Pontifícia Universidade Católica
do Rio de Janeiro

Arthur Maurício Rodrigues

Causes and consequences of infrastructure concession failure: evidence from Brazilian roads.

Dissertação de Mestrado

Masters dissertation presented to the Programa de Pós–graduação em Economia, do Departamento de Economia da PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Economia.

Advisor: Prof. Leonardo Rezende

Rio de Janeiro
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To my parents, for their support
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Abstract

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Concession agreements are widely used in developing countries for financing infrastructure projects such as highways, railroads, and power and water systems. However, many concession contracts fail and are terminated prematurely, leading to unfulfilled investments and deteriorating infrastructure. This study consists of complementary analyses aimed at exploring the causes and consequences of concession contract failures within the institutional context of Brazilian transportation concessions. First, we develop a dynamic structural model in which concession firms decide their investment levels and whether to terminate their contracts early. The results reveal that firms face significant exit costs and incur penalties for delaying investment. Second, we examine the relationship between road conservation status and transportation costs, given that highways under concession contracts exhibit significantly better quality than publicly managed ones. The results suggest that traveling on roads of excellent quality is about half as costly as traveling on poorly maintained roads. This dual framework provides insights into the welfare implications of early contract terminations in transportation concession agreements.

Keywords

infrastructure financing; concession contracts; contract termination; transportation infrastructure; dynamic discrete choice model; highway concessions; toll pricing.

Resumo

Maurício Rodrigues, Arthur; Rezende, Leonardo. **Causas e consequências do insucesso de concessões de infraestrutura: evidências de rodovias brasileiras.**. Rio de Janeiro, 2025. 45p. Dissertação de Mestrado – Departamento de Economia, Pontifícia Universidade Católica do Rio de Janeiro.

Contratos de concessão são amplamente utilizados nos países em desenvolvimento para financiar projetos de infraestrutura, como rodovias, ferrovias e sistemas de energia e saneamento básico. Entretanto, muitos contratos de concessão são rescindidos antes de sua conclusão, causando deterioração da infraestrutura física em função de investimentos não realizados. Este estudo é constituiído de análises complementares com o objetivo de explorar as causas e as consequências dos fracassos dos contratos de concessão no contexto institucional das concessões de transporte rodoviário brasileiras. Primeiramente, desenvolvemos um modelo estrutural dinâmico de escolha discreta no qual as empresas concessionárias decidem seus níveis de investimento e se rescindem seus contratos antecipadamente. Em segundo lugar, examinamos a relação entre o status de conservação das estradas e os custos de transporte, uma vez que as rodovias sob contratos de concessão apresentam qualidade significativamente melhor do que as administradas pelo poder público. Os resultados indicam que viajar em estradas de excelente qualidade custa aproximadamente a metade do que viajar em estradas mal conservadas. Essa estrutura permite investigar as implicações das rescisões antecipadas no bem-estar.

Palavras-chave

financiamento de infraestrutura; contratos de concessão; rescisão contratual; infraestrutura de transportes; modelo dinâmico de escolha discreta; concessões rodoviárias; precificação de pedágios.

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List of Abbreviations

NLLS – Nonlinear Least Squares
PPPs – Public-private Partnerships (PPPs)
BOT – Build, Operate and Transfer
PPI – Private Partnership in Infrastructure database
PROCOFE – Program of Concession of Federal Roadway
ANTT – National Agency of Land Transport
CNT – National Confederation of Transportation
ESALQ – Logistic Group of the College of Agriculture Luiz de Queiroz
BBL – (BAJARI; BENKARD; LEVIN, 2007)
CCP – Conditional Choice Probability

1
Introduction

Historically, governments have been the primary providers of infrastructure services in developing countries, either through direct investment or the establishment of public entities dedicated to the construction and operation of large-scale projects. However, these governments often face fiscal constraints and may lack the necessary execution capabilities to expand infrastructure stock efficiently. Consequently, a significant global trend has emerged, with developing countries increasingly relying on public-private partnerships (PPPs) to finance their infrastructure needs. Among PPPs, one widely adopted contract model in these countries is the build, operate and transfer (BOT) concession. Under this arrangement, private firms invest in an infrastructure project, manage and operate it for a predetermined period while generating revenue through user charges, and ultimately transfer ownership back to the public sector. Although BOT contracts are not exclusively used by low- and middle-income countries, they are particularly attractive to them: unlike traditional procurement, BOT concessions do not depend on direct government transfers to firms. Instead, firms are remunerated entirely through user charges, facilitating project financing in contexts of limited fiscal capacity. Such contracts are widely employed across infrastructure sectors from electricity generation, transmission and distribution to water supply and sanitation. In the transportation sector, they have been used to franchise existing (brownfield) highways, tunnels, bridges, railroads, ports, airports and highways, as well as to develop new (greenfield) projects. According to the Private Partnership in Infrastructure database (PPI) (World Bank, 2023), there are currently 5,989 active BOT contracts in low- and middle-income countries, representing over $1.1 trillion in expected investment.

Despite their widespread adoption, concession contracts often face significant challenges. Incumbent firms frequently request renegotiation of contractual terms, either to address unforeseen financial shocks or as a result of opportunistic behavior. Ultimately, these issues may result in the early termination of contracts, demanding assets to be re-allocated. This severely undermines the advantages of PPPs, causing delays in new investments and the deterioration of existing infrastructure, with adverse welfare implications. According to the PPI database, there are 1.6 canceled BOT projects for every successfully concluded one. Regardless of their practical relevance, these problems remain under-explored in the economic literature.

In this work, we empirically investigate concession failures in the transportation sector, with data from highway BOT concessions in Brazil. Our main objective is to understand the factors influencing incumbents' decision to terminate concession contracts and quantify the welfare impacts of early termination. First, we propose a dynamic discrete choice model to capture the economic reasoning behind firms' decisions to either invest in or abandon a concession. Our findings reveal that firms face substantial exit costs and are penalized by regulators for failing to meet investment schedules. Exit cost decreases substantially when new legislation allows for a formal early termination request and process. Second, we gather data on road conservation status to assess the association between BOT concessions and infrastructure quality improvements. Employing a network-based, data-driven approach, we estimate the costs of transporting agricultural goods on roads of varying quality. The analysis indicates that transportation on well-maintained roads is less than half as costly as on poorly maintained ones. Then, we compute the welfare cost of concession early termination, given that BOT concession roads display better quality than public ones, and compare it with the exit cost faced by firms.

This study contributes to multiple strands of economic literature. First, we build on the narrow literature on concession contracts, where theoretical works have aimed to characterize optimal concession allocation (RIORDAN; SAPPINGTON, 1987; ENGEL; FISCHER; GALETOVIC, 2001) and characterized the benefits of PPPs (AURIOL; PICARD, 2013). GUASCH; LAFFONT; STRAUB (2008) investigates renegotiation in concession contracts, offering a model of renegotiation and a reduced-form approach to identify factors that drive contract renegotiations in Latin American concessions. We extend this literature by empirically examining the critical issue of early terminations. Thereby, we also contribute to the broader empirical regulation literature (RYAN, 2020; ABITO, 2020; DUFLO et al., 2018; LEWIS; BAJARI, 2014), which usually employs structural models of firm behavior to assess impacts of contract allocation and enforcement in infrastructure procurement PPPs. We add to this body of work by using similar methods to investigate concession contracts, which have received limited attention in this literature.

This work also relates to the literature on the impacts of transportation infrastructure on trade cost reduction (DONALDSON; HORNBECK, 2016; DONALDSON, 2018; BANERJEE; DUFLO; QIAN, 2020), which so far has focused on the effects of constructing new railways. We contribute to this area by examining the rehabilitation of degraded highway infrastructure, demonstrating that the recovery of existing assets can yield impacts comparable to those achieved through the development of new infrastructure projects.

Apart from this Introduction, the rest of this dissertation is organized as follows. Chapter 2 provides an overview of the institutional background of federal highway concessions in Brazil, along with a discussion on the concession outcomes and road quality data utilized in the empirical analysis. Chapter 3 proposes a dynamic discrete choice model of firm behavior and estimates structural parameters related to firm exit costs and investment delay penalties. Chapter 4 estimates transportation costs across PPP-operated and public roads with varying levels of quality. Chapter 5 quantifies the costs incurred by different types of vehicles when traversing BOT-administered roads and evaluates the welfare impacts of early contract terminations. Chapter 6 briefly concludes and outlines opportunities for future research.

2
Institutional background and data

In this chapter, we delve into the institutional background and present the data which will be used in our work. First, in Section 2.1, we briefly present the institutional context and history of Brazil's federal highway concession program. Section 2.2 describes and shows data on concessions and toll stations used in the exercise performed in Chapter 3. Finally, Section 2.3 presents additional data on road conservation status and freight rate between Brazilian municipalities, which will be necessary for Chapter 4.

2.1
Brazilian federal highway concessions

Most of the Brazil's existing roads were built in the 20th century by federal and state governments, which were also initially responsible for their maintenance and operation. However, due to fiscal restrictions and as part of a broader trend toward outsourcing services to private firms in the 1990s, the federal government established the Program of Concession of Federal Roadways (PROCOFE) in 1993. Since then, three distinct phases of concessions have been implemented, encompassing a total of 20 federal roads covering approximately 11,000 kilometers. These concessions fall under the regulatory oversight of the National Agency of Land Transports (ANTT).

These roads were auctioned through long-term contracts (15 to 35 years) using lowest price cap bidding. That is, contracts were allocated to firms willing to charge consumers less through toll stations situated alongside the road. Each contract specifies tasks needed to improve the quality of the road, as well as a deadline for each of them. The contracts stipulate fines for failing to meet deadlines. Given the list of contractual obligations, ANTT provides an estimate of annual investment commitments necessary to fulfill the contract appropriately. Investment commitments are typically concentrated in the first years of the contract, with firms promising to quickly recover deteriorated sections and build more lanes to expand capacity. In principle, toll price caps [1] are adjusted according to a pre-determined, inflation-based formula outlined in the concession agreements.

[1]While firms can theoretically charge below than the cap, we found no single instance of such behavior. Therefore, from this point onward we refer to toll price caps and toll prices interchangeably. Our empirical exercise also assumes all firms charge exactly the cap.

Table 2.1: Federal Highway Concessions in Brazil

Phase	Concession	Lenght (km)	Duration (years)
1st (1995-1998)	CONCER	180	25
	CCR PONTE	13	20
	NOVADUTRA	407	25
	CRT	144	25
	CONCEPA	112	20
	ECOSUL	624	25
2nd (2008-2009)	PLANALTO SUL	413	25
	LITORAL SUL	406	25
	REGIS BITTENCOURT	402	25
	FERNAO DIAS	562	25
	FLUMINENSE	320	25
	TRANSBRASILIANA	322	25
	RODOVIA DO ACO	200	25
	VIA BAHIA	680	25
3rd (2013-2014)	ECO101	476	25
	ECO050	437	30
	CONCEBRA	1177	30
	CRO	851	30
	MSVIA	847	30
	VIA 040	937	30

Note: Highways in red indicate failed concessions.

Brazilian infrastructure companies can also request early termination of their concession contracts under the provisions of Law 13.448/17, enacted in June 2017. This legislation allows incumbents in regulated infrastructure sectors to make an "irrevocable and irreversible" decision to amicably terminate their concession agreements with the government. To initiate the process, companies must submit a comprehensive report detailing the technical reasons for the termination, outlining minimum necessary investments to keep the asset under operation and include a commitment to abstain from participating in any potential re-allocation process. Once submitted, the request undergoes evaluation by both the Regulatory Agency and the Ministry of Infrastructure. If accepted[2], the government begins planning the rebidding process, while the incumbent firm is obligated to ensure the continuity of services until a new auction is successfully conducted. Then, firms must be reimbursed by the government for their unamortized investments.

Law 13.448/17 marks a significant departure from the previous early termination framework established by the Law 8.987/95 (the Concessions Law). Under the previous regime, concessionaires in default were subject to a litigious expiration process, initiated unilaterally by the government as a punitive response to serious and repeated contractual breaches. Concessionaires were typically not entitled to compensation for unamortized investments, and the government was expected to temporarily assume operation of the asset until

[2]In practice, all requests have been promptly accepted by ANTT.

a new concession could be tendered. As a result, this process imposed higher exit costs on both public authorities and private operators.

After the enaction of Law 13.448/17, the voluntary early termination procedure has been requested by a highway concessionaire for the first time in September 2017, and until December 2022, seven out of the 23 (35%) concessions made such requests [3]. All federal highway concessions are listed in Table 2.1, with concessions for which amicable devolution has been requested highlighted in red.

Notably, as of 2022 — five years after the establishment of the program and the initial termination requests — no highway reallocation process had been initiated. Following the 2022 election, the new federal administration committed to renegotiating concession contracts with incumbent firms in order to circumvent the lengthy termination process, aiming to resume investments quickly. Once renegotiation between the government, concessionaire, and judiciary is concluded, a simplified competitive process must be conducted, allowing other firms to submit bids if they can offer more favorable terms for operating the asset.

Beyond the seven highways that had already requested early termination, an additional eight concessionaires joined the federal government's renegotiation program: CONCER, ECOSUL, FERNÃO DIAS, LITORAL SUL, PLANALTO SUL, RÉGIS BITTENCOURT, TRANSBRASILIANA, and VIA BAHIA. As of March 2025, only one of the fifteen highways (VIA 040) has been officially terminated and re-auctioned, while three others (MS VIA, ECO101, and FLUMINENSE) have successfully concluded their renegotiation processes, with their competitive bidding processes scheduled for 2025. To mitigate concerns about opportunistic behavior in renegotiation requests, my empirical analysis ends in 2022 and considers only the initial requests for formal irrevocable early termination.

2.2
Data on federal concessions outcomes

This study leverages a novel dataset that integrates information on toll stations, road segments, and concession outcomes, manually compiled from both regulatory sources and third-sector organizations. We collect data from ANTT on toll rates, toll locations, vehicle flow, investment commitments, and realized investments for each highway concession. All monetary values are expressed in constant 2022 reais (R$). Toll price changes are documented in

[3]Highway concessions account for the majority of devolution requests, making this sector a natural focus for studying this procedure. In comparison, only 3 of the 49 airport concessions and 1 of the 131 energy concessions in the country have invoked this mechanism.

official enactment PDFs, which we systematically scraped. Additionally, media reports on termination processes provide information on the year of contract termination requests. For each firm and year, we construct a dataset that includes yearly concession revenue, a dummy variable indicating periods of high investment (i.e., actual investment greater than investment commitment for that period), and a dummy variable for early termination. To measure delays in investment, we calculate the cumulative difference between the total investments made and the total investment commitments as of each period. Table 2.2 presents the descriptive statistics of the concession outcome data, summarizing key variables relevant to the analysis.

Table 2.2: Descriptive Statistics: Concession Data Summary

Statistic	N	Mean	Min	Max
Revenue	282	351,812		
		(391,917)	0	2,061,192
Expected Investment (commitment)	328	203,026		
		(350,092)	328	2,320,620
Actual Investment	277	236,933		
		(248,615)	0	1,461,098
Investment Delay	203	124,649		
		(1,225,664)	−4,653,425	5,912,866
High Investment (greater than commitment)	199	0.59		
		(0.49)	0	1
Early Termination	301	0.02		
		(0.15)	0	1

Additionally, this data can be organized at the toll station level, which is particularly useful for the transportation cost analysis. Using this information, we construct an annual dataset that includes the geolocation of toll stations, average annual toll prices, and total traffic flow for each station. Table 2.3 presents the corresponding descriptive statistics.

Table 2.3: Descriptive Statistics of Toll Prices and Revenue

Statistic	N	Mean (St. Dev)	Min	Max
Vehicle Flow (equivalent)	1,815	10,327,356		
		(8,716,495)	30	42,842,452
Toll price (R$ 2022)	5,065	8.56		
		(5.22)	1.08	39.34
Toll Revenue (R$ 2022)	1,583	71,764,053		
		(78,309,595)	204,608	523,937,108

Toll stations exhibit substantial variation in vehicle flow and toll rates, leading to significant differences in revenue generation. In the monthly concession dataset, there are seven instances of early termination, representing 2% of all observations. On average, revenue slightly exceeds investment per period, and observed investments surpass investment commitments in 59% of cases. However, investment schedules are heavily front-loaded, with the majority of commitments concentrated within the first three years of the project. This timing imposes significant financial strain on firms during the initial stages of operation, as they must face substantial deficits while executing the bulk of their investments. To offset these early losses, firms should generate profits during the later years of the concession. The average financial plan outlined by ANTT for 25-year projects is depicted in Figure 2.1, illustrating the temporal distribution of investment commitments and expected revenue throughout the concession period.

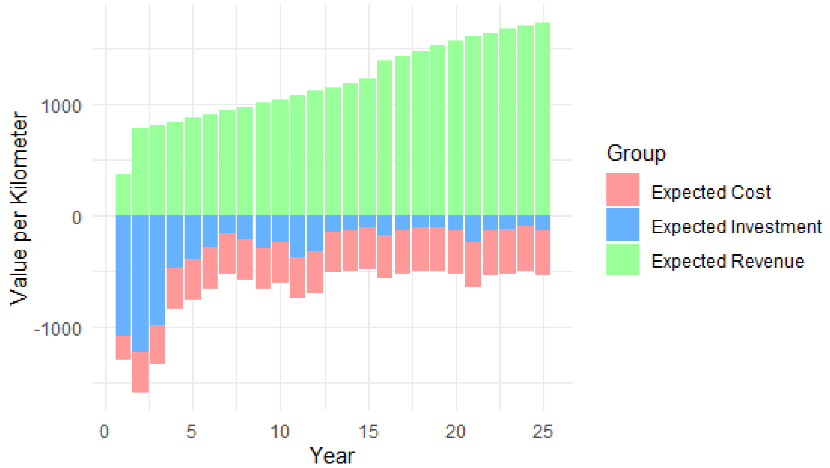

Figure 2.1: ANTT Financial Plans – Investment Commitments and Expected Revenue

Table 2.2 reveals a substantial variation in investment delays across concessions, ranging from over negative R$ 4 billion (indicating investments ahead of schedule) to positive R$ 6 billion (indicating significant delays). Understanding the evolution of these delays for each concession is useful, as it may shed light on their relationship with contract early termination. To explore this, we plot the progression of investment delays for each concession in Figure 2.2, providing a visual representation of how delays develop over time and their potential connection to concession outcomes.

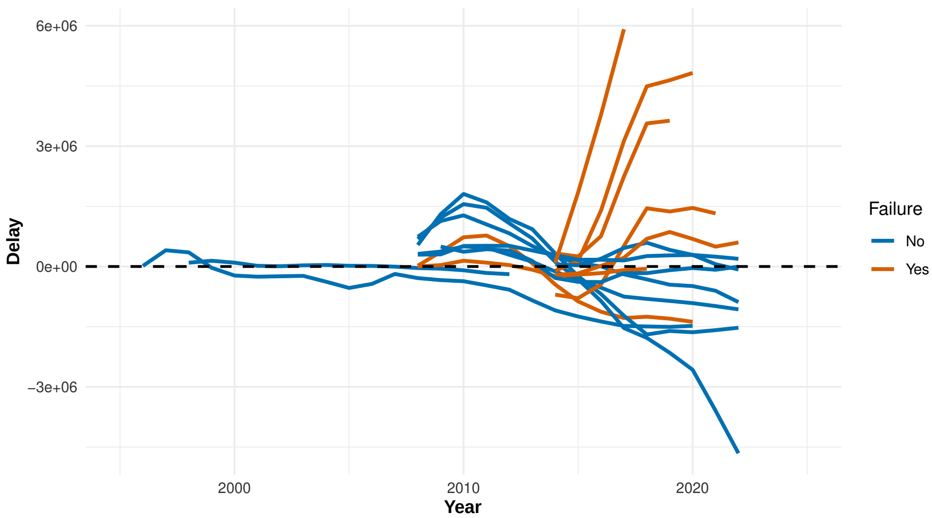

Figure 2.2: Annual Investment Delay by Firm and Concession Outcome

In Figure 2.2, each line corresponds to a specific concession, with red lines representing concessions that failed. At first glance, there appears to be a clear association between delays and failure: six of the seven failed concessions exhibited positive delays at the time of early termination. Notably, with the exception of one concession that consistently reduced its delays over time, all successful concessions appear to eventually converge to a negative delay.

To further examine the dynamics of delays, we plot the relationship between delay in period t and delay in period $t+1$ in Figure 2.3, including a 45º line for reference. This plot highlights the persistence or adjustment of delays over time, providing insights into whether concessions are able to recover from delays or if they tend to exacerbate over subsequent periods.

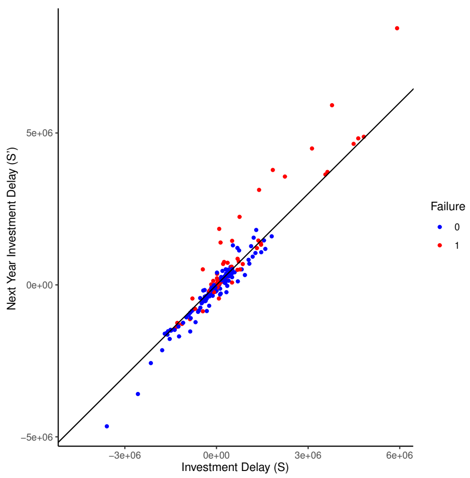

Figure 2.3: Relationship Between Current and Future Investment Delays

In Figure 2.3, points above the 45º line represent instances where firms invested less than their committed amounts, thereby increasing their level of delay. Conversely, points below the 45º line represent high-investment periods, where firms invested sufficiently to reduce their delays. Points in red correspond to concessions that ultimately failed. Note that failed concessions are associated with persistent and dynamic increases in delay, where firms underinvest relative to their commitments. This behavior suggests a strategy of "running the concession down", where firms that recognize their contracts are not economically viable choose to minimize investment consistently while continuing to collect toll revenue, rather than attempting to catch up with ANTT's investment schedules. Over time, however, this noncompliance exacerbates delays and likely triggers increasingly severe penalties from ANTT. Eventually, these penalties render the concession financially untenable, forcing early termination.

2.3
Data on Road Quality and Freight Rates

In order to assess road conservation status, we compile data manually from the *Pesquisa CNT Rodovias* reports, an annual survey conducted by Brazil's National Confederation of Transportation (1996–2023). These reports assess road segment quality through on-site inspections, evaluating factors such as pavement quality, signage, and road geometry. Based on these evaluations, road segments are classified into four categories: poor, average, good, or excellent. Each road segment is identified by its origin and destination municipalities, along with specific road identifiers. Table 2.4 provides descriptive statistics summarizing the distribution of road quality categories under public and private management.

Table 2.4: Road Condition by administration type (2023)

State	Administration	Count (n)	Percentage (%)
Poor	Private (BOT)	6	2.86
Average	Private (BOT)	52	24.76
Good	Private (BOT)	131	62.38
Excellent	Private (BOT)	21	10
Poor	Public	339	27.67
Average	Public	692	56.49
Good	Public	185	15.10
Excellent	Public	9	0.74

The data reveals stark differences in road quality based on administration type. Privately managed roads under BOT concession arrangements show significantly higher proportions of good (62.38%) and excellent (10.00%) conditions compared to publicly administered roads, which are predominantly rated as poor (27.67%) or average (56.49%). When considering only federal roads, a significant improvement in road quality is evident starting from the second year of concession contracts. This trend is consistent with the investment schedule of concessions, which concentrates most investment commitments in the first years of the contracts. Figure 2.4 shows increase in average road quality ratings after the initiation of the concession.

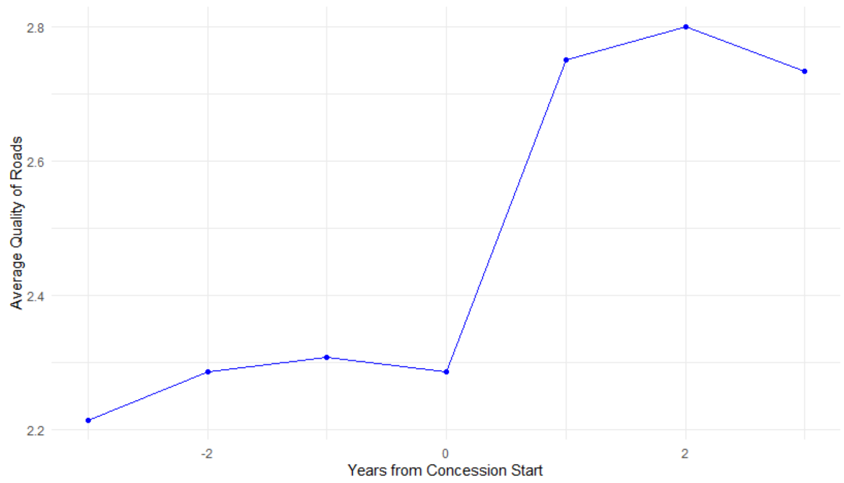

Figure 2.4: Average Quality of Roads Before and After Concession Start

Note: Road quality ratings are assigned numerical values: 1 = Poor, 2 = Average, 3 = Good, 4 = Excellent.

Additionally, the freight rate data utilized in this study is sourced from the Logistic Group of the College of Agriculture Luiz de Queiroz (ESALQ) at the University of São Paulo. It comprises information collected from logistic operators on average annual freight costs for 5,742 unique origin-destination pairs (o, d) from 2008 to 2013. The dataset focuses on transporting agricultural commodities, including rice, coffee, corn, soy, wheat, and beef.

Freight costs are measured in R$/ton and are normalized by the product's tonnage price to ensure comparability across different commodities. Figure 2.5 provides a visual representation of the origin-destination pairs in the dataset. Each black line on the map corresponds to a specific (o, d) pair covered in the ESALQ data.

Figure 2.5: Map of Freight Origin-Destination from ESALQ

3
A model of Incumbent Exit

In this chapter, we conduct the empirical analysis of Brazilian highway concessions. Section 3.1 presents a dynamic discrete choice model in which firms decide on their investment levels and whether to pursue early termination. Section 3.2 outlines our empirical strategy for estimating the structural parameters and discusses the results. Finally, Section 3.3 performs the same exercise in a restricted dataset from the implementation of the exit policy (2017) onward.

3.1
Model

Consider a dynamic maximization problem where each firm $i \in \{1, 2, ..., I\}$ observes a state vector S_t^i in time $t \in \{1, 2, ...T_i\}$. The state vector S_t^i includes the firm's investment commitment schedule $X^i = (x_1^i, x_2^i, ..., x_T^i)$, revenue R_t^i and stock of delayed investment D_t^i. Given state variables, the firm chooses binary control variables: investment level $I_t^i \in \{I_t^H > x_t^i, I_t^L < x_t^i\}$, indicating whether the firm invests above or below its commitment, and whether to exit the market $d_t^i \in \{0, 1\}$, where $d_t^i = 1$ represents a decision to terminate the concession.

In this model, we make three main assumptions. First, we assume revenue R_t^i is exogenous to the firm, and therefore independent of the firm's investment decisions. Thus, investment levels do not directly influence highway usage or toll collection. Second, the process for requesting early termination is not explicitly modeled: we assume all termination requests are accepted immediately, as observed in historical data up until 2022. Finally, as original termination requests are considered irrevocable, they are assumed to reflect genuine economic motives rather than strategic opportunism in order to negotiate more advantageous contractual terms.

We propose an instant payoff function such that incumbent's Value Function $V(S_t^i)$ is represented by the following Bellman Equation:

$$V(S_t^i) = \max_{d_t^i, I_t^i} \left\{ R_t^i - I_t^i - \theta \max\{D_{t+1}^i, 0\} + \beta \mathbb{E}[V(S_{t+1}^i | S_t^i, I_t^i, d_t^1)], \gamma \right\}$$
$$\text{s.t. } D_{t+1}^i = D_t^i + x_t^i - I_t^i, D_0^i = 0 \tag{3-1}$$

Where β is the discount factor, γ is a scrap value of exiting the market and θ is the linear penalty rate for investment delay, representing the proportional cost of delayed investments. Delay D_t^i evolves according to the law of motion $D_{t+1}^i = D_t^i + x_t^i - I_t^i$, implying when firm chooses $I_t^L < x_t^i$, it increases the stock of delay D_t^i and leads to higher penalties in future periods. Conversely, when firm chooses $I_t^H > x_t^i$, it reduces D_t^i, potentially avoiding future penalties at the expense of higher current investment costs. For a fixed revenue R_t^i and constant I_t^L an I_t^H, the value function $V(S_t^i)$ across delay D_t^i values is described in Figure 3.1.

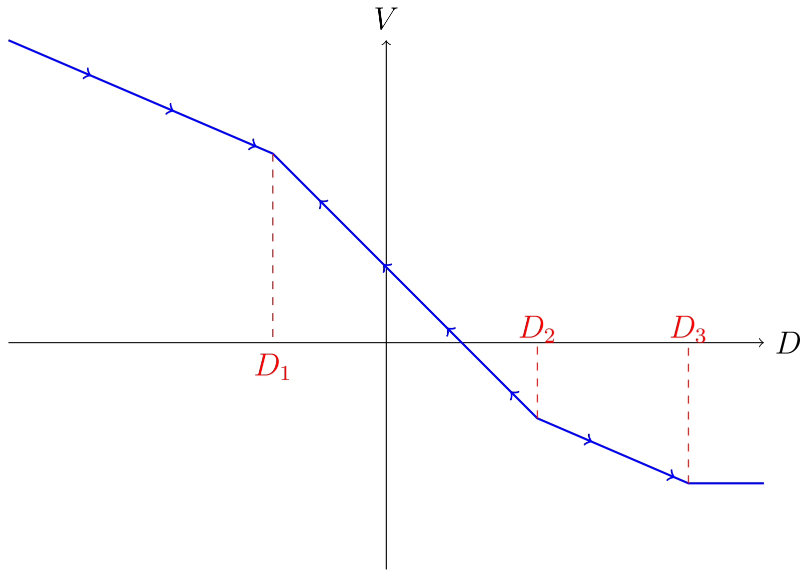

Figure 3.1: Value Function over Investment Delay

For different levels of delay D, the firm's optimal investment strategy and market participation decision follow distinct regimes. For very negative levels of delay ($D < D_1$), where the stock of delay is far below the penalty threshold, firms will face no costs from delay soon. In this regime, it is optimal to invest at the low level I^L, allowing the delay to increase gradually over time until it reaches D_1, where penalties begin to come into consideration. For moderate delays ($D_1 \leq D \leq D_2$), it is optimal to invest at high level I^H to avoid or minimize penalties. This regime decreases the delay continuously, until it eventually converges to D_1, where concession is running smoothly above schedule and the firm pays no penalty. For sufficiently high delays ($D > D_2$), the cost of reducing the delay to negative levels becomes so large that the firm no longer find it viable to fully comply with investment commitments. In this regime, firms "run the concession down", investing at the low level I^L repeatedly and allowing delays to grow further. When the delay exceeds D_3, the penalties become so severe that continuing operations is no longer optimal. At this point, the firm exits the market ($d_t = 1$), foregoing future operations and triggering early termination of the concession. Note that, in this model, successful concessions will stabilize delay near D_1, while external shocks can push concessions into high-delay regimes that lead to concession failure after a few periods of minimal investment.

3.2 Estimation

We adopt a two-step estimation procedure following the tradition of HOTZ; MILLER (1993) and BAJARI; BENKARD; LEVIN (2007). This approach separates the estimation of firms' policy functions from the recovery of structural parameters, allowing for their estimation without explicitly solving the full model. In the first step, we construct the firms' policy functions for investment and exit decisions using conditional choice probabilities $P(d|S)$ and $P(I|S)$ observed in the data. In the second step, we recover structural parameters θ (penalty parameter for delay) and γ (scrap value) using equilibrium conditions derived from simulated value functions of optimal and alternative policies.

We assume that revenue for each firm R_t^i independently and identically distributed across time, such that: $R_t^i \perp\!\!\!\perp R_{t+1}^i$, $R_t^i \sim \mathcal{N}(\mu^i, \sigma^i)$. Parameters μ^i and σ^i are calibrated directly from observed revenue data for each firm. Given that revenue is not time-persistent and the law of motion for investment delay is deterministic, we do not need to estimate state transitions.

3.2.0.1 Policy Function Estimation

In this subsection, we apply the Hotz-Miller inversion to estimate the policy functions for termination $d : S \times \mathcal{V}^1 \rightarrow \{0, 1\}$ and investment $I : S \times \mathcal{V}^2 \rightarrow \{I^L, I^H\}$, where $\mathcal{V}^1$ and $\mathcal{V}^2$ represent the sets of possible shock values associated with these decisions. We adopt a parametric approach and model the CCPs using logistic regression. To illustrate the early termination decision, Figure 3.2 plots the estimated probabilities of termination $\hat{P}(d^i = 1|S^i)$ across different levels of delay D_t^i and revenue R_t^i. The other variable in each panel is held constant at either the first or ninth decile of its observed data distribution.

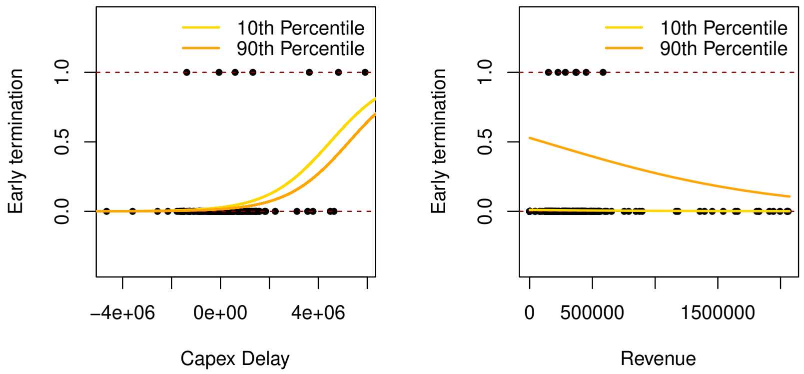

Figure 3.2: Estimated Probability of Termination (CCP)

The data reveals that termination observations are concentrated among firms experiencing high investment delays and low revenues. Specifically, for a given revenue level, higher delays correspond to a greater likelihood of termination. Conversely, for any fixed level of delay, lower revenues are consistently associated with a higher probability of termination. However, even for firms with very low revenues, delays in the first decile are associated with an almost zero probability of exit. This finding aligns with the "run the concession down" behavior described earlier. Firms tend to remain in economically non-viable concessions for a period, collecting toll revenue while delaying investments, until the accumulated penalty for delay becomes unsustainable, ultimately forcing their exit.

We adopt the standard assumption in the conditional choice literature that each firm's payoff is additively separable between profits and a choice-specific vector of shocks $\nu_i^1 = (\nu_i^1(d = 0), \nu_i^1(d = 1))$, which accounts for unobserved variability in firms' behavior. Let $v_i(d_i, S_i)$ denote the choice-specific value function for firm i. Firm i selects the action d_i that maximizes its utility, satisfying the following optimality condition:

$$v_i(d_i, S_i) + \nu_i^1(d_i) \geq v_i(d_i', S_i) + \nu_i(d_i') \quad \forall d_i' \in \{0, 1\} \tag{3-2}$$

Given the assumption that $\nu_i^1(d)$ follows a Type I Extreme Value distribution (EVT1), we can use the Hotz-Miller inversion method proposed by HOTZ; MILLER (1993) to recover the choice-specific value functions from the observed CCPs at each state. This method allows us to express the difference between the choice-specific values as:

$$v_i(d_i = 1, S_i) - v_i(d_i = 0, S_i) = ln(\hat{P}(d_i = 1|S_i)) - ln(\hat{P}d_i = 0|S_i) \quad \text{(3-3)}$$

Normalize $\tilde{v}_i(d_i = 0, S_i)\forall i$. Then, we are able to recover each firm's policy function from observed states and their private shocks from Equations 3-3 and 3-2. Firm i's policy function for early termination is described as:

$$d_i(S_i, \nu_i) = argmax_d\{\tilde{v}_i(d_i, S_i) + \nu_i(d_i)\} \quad \text{(3-4)}$$

To estimate the investment policy function $I : S \times \mathcal{V}_i^2 \rightarrow \{I^L, I^H\}$, we adopt strategy similar to the one used for estimating termination decisions. That is, we assume that the binary investment levels I^H (high investment) and I^L (low investment) are determined according to the following equation:

$$I_t^i = \begin{cases} I_t^{H,i} = x_t^i \epsilon_t^H \ , \ \epsilon_t^H \sim N(\mu_H, \sigma_H) \\ I_t^{L,i} = x_t^i \epsilon_t^L \ , \ \epsilon_t^L \sim N(\mu_L, \sigma_L) \end{cases}$$

In other words, to account for the observed variation in high and low investment levels, we assume that at each period t, the firm observes two possible investment values based on its investment commitment x and shocks ϵ_t^H and ϵ_t^L, which are drawn from separate normal distributions. The parameters $\mu_H, \sigma_H, \mu_L, \sigma_L$ are calibrated from the observed data, with the constraint that $\epsilon_t^H > 1$ and $0 < 1\epsilon_t^L < 1$. This assumption ensures that low investment always increases delay and high investment always decreases delay, consistent with the proposed model's dynamics.

Next, we estimate the CCPs $\hat{P}(I^i = I_t^H|S_t^i)$ using logistic regression, as in the case of the termination decision. To capture the nonlinear relationship between delay and investment, as predicted by the model, we apply a natural cubic spline transformation to the delay variable D. The results of this estimation are presented in Figure 3.3.

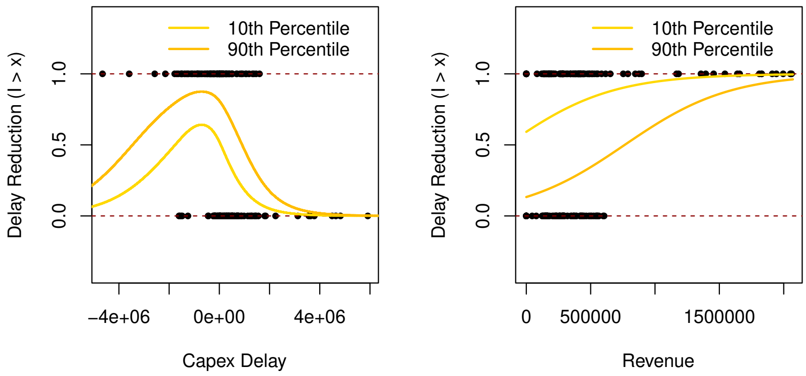

Figure 3.3: Estimated Probability of High Investment (CCP)

As before, we observe that the probability of choosing high investment (I^H) is monotonically increasing with revenue for all levels of delay. However, the relationship between delay and the probability of high investment follows a non-monotonic pattern: it is low for very negative delays, increases for intermediate delays, and decreases for very high delays. Importantly, this pattern does not emerge from the data itself, but rather is a direct consequence of the model's structural assumptions. We assume that the instant payoff is additively separable between profit and a choice-specific vector of shocks $\nu_i^2 = (\nu_i^2(I = I^H), \nu_i^2(I = I^L))$. Under the condition of optimality, the firm's investment decision satisfies the following equation:

$$v_i(I_i, S_i) + \nu_i^2(I_i) \geq v_i(I_i', S_i) + \nu_i(I_i') \quad \forall I_i' \in \{I^L, I^H\} \tag{3-5}$$

This ensures that the chosen investment level maximizes the firm's payoff, taking into account both the deterministic and stochastic components of the value function. Once again, we assume $\nu_i^2 \in \mathcal{V} \sim EVT1$, with the density of the extreme value type 1 distribution ensuring that:

$$v_i(I_i = I^H, S_i) - v_i(I_i = I^L, S_i) = ln(\hat{P}(I_i = I^H|S_i)) - ln(\hat{P}(I_i = I^L|S_i)) \tag{3-6}$$

By normalizing $\tilde{v}_i(I_i = I^L, S_i)\forall i$, we can recover the value functions for high and low investment. Using the expression above, along with the optimality condition from Equation 3-5, the investment policy function is defined as:

$$I_i(S_i, \nu_i) = argmax_I\{\tilde{v}_i(I_i, S_i) + \nu_i(I_i)\}$$

3.2.0.2
Structural Parameters

In this subsection, we perform the second-stage estimation following the simulation-based procedure outlined by BAJARI; BENKARD; LEVIN (2007). This approach relies on equilibrium conditions and simulations to estimate structural parameters. Given that instantaneous payoff function is linear in unknown parameters, we define parameter vector $\Theta = (1, \theta, 1, \gamma)$ and a vector of basis functions $\Psi_i(S; d, I) = (R, -max\{D + x - I, 0\}, -I, 1_{\{d=1\}})$. Here, Θ comprises the coefficients to be estimated. We then define $W_i(S_t; d(S_t, \nu_t^1), I(S_t, \nu_t^2))$ such that firm's Value function V_i is expressed by Equation 3-7.

$$\begin{aligned} V_i(S; d(\cdot), I(\cdot); S; \nu^1, \nu^2) = & \\ &= \mathbb{E}_0 \left[\sum_{t=0}^{T_i} \beta^t \Psi_i(S_t; d(S_t, \nu_t^1), I(S_t, \nu_t^2)) \right] \cdot \Theta \\ &= W_i(S_t; d(S_t, \nu_t^1), I(S_t, \nu_t^2)) \cdot \Theta \end{aligned} \tag{3-7}$$

This simplification is useful as the components of $W_i(\cdot)$ do not depend on parameters, so simulation of $W_i(\cdot)$ can be performed separately from the estimation of Θ. This significantly reduces computational burden. Given that $d = 1$ causes a terminal state representing exit from the market, all future profit flows becomes zero once this action is chosen. To simulate $W_i(\cdot)$ for each concession, we use the policy functions $d_i(S_i, \nu_i^1)$ and $d_i(I_i, \nu_i^2)$, derived from observed conditional choice probabilities. We impose the laws of motion for each firm's state variables S_i given their investment decisions that affect the level of delay. Simulations are conducted over all periods T_i specified in each concession contract. For each firm, we average results over $N = 100$ simulated paths.

To estimate the structural parameters using the method described in BAJARI; BENKARD; LEVIN (2007) (henceforth, BBL), it is necessary to specify alternative policy functions. To construct them, we follow the Hotz-Miller inversion introducing normally distributed shocks $\xi \sim N(0, 0.25)$. These shocks directly affect the probabilities of firms returning their concessions or choosing high investment values. Therefore, alternative policy functions indicate firms are either slightly more pessimistic or optimistic about future revenues, and consequently more or less inclined to invest higher amounts or terminate their concession contracts for a given state vector S_t^i.

We generate ten alternative pairs of policy functions. For each pair, we simulate $W'(S_i, d_i'(S_i, \nu_i^1), I_i'(S_i, \nu_i^2))$. Since the observed conditional choice probabilities reflect equilibrium behavior, the estimation relies on equilibrium conditions that compare the simulated W' from the alternative policies with those from the observed optimal policies. The equilibrium conditions shown in Equation 3-8 provide the basis for estimating the structural parameters in the model.

$$\begin{aligned} V_i(S; d(\cdot), I(\cdot); S; \nu^1, \nu^2) &\geq V_i(S; d'(\cdot), I'(\cdot); S; \nu^1, \nu^2) \\ \Theta \cdot W_i(S; d(\cdot), I(\cdot); S; \nu^1, \nu^2) &\geq \Theta \cdot W_i(S; d'(\cdot), I'(\cdot); S; \nu^1, \nu^2) \end{aligned} \tag{3-8}$$

Note that Equation 3-8 holds for all firms i and for each alternative policy function pair $(d_i'(S; \nu^1), I_i'(S; \nu^2))$. Since we generated ten alternative policies, this provides $K = 200$ equilibrium conditions. Define M as a K-row matrix constructed by stacking the simulated results of the correct policy function M_0 ten times. Similarly, define M' as the K-row matrix that stacks the simulation results for all ten alternative policy functions. Using all $k \in \{1, ..., K\}$ equilibrium conditions and setting $\beta = 0.95$, we estimate structural parameters that solve the following problem:

$$\widehat{\Theta} := \arg\min_{\Theta} \sum_{k=1}^{K} (\Theta \cdot \min\{[M_k - M_k'], 0\})^2 \tag{3-9}$$

The results of the estimation are shown in Table 3.1.

Parameters	Estimate
θ	0.16
γ	-2,464,211

Table 3.1: BBL Estimation Results

The estimated values of γ suggest that firms incur substantial exit costs exceeding R$2 billion (in December 2022 values), approximately seven times the average revenue observed in the data. This high cost is likely driven by anticipated litigation expenses and contractual breach fines. Additionally, the estimated value of θ indicates firms face a sizable investment delay penalty, equivalent to 16% of the monetary value of the delay. Given that the average delay is R$124 million, the corresponding total annual penalty for a typical concessionaire is around R$20 million. For comparison, in 2023, ANTT initiated 43 penalty processes totaling R$175 million, implying an average fine of approximately R$4 million. Notably, firms often face multiple penalties within a given year.

3.3 Restricted dataframe

Here, we replicate the previous exercise, first estimating policy functions based on conditional choice probabilities and then recovering the structural parameters using equilibrium conditions. However, this analysis restricts the dataset to observations from 2017 onward, following the implementation of Law 13.448/17. As a result, the findings can be interpreted as a policy change analysis of the early termination bill. The estimated results are presented in Table 3.2.

Parameters	Estimate
θ	0.08
γ	992,034

Table 3.2: BBL Estimation Results (restricted for 2017 onward)

The estimated exit cost γ decreased following the implementation of Law 13.448/17, as expected. In fact, it turned into a positive scrap value, likely due to the law's provision that firms requesting early termination are entitled to reimbursement for their non-amortized investments and for operating the highway until a new auction takes place. As previously discussed, the re-bidding process is lengthy, often requiring firms to continue operating the road for several years before the concession is officially transferred. Furthermore, the parameter θ associated with investment delay penalties decreased, suggesting that ANTT has relaxed its regulatory fines for project delays after the implementation of Law 13.448/17.

4
Road Quality and Transportation Costs

This chapter aims to estimate transportation costs for roads with varying levels of conservation quality. The analysis integrates data on road conditions and geolocation, toll locations and prices, and freight rates. We employ an estimation strategy inspired by DONALDSON (2018), but the availability of data eliminates the need for additional assumptions on demand and allows for a fully data-driven approach.

4.0.1
Estimation

To geolocate the data on road quality, we utilize the OpenStreetMap API. As specified before, the CNT data contains annual freight rates for 5,742 unique origin-destination pairs. By leveraging the information on the municipality of origin, municipality of destination, and the specific road ID name from the CNT survey, we parse the relevant data into OpenStreetMap to generate georeferenced routes. This process enables us to create a unified transportation network, combining both road segments and toll stations. The resulting transportation network for 2023 is shown in Figure 4.1.

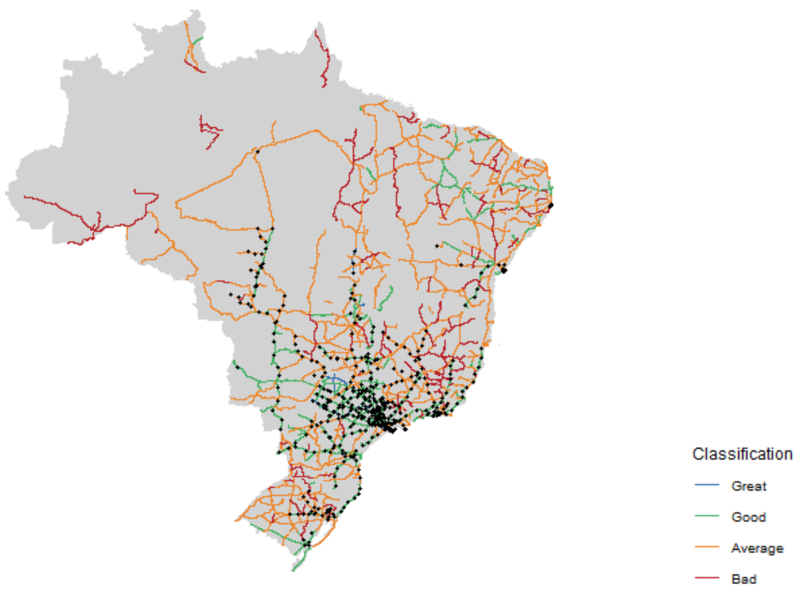

Figure 4.1: Road quality and toll station locations (2023)

We estimate transportation costs using a non-linear least squares (NLLS) approach inspired by DONALDSON (2018). An advantage of our implementation is that we use direct data on freight rates rather than inferring costs from price differences among cities. Consequently, our approach does not require modeling demand for the transported goods.

To perform our estimation, we first convert the network into a raster graph N_t, where each grid cell represents a 10 km $\times$ 10 km (100 km^2) area. Each pixel is then classified as either containing a road segment, a toll station, or belonging to terrain without roads.

Next, we assign a cost vector $\alpha = (\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ to road pixels based on their maintenance quality, where each parameter represents the cost of traversing roads in excellent, good, average, and poor conditions, respectively. Toll station pixels are assigned a cost corresponding to the observed toll price at that location in year t, while non-road pixels are deemed inaccessible, effectively having an infinite cost. Using this framework, we apply Dijkstra's shortest path algorithm to compute the estimated non-monetary cost of transporting goods between origin-destination pairs (o, d) in a given year t, denoted as $C\_graph(N_t; \alpha)_{odt}$.

To establish the relationship between freight rates and estimated transit costs, we regress the observed freight cost on the computed non-monetary cost using the following specification:

$$C_{odt} = \beta_1 + \beta_2 C\_graph(\alpha; N_t)_{odt}$$

We then perform a grid search over different parameter values for α and select the values that yield the highest R-squared. The estimates for the best-fit models are presented in Table 4.1.

Quality	Cost
Excellent (α_1)	3.00
Good (α_2)	3.59
Average (α_3)	3.65
Poor (α_4)	7.44

Table 4.1: NLLS Transportation Cost Parameters

The estimated costs suggest that roads in poor condition significantly increase transportation costs compared to those in excellent condition. Specifically, the cost of traversing roads in poor condition is more than double that of roads in excellent condition. This finding aligns with similar estimates in the literature, such as those by DONALDSON (2018), who found comparable cost differences when comparing transportation between roads and railways. These results underscore that enhancing road conditions can have an impact on transportation costs that is comparable to the construction of entirely new infrastructure projects.

5
Welfare Impacts of Early Termination

In this chapter, we leverage the road quality estimates from Chapter 4 to calculate the implied cost of Brazil's eight instances of highway concession early termination. To do so, we use traffic flow data for each toll station, which records the number of vehicles in each category passing through each station annually. Since each vehicle category pays a different toll rate and carries varying amounts of goods, we require additional information on the tonnage and payload capacity for each vehicle type. This information is detailed in Table 5.1. Data on maximum total tonnage per category is sourced from Brazil's National Department of Transport Infrastructure (DNIT), while the maximum payload for commercial vehicles is obtained by subtracting the empty vehicle weight from its total capacity.

Table 5.1: Vehicle category information

Category	Type	Axles	Description	Tonnage	Payload	Toll ×
1	Passenger	2	Car, pick-up truck and van	3.5	-	1.0
2	Commercial	2	Light truck, bus, truck-tractor and van	7.5	2	2.0
3	Passenger	3	Car and pick-up truck with semi-trailer	16.5	-	1.5
4	Commercial	3	Truck, truck-tractor, truck-tractor with semi-trailer and bus	24.5	12	3.0
5	Passenger	4	Car and pick-up truck with trailer	29	-	2.0
6	Commercial	4	Truck with trailer and truck-tractor with semi-trailer	29	15	4.0
7	Commercial	5	Truck with trailer and truck-tractor with semi-trailer	45	25	5.0
8	Commercial	6	Truck with trailer and truck-tractor with semi-trailer	58.5	35	6.0
9	Motorcycle	2	Motorcycles, scooters and motorized bicycles	0.2	-	0.5
10	Commercial	7	Truck with trailer, truck-tractor with semi-trailer	74	45	7.0
11	Commercial	8	Truck with trailer, truck-tractor with semi-trailer	91	60	8.0
12	Commercial	9	Truck with trailer, truck-tractor with semi-trailer	100	70	9.0
13	Commercial	10	Truck with trailer, truck-tractor with semi-trailer	120	85	10.0

Vehicles are categorized based on their usage (passenger or commercial), the number of axles, and the presence of a semi-trailer. Consequently, each category is subject to a different toll rate, calculated by multiplying the base toll rate by a vehicle-specific multiplier (as shown in the "Toll ×" column). Using toll cost data for each vehicle category alongside the estimated cost of transporting one ton of goods for each road quality, we calculate the implied cost for a fully loaded commercial vehicle of each category to traverse the full extent of each concession, taking into account all tolls paid and observed road quality.

Tables 5.2 to 5.8 compare these calculated costs with the cost incurred by a vehicle of the same category traveling along a hypothetical road of equivalent length without any tolls, but in poor condition. It is important to note that all BOT highways experienced at least one period of poor condition before their concession agreements, whereas no instances of poor condition have been recorded for any road post-concession.

Table 5.2: Comparison between concession and poor quality costs - AUTOPISTA FLUMINENSE

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	509	952	443
4	1,798	3,571	1,774
6	2,167	4,285	2,118
7	3,570	7,142	3,572
8	4,974	9,999	5,026
10	5,918	11,904	5,986
11	7,666	15,475	7,810
12	8,839	17,856	9,017
13	10,587	21,427	10,840

Table 5.3: Comparison between concession and poor quality costs - CONCEBRA

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	1,794	3,501	1,707
4	6,492	13,130	6,638
6	7,812	15,756	7,944
7	12,932	26,259	13,327
8	18,053	36,763	18,711
10	21,484	43,766	22,282
11	27,872	56,896	29,024
12	32,148	65,649	33,501
13	38,535	78,778	40,243

Table 5.4: Comparison between concession and poor quality costs - CRO

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	1,328	2,532	1,204
4	4,787	9,496	4,709
6	5,762	11,395	5,633
7	9,532	18,992	9,460
8	13,302	26,589	13,287
10	15,829	31,653	15,824
11	20,531	41,150	20,619
12	23,679	47,480	23,801
13	28,381	56,976	28,595

Table 5.5: Comparison between concession and poor quality costs - ECO101

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	742	1,416	674
4	2,651	5,311	2,660
6	3,193	6,373	3,180
7	5,273	10,622	5,349
8	7,353	14,871	7,518
10	8,749	17,703	8,954
11	11,341	23,015	11,673
12	13,079	26,555	13,476
13	15,672	31,866	16,195

Table 5.6: Comparison between concession and poor quality costs - MSVIA

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	1,331	2,521	1,190
4	4,734	9,455	4,721
6	5,704	11,346	5,642
7	9,411	18,910	9,499
8	13,118	26,473	13,355
10	15,609	31,516	15,907
11	20,228	40,971	20,743
12	23,327	47,274	23,947
13	27,946	56,729	28,782

Table 5.7: Comparison between concession and poor quality costs - RODOVIA DO ACO

	Cost		
Category	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
2	328	595	268
4	1,138	2,232	1,094
6	1,373	2,678	1,305
7	2,255	4,464	2,209
8	3,137	6,250	3,113
10	3,732	7,440	3,708
11	4,829	9,672	4,843
12	5,567	11,160	5,593
13	6,664	13,392	6,727

Table 5.8: Comparison between concession and poor quality costs - VIA 040

Category	BOT cost	Poor	Concession gain
2	1,459	2,793	1,334
4	5,221	10,475	5,254
6	6,287	12,570	6,282
7	10,386	20,950	10,563
8	14,486	29,329	14,844
10	17,237	34,916	17,679
11	22,347	45,391	23,044
12	25,772	52,374	26,602
13	30,882	62,849	31,967

For all roads, the cost differences between the current level of road maintenance quality and a poorly maintained road are so significant that concessions remain considerably less costly for drivers, even after accounting for toll prices. This difference is even more pronounced for large vehicles, as toll prices do not scale proportionally with vehicle weight and payload. As a result, for vehicles with a large number of axles, concessions become even more advantageous — the total cost of using a concessioned road is less than half of what it would be on a poorly maintained, toll-free road.

Finally, we estimate the overall yearly welfare impact of early terminations using data on the number of vehicles passing through each toll station in 2022. To do so, we rely on three main assumptions. First, we assume that each commercial vehicle carries half of its payload (or, equivalently, that half of the vehicles are fully loaded). Second, we impose inelastic demand, meaning that vehicle traffic on a given highway remains unchanged regardless of its maintenance condition. While this is a strong assumption, it is justified by the limited intermodal competition for commercial transportation in Brazil. Lastly, we divide each highway into equal-length segments and assume that every vehicle crossing a toll station travels the full length of its respective segment. For example, if a highway spans 500 km and has five toll stations, we assume that vehicles passing through any given station have traveled 100 km on the road.

Using this approach, we compare the total costs associated with tolls and road quality under current concession conditions versus a counterfactual scenario in which the road is in poor condition but toll-free. The resulting welfare estimates are presented in Table 5.9.

Table 5.9: Welfare Gains from BOT Concessions

	Cost		
Concession	BOT quality (i)	Poor (ii)	Concession Gain (i - ii)
FLUMINENSE	1,513,078,091	2,773,121,818	1,260,043,728
CONCEBRA	12,297,928,482	24,098,510,484	11,800,582,003
CRO	10,930,930,951	21,356,777,364	10,425,846,413
ECO101	2,219,254,891	4,301,090,314	2,081,835,423
MSVIA	4,097,795,227	7,970,770,409	3,872,975,182
RODOVIA DO ACO	760,579,653	1,417,050,780	656,471,127
VIA 040	4,111,313,337	7,940,947,071	3,829,633,733

That is, assuming inelastic demand and a return to poor condition after concession abandonment, the seven instances of early termination have collectively imposed a cost exceeding R$33 billion in 2022 for commercial vehicles alone. On average, each concession failure resulted in an annual loss of approximately R$4.8 billion — twice the estimated burden on firms of R$2.4 billion per termination, as captured by the exit cost parameter γ from Chapter 3.1. On aggregate, BOT-administered roads are 48% less costly than a scenario where highways revert to poor condition, even after accounting for the absence of tolls. The actual welfare cost is likely even higher, as deteriorated road quality also imposes significant costs on passenger vehicles. Additionally, there are important externalities associated with well-maintained roads that may not fully captured in freight costs but nonetheless contribute to overall welfare, such as reductions in pollution, traffic accidents and fatalities.

6
Conclusion

While private participation in infrastructure financing has increased in recent years, there remains excess demand for investment in developing countries. Built-operate-and-transfer concessions have become a popular contractual design to attract this much-needed investment. However, these contracts frequently encounter issues that lead to early termination, resulting in unrealized investments and underdeveloped infrastructure.

In the first exercise from this study, we outlined a dynamic discrete choice to capture the economic intuition behind firms' decision to terminate contracts early. Estimation using data from Brazil's federal highway concession program reveals that firms incur significant exit costs and face penalties for delays in meeting their investment schedules. However, these costs were reduced following the enactment of the 2017 early termination legislation. Additionally, we observe a "running the concession down" behavior, where firms that recognize the concession is not economically viable strategically minimize investment for a few periods, extracting value from drivers before ultimately requesting early termination.

In the second exercise, we investigate the impact of maintenance quality on transportation costs. Since concession contracts are linked to improvements in road quality, this analysis highlights potential advantages of BOT arrangements. Our findings show that upgrading a road from poor to excellent condition can reduce transportation costs by more than half, reinforcing the economic benefits of maintaining high-quality infrastructure. This approach enables us to quantify the welfare impacts of early terminations, under the assumptions of inelastic demand and a reversion to poor maintenance conditions under public administration. Our results indicate a substantial annual cost of over R$ 33 billion.

The findings of this work elicit questions for future research on the trade-offs between toll prices and termination risk, as well as the role of auction design in shaping post-auction incumbent behavior. The framework developed here provides a foundation for analyzing whether different auction models lead to distinct contractual outcomes, influencing firms' incentives to abandon concessions and generating broader welfare implications. Intuitively, concessions allocated through lowest-price bidding tend to result in outcomes with lower expected revenue, leaving them more susceptible to exogenous economic shocks. Moreover, this approach may incentivize overly optimistic bids concerning future demand, exacerbating winner's curse. Alternatively, allocating concessions using a higher fixed price while allowing firms to bid on the highest fee paid to the government could mitigate these risks. In this setup, the fee serves as a sunk cost, potentially stabilizing the contract and reducing the risk of early termination.

7
Bibliography

ABITO, J. M. Measuring the welfare gains from optimal incentive regulation. **The Review of Economic Studies**, Oxford University Press, v. 87, n. 5, p. 2019–2048, 2020.

AURIOL, E.; PICARD, P. M. A theory of bot concession contracts. **Journal of economic behavior & organization**, Elsevier, v. 89, p. 187–209, 2013.

BAJARI, P.; BENKARD, C. L.; LEVIN, J. Estimating dynamic models of imperfect competition. **Econometrica**, Wiley Online Library, v. 75, n. 5, p. 1331–1370, 2007.

BANERJEE, A.; DUFLO, E.; QIAN, N. On the road: Access to transportation infrastructure and economic growth in china. **Journal of Development Economics**, Elsevier, v. 145, p. 102442, 2020.

DONALDSON, D. Railroads of the raj: Estimating the impact of transportation infrastructure. **American Economic Review**, American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203, v. 108, n. 4-5, p. 899–934, 2018.

DONALDSON, D.; HORNBECK, R. Railroads and american economic growth: A "market access" approach. **The Quarterly Journal of Economics**, MIT Press, v. 131, n. 2, p. 799–858, 2016.

DUFLO, E. et al. The value of regulatory discretion: Estimates from environmental inspections in india. **Econometrica**, Wiley Online Library, v. 86, n. 6, p. 2123–2160, 2018.

ENGEL, E. M.; FISCHER, R. D.; GALETOVIC, A. Least-present-value-of-revenue auctions and highway franchising. **Journal of political economy**, The University of Chicago Press, v. 109, n. 5, p. 993–1020, 2001.

GUASCH, J. L.; LAFFONT, J.-J.; STRAUB, S. Renegotiation of concession contracts in latin america: Evidence from the water and transport sectors. **International journal of industrial organization**, Elsevier, v. 26, n. 2, p. 421–442, 2008.

HOTZ, V. J.; MILLER, R. A. Conditional choice probabilities and the estimation of dynamic models. **The Review of Economic Studies**, Wiley-Blackwell, v. 60, n. 3, p. 497–529, 1993.

LEWIS, G.; BAJARI, P. Moral hazard, incentive contracts, and risk: evidence from procurement. **Review of Economic Studies**, Oxford University Press, v. 81, n. 3, p. 1201–1228, 2014.

RIORDAN, M. H.; SAPPINGTON, D. E. Awarding monopoly franchises. **The American Economic Review**, JSTOR, p. 375–387, 1987.

RYAN, N. Contract enforcement and productive efficiency: Evidence from the bidding and renegotiation of power contracts in india. **Econometrica**, Wiley Online Library, v. 88, n. 2, p. 383–424, 2020.

World Bank. Private participation in infrastructure (ppi). World Bank, 2023.