0.080	0.120	-0.040	0.659	Do not reject H0 at 5%

Notes: Nearest neighbor propensity score matching. t-tests for matched sample in Table 6.4. Robustness check considered only ITs with at least one mining request in the period (2006-2018). The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Table A.10 – Robustness check no pre-1996 homologated ITs: unmatched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	504.173	599.735	-95.562	0.031	Reject H0 at 5%
Distnearmun	60.872	63.687	-2.815	0.682	Do not reject H0 at 5%
Area	264201.673	444048.720	-179847.046	0.205	Do not reject H0 at 5%
Population	611.980	715.888	-103.908	0.765	Do not reject H0 at 5%
Frontier	0.168	0.271	-0.103	0.075	Do not reject H0 at 5%
Overlap	0.238	0.093	0.144	0.035	Reject H0 at 5%

Notes: Nearest neighbor propensity score matching. t-tests for unmatched sample in Table 6.5. Robustness check disregarded the ITs homologated before PPTAL started (1988-1995). The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Table A.11 – Robustness check no pre-1996 homologated ITs: matched sample balance test

Variable	Mean_Control	Mean_Treated	Difference	p-value	Conclusion
Distocap	569.119	559.685	9.434	0.908	Do not reject H0 at 5%
Distnearmun	61.884	61.988	-0.105	0.992	Do not reject H0 at 5%
Area	236063.586	250199.495	-14135.909	0.907	Do not reject H0 at 5%
Population	312.768	422.788	-110.020	0.398	Do not reject H0 at 5%
Frontier	0.222	0.212	0.010	0.905	Do not reject H0 at 5%
Overlap	0.121	0.101	0.020	0.738	Do not reject H0 at 5%

Notes: Nearest neighbor propensity score matching. t-tests for matched sample in Table 6.5. Robustness check disregarded the ITs homologated before PPTAL started (1988-1995). The $H0$ hypothesis is that there are no differences in the covariates' means between treated and control groups.

Appendix B – Resumo estendido: Língua Portuguesa

A mineração está presente no Brasil desde o período da colonização. Ela tem influenciado transformações sociais e econômicas, desde ascensões sociais até o surgimento de cidades e conexões de mercado. Também está associada à degradação ambiental (Manzolli et al. 2021). Os povos indígenas habitam essa área e muitas outras desde antes da descoberta do Brasil. Seus territórios são conhecidos por serem fontes minerais e têm atraído inevitavelmente os mineradores. A mineração em territórios indígenas homologados é proibida por lei, mas grupos de políticos e mineradores sempre tentaram regularizar a atividade nessas áreas.

A regulamentação da mineração em territórios indígenas frequentemente está na agenda do Congresso Brasileiro. O primeiro projeto de lei foi o PL 1610/1996, que foi rejeitado na década de 1990. No entanto, o governo Bolsonaro renovou os esforços para regulamentação ao propor um novo projeto de lei, o PL 191/2020. Nas eleições de 2022, 79 candidatos tinham ligações com a indústria da mineração (Folha de S. Paulo 2022). Muitos deles representavam a causa do garimpo, apoiando a regulamentação da atividade em territórios indígenas. Enquanto isso, empresas e mineradores de pequena escala continuam solicitando processos de mineração na esperança de que suas empreitadas sejam regulamentadas em territórios indígenas. Além disso, mineradores de pequena escala têm sido associados a atividades ilegais nessas áreas.

Neste artigo, temos como objetivo medir o impacto dos direitos de propriedade indígenas na mineração. Seguindo a literatura de Análise Institucional e Organizacional (Coase 1960, Demsetz 1967, Libecap 1990, Alston e Mueller 2005 e Alston et al. 2018), argumentamos que essas constantes solicitações de pesquisa e licenças de mineração, atividades ilegais e apoio à regulamentação da mineração no Congresso são formas pelas quais os atores demandam novos arranjos institucionais. Em um mundo de custos de transação zero, o teorema de Coase (1960) afirma que, se os direitos de propriedade estiverem bem definidos, a troca entre as partes será eficiente. No entanto, sob nosso contexto, dada a heterogeneidade entre as partes envolvidas, argumentamos que os custos de transação são tão altos em territórios homologados que é improvável que ocorra um novo arranjo institucional regulando a mineração em áreas indígenas. Como as empresas não têm direito legal de produzir nessas áreas, tudo o que podemos analisar são suas expectativas caso a atividade seja regulamentada no futuro.

Entre 1996 e 2005, uma iniciativa do Banco Mundial ajudou a identificar e reconhecer territórios indígenas na Amazônia, o PPTAL. Utilizamos o PPTAL para construir uma amostra contrafactual de territórios não homologados para ser comparada com as terras "tratadas" pelo programa. Utilizamos o método de pareamento de escores de propensão de vizinho mais próximo para estimar o impacto causal dos direitos de propriedade na mineração. Descobrimos que os territórios indígenas tratados (homologados) têm, em média, menos solicitações de mineração do que o grupo de controle (não homologados) após o término do programa. Realizamos verificações de robustez e, embora o efeito tenha permanecido negativo, perdemos a significância estatística. No entanto, nossos resultados indicam que a homologação não apenas reduz a violência, como mostrado por Mueller (2022), mas também reduz os danos ambientais, já que as atividades de mineração muitas vezes estão associadas ao desmatamento e à poluição dos rios (Manzolli et al. 2021).

Este artigo contribui para a literatura sobre terras indígenas brasileiras. Nosso trabalho segue o de Mueller (2022) e continua investigando o papel dos direitos de propriedade indígenas nas questões de desenvolvimento do Brasil. A literatura consolidou a importância do estabelecimento e aplicação de direitos de propriedade para impulsionar o desenvolvimento econômico (North e Thomas 1973, North 1981, North 1990, Acemoglu e Johnson 2005 e Acemoglu e Robinson 2012). Além disso, pesquisas anteriores estudaram o efeito dos direitos de propriedade na violência (Mueller 2022, Fetzer e Marden 2017) e no desmatamento (BenYishay et al. 2017). A evidência mostra que direitos de propriedade mais seguros reduzem a violência e os conflitos relacionados à terra, mas não o desmatamento. Agora investigamos como a posse da terra afeta o setor de mineração.