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ESSAYS ON POLITICAL ECONOMY OF COVID-19: THEORY AND EVIDENCES FROM BRAZIL

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Tese submetida ao Programa de Pós-Graduação em Economia da Faculdade de Ciências Econômicas da UFRGS como requisito parcial para obtenção do título de Doutor em Economia.

Orientador: Prof. Dr. Marcelo de Carvalho Griebeler

Coorientador: Prof. Dr. Giácomo Balbinotto Neto

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"At heart, science is the quest for awesome - the literal awe that you feel when you understand something profound for the first time."
— Sean Carroll, The Particle at the End of the Universe

"It is a mistake to conceive of choice and decision-making as a process of selecting from existing options according to a fixed formula. That omits the most important element of decision-making, namely the creation of new options."
— David Deutsch, The Beginning of Infinity

ABSTRACT

This thesis comprises three essays analyzing different aspects of the political economy and individual behavior during the COVID-19 pandemic in Brazil. The first essay investigates the role of electoral incentives in shaping policies adopted by mayors during the pandemic, finding that right-wing incumbents running for reelection adopted less stringent measures against COVID-19 when business closures were considered. The second essay explores the factors influencing vaccine hesitancy as the number and the interval between COVID-19 vaccine doses in Brazil, highlighting the importance of addressing vaccine hesitancy and promoting vaccine uptake. The third essay examines the relationship between city-level voting patterns and vaccination rates in Brazil, suggesting that voting patterns and political views play a significant role in vaccination decisions. The findings provide important insights into the complexities and heterogeneity of the COVID-19 pandemic in Brazil and have implications for the development of evidence based public health policies and interventions aimed at addressing vaccine hesitancy and other challenges imposed by health crises.

Key-words: COVID-19. Political economy. Electoral incentives. Vaccine hesitancy. Brazil.

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RESUMO

Esta tese é composta por três ensaios que analisam diferentes aspectos da economia política e do comportamento individual durante a pandemia da COVID-19 no Brasil. O primeiro investiga o papel dos incentivos eleitorais na definição das políticas adotadas pelos prefeitos durante a pandemia. O estudo conclui que os titulares alinhados à direita e concorrendo à reeleição adotaram medidas menos rigorosas contra a COVID-19 quando consideradas as restrições à abertura do comércio local na construção dos índices. O segundo ensaio explora os fatores que influenciam a hesitação em vacinar medida como o número e o intervalo entre as doses da vacina contra a COVID-19 no Brasil, destacando a importância de abordar a hesitação em vacinar e promover a adesão à vacinação. O terceiro ensaio examina a relação entre os padrões de votação em nível municipal e as taxas de vacinação no Brasil, sugerindo que os padrões de votação e as visões políticas desempenham um papel significativo nas decisões de vacinação. Os resultados fornecem informações importantes sobre as complexidades e a heterogeneidade da pandemia da COVID-19 no Brasil e têm implicações para a formulação e implementação de poíticas públicas baseadas em evidências na área de saúde pública voltadas para enfrentar a hesitação em vacinar e os demais desafios que crises sanitários proporcionam.

Palavras-chaves: COVID-19. Economia política. Incentivos eleitorais. Hesitação vacinal. Brasil.

JEL Classification: D72, H51, I18.

LIST OF FIGURES

Figure 2.1 – Signaling game in extensive form. 28
Figure 2.2 – Pooling equilibrium ($x_R^* = 1, x_L^* = 1$) - feasible area 35
Figure 2.3 – Mass of observations around the cutoff point 42
Figure 2.4 – NPI index around discontinuity for different incumbent ideologies. 43
Figure 2.5 – NPI IBGE index (no business closure mandates) around discontinuity . 43
Figure 2.6 – Social protection policies around discontinuity 43

LIST OF TABLES

Table 2.1 – Descriptive statistics 39
Table 2.2 – Balance Table 44
Table 2.3 – Results – y = NPI index 45
Table 2.4 – Results – IBGE variables 45
Table 2.5 – Results - Ideology of incumbents and voters 46
Table 2.6 – Results - Ideology of incumbents and voters 55
Table 2.7 – Placebo tests 55
Table 2.8 – Robustness checks 56
Table 2.9 – Estimated Bandwidths 56
Table 3.1 – Summary statistics - sample of municipalities 67
Table 3.2 – Descriptive statistics of variables - full sample 68
Table 3.3 – Descriptive statistics 69
Table 3.4 – Results - entire population 70
Table 3.5 – Results - population with comorbidities 72
Table 3.6 – Descriptive statistics of variables - regions 77
Table 3.7 – Descriptive statistics - Supplier of dose 3 78
Table 3.8 – Results - Health Professionals 79
Table 3.9 – Results - Security Forces 80
Table 3.10–Results - North 81
Table 3.11–Results - Northeast 82
Table 3.12–Results - Center-West 83
Table 3.13–Results - Southeast 84
Table 3.14–Results - South 85
Table 4.1 – Descriptive statistics 93
Table 4.2 – Results - vaccination Bolsonaro votes 97
Table 4.3 – Results - vaccination outer-wings 98
Table 4.4 – Results by region - COVID-19 vaccination Bolsonaro votes 99
Table 4.5 – Results, by region - general vaccination Bolsonaro votes 100
Table 4.6 – Descriptive statistics - North 102
Table 4.7 – Descriptive statistics - Northeast 103
Table 4.8 – Descriptive statistics - Center-West 104
Table 4.9 – Descriptive statistics - Southeast 105
Table 4.10–Descriptive statistics - South 106
Table 4.11–Correlation matrix - Selected variables 107
Table 4.12–Results - vaccination Bolsonaro share in 2018 108
Table 4.13–Results - vaccination Ciro Gomes share (3rd place in 2018) 109

Table 4.14–Results - vaccination Simone Tebet share (3rd place in 2022) 110

LIST OF ABBREVIATIONS AND ACRONYMS

COVID-19	Coronavirus Disease of 2019
IBGE	Instituto Brasileiro de Geografia e Estatística
Logit	Logistic Unit Regression
NPI	Non-Pharmaceutical Interventions
OLS	Ordinary Least Squares
PL	Partido Liberal
PSL	Partido Social-Liberal
PT	Partido dos Trabalhadores
RDD	Regression Discontinuity Design
SARS-COV2	Severe Acute Respiratory Syndrome Coronavirus 2
STF	Supremo Tribunal Federal
TSE	Tribunal Superior Eleitoral
US	United States (of America)

CONTENTS

1 INTRODUCTION 15

Introduction 15

2 ELECTIONS IN THE TIME OF COVID-19: INCUMBENCY EFFECTS ON NON-PHARMACEUTICAL INTERVENTIONS IN BRAZILIAN CITIES 18
2.1 Introduction 18
2.1.1 Literature Review 20
2.1.2 Outline 24
2.2 The model 25
2.2.1 Legal framework 25
2.2.2 Basic setting 26
2.2.3 Incumbent's problem 28
2.2.4 Voters' behavior 29
2.2.5 Equilibria 30
2.3 Empirical Strategy 37
2.3.1 Data Description 37
2.3.2 Data Analysis 40
2.3.3 Theoretical Predictions 41
2.3.4 Results 42
2.4 Discussion 46
2.5 Concluding Remarks 49
2.6 Appendix 50
2.6.1 Proof of proposition 2.2 50
2.6.2 Proof of proposition 2.3 51
2.6.3 Proof of proposition 2.4 52
2.6.4 Proof of proposition 2.5 53
2.6.5 Proof of proposition 2.6 54
2.6.6 Results - Centrist incumbent 55
2.6.7 Placebo Tests 55
2.6.8 Robustness checks 56
2.6.9 Optimum Bandwidth Selection Algorithms 56

3 MAY THE CHOICE BE WITH YOU? INDIVIDUAL AND SOCIAL DETERMINANTS OF VACCINE HESITANCY IN BRAZIL 57

3.1 Introduction **57**
3.1.1 Literature Review 58
3.1.2 Outline 62
3.2 A Conceptual Framework for Vaccination Decision **62**
3.3 Empirical Strategy **64**
3.3.1 Data Description 64
3.3.2 Data analysis 66
3.3.3 Theoretical Predictions 68
3.3.4 Results 69
3.4 Discussion **73**
3.5 Concluding remarks **75**
3.6 Appendix **77**
3.6.1 Descriptive Statistics 77
3.6.2 Full Results 79

4 THE BALLOT AND THE NEEDLE: INVESTIGATING CORRELATIONS BETWEEN VOTING PATTERNS AND COVID-19 VACCINATION IN BRAZIL **86**
4.1 Introduction **86**
4.1.1 Outline 87
4.1.2 Literature Review 87
4.2 Empirical Strategy **91**
4.2.1 Data Description 91
4.2.2 Predictions 93
4.2.3 Data Analysis 94
4.2.4 Main Results 95
4.3 Discussion **96**
4.4 Concluding Remarks **100**
4.5 Appendix **102**
4.5.1 Descriptive Statistics - Regions 102
4.5.2 Sensitivity Tests 108

5 GENERAL CONCLUSIONS **111**

General Conclusions **111**

REFERENCES **113**

1 INTRODUCTION

Microeconomic models are simplified means to explicitly depict relationships between specific variables, whereas in real life, causes and consequences of human behavior are generally too complex to be deduced[1]. Given the abundance of data regarding human activity, recent decades[2] have seen models being developed to analyze an ever-growing number of subjects. As a result, in the current century, economics as a study field has opened itself up to virtually every aspect of human decision-making.

The COVID-19 pandemic, in turn, has been a defining moment in recent history, affecting nearly every aspect of our lives, from public health and politics to economics and society. In Brazil, the pandemic has brought to the forefront the importance of understanding the individual and social factors that influence vaccine uptake, as well as the political response to the crisis.

The present thesis tackles these crucial issues head-on, with the goal of advancing our understanding of the complex and interrelated factors that shape vaccine hesitancy, political response, and vaccination rates in Brazil. The thesis comprises three chapters, each exploring a different but equally important aspect of the COVID-19 pandemic in Brazil. In summary, it will evaluate the question of whether electoral incentives play a role in shaping the policies adopted by mayors during the COVID-19 pandemic, what factors influence vaccine hesitancy and the interval between vaccine doses, and the relationship between city-level voting patterns and vaccination rates in Brazil.

To do so, Chapter 1 investigates the role of electoral incentives in shaping the policies adopted by mayors during the COVID-19 pandemic in 2020. This chapter aims to answer the question of how political incentives may have influenced the behavior of incumbents of different ideologies, given the fact that local elections were held in October 2020, and non-pharmaceutical interventions, such as mask-wearing and social distancing, became heavily politicized in Brazil. To answer this question, the chapter employs a signaling model and uses regression discontinuity design to analyze the data from the Santos et al. (2021) dataset. The hypotheses of the chapter are that incumbents of different ideologies will react differently to electoral incentives and that right-wing incumbents will adopt less stringent measures against COVID-19 compared to left-wing incumbents. To evaluate these hypotheses, the chapter will use regression analysis and control for a variety of factors, including the ideology of the political party, the political stance of the incumbent, and the level of public support for non-pharmaceutical interventions. The

[1] The implications from this simple fact were first systematically organized by Friedman (1953).
[2] Following the tradition established by Becker (1976) and developed by Lazear (2000) and Tullock (2002) among many others.

chapter will provide a unique perspective on the politics of pandemics and the behavior of political incumbents during crisis situations and will help inform policymakers on how to best respond to future public health crises.

The COVID-19 pandemic has underscored the importance of understanding not only the political factors that influence vaccination rates but also the complex individual behavior surrounding vaccine hesitancy. Therefore, the subsequent two chapters of this thesis will delve deeper into vaccine hesitancy, exploring the various externalities and economic concepts that make this subject crucial for public health and policy. By examining the interplay between individual decision-making, information asymmetry, and the potential positive and negative externalities arising from vaccination, these chapters will shed light on the multifaceted nature of vaccine hesitancy and its consequences. This comprehensive analysis aims to inform more effective public health interventions and policies, as well as contribute to a broader understanding of how economic concepts and principles can help address the challenges posed by vaccine hesitancy in the context of a global health crisis.

Vaccines exhibit positive externalities as their benefits extend beyond the individuals who receive them. When a significant portion of a population is vaccinated against a contagious disease, it reduces the likelihood of transmission, leading to what is known as herd immunity. This protects those who cannot be vaccinated or for whom the vaccine is less effective, such as infants, the elderly, or immunocompromised individuals. Due to these positive externalities, vaccines can be considered public goods. In the case of vaccines, when herd immunity is achieved, even unvaccinated individuals benefit from the reduced likelihood of contracting the disease. Additionally, one person's vaccination does not diminish the benefits that others receive from being vaccinated.

Chapter 2 focuses on identifying the factors that influence vaccine hesitancy and the interval between COVID-19 vaccine doses in Brazil. The essay intends to address which factors contribute to vaccine hesitancy in the form of refusing to get extra doses or postponing the shots. To answer this question, the chapter builds on a general choice under uncertainty framework and uses a large dataset of doses administered combined with individual, socioeconomic, and electoral variables. The hypotheses of the chapter are that demographic, socioeconomic, and ideological factors will influence vaccine uptake, and that the interval between vaccine doses will be correlated with similar factors. To evaluate these hypotheses, the chapter will use regression analysis and control for a variety of factors, including age, skin color, income, gender, and political ideology. The chapter will provide important insights into the role that information and public health policies play in addressing vaccine hesitancy, especially in the context of developing countries.

Chapter 3 examines the relationship between city-level voting patterns and vaccination rates in Brazil. This chapter aims to provide information regarding the relation between voting patterns and vaccination rates, and whether this relationship is consistent throughout the country. To answer this question, the chapter employs a variety of statistical models and uses data on city-level voting patterns and vaccination rates. The hypotheses of the chapter are that voting patterns will be significantly correlated with vaccination rates, and that this relationship will be consistent throughout the country. To evaluate these hypotheses, the chapter will use regression analysis and control for a variety of factors, including sociodemographic variables, such as household income and population density. The chapter will provide a deeper understanding of the impact of political views and ideologies on vaccination decisions and will help to inform policymakers on how to promote vaccination uptake and protect public health.

Studying vaccine hesitancy is important for economics as a science as it sheds light on the complex interplay between individual decision-making, information, and externalities. Vaccine hesitancy can arise due to various factors, such as misinformation, mistrust, or cultural and social influences, which can lead to suboptimal vaccination rates and hinder the achievement of herd immunity. By understanding the underlying causes of vaccine hesitancy and identifying strategies to address it, economists can contribute to the design of more effective public health policies and interventions that promote vaccination uptake and protect public health. Moreover, vaccine hesitancy offers an opportunity for economists to explore the role of information, social preferences, and other behavioral factors in individual decision-making. By studying vaccine hesitancy, economists can enhance their understanding of human behavior and decision-making processes, which in turn can enrich the broader field of economics and inform the development of more effective policies in various domains.

Following these steps, this thesis hopes to advance our understanding of the individual and social factors that shape vaccine uptake and the political response to the COVID-19 pandemic in Brazil. The studies, while located within the economic science, intend to use a multidisciplinary approach, combining political science and public health with empirical evidence and theoretical frameworks, to shed light on the complex and interrelated factors that influence political responses and vaccination rates. The findings of this thesis have the potential to inform evidence-based public health policies, contributing to the academic literature and improving our general knowledge on the impact of political and social factors on individual decisions concerning health crises.

2 ELECTIONS IN THE TIME OF COVID-19: INCUMBENCY EFFECTS ON NON-PHARMACEUTICAL INTERVENTIONS IN BRAZILIAN CITIES

The study investigates the role of electoral incentives in shaping policies adopted by mayors during the pandemic in Brazil aiming to reduce the virus circulation during the year 2020. A signalling model was constructed to formulate the hypothesis that the ideology from the mayor as well as the constituents may shape the adoption of Non-Pharmaceutical Interventions during election season. To test it, a dataset was constructed combining public data and datapapers with electoral results, finding that right-wing incumbents running for reelection adopted less stringent measures against COVID-19 when business closures were considered and more social protection policies. The empirical analysis validated the theoretical predictions, indicating that political ideology and voter beliefs and preferences exert electoral incentives during crises.

Keywords: COVID-19, NPIs, political economy, electoral incentives, Brazil

2.1 INTRODUCTION

Multiple studies have shown that incumbents running for re-election have incentives to implement policies that increase their chances of winning the election (BESLEY; CASE, 1995; LIZZERI; PERSICO, 2001; FRANZESE-JR, 2002; FINAN; MAZZOCCO, 2021). Given its particular federate and electoral systems, Brazil presents itself as a relevant case for empirical study in this field (FERRAZ; FINAN, 2011; DEMAGALHAES, 2015; KLAŠNJA; TITIUNIK, 2017; SCHETTINI; TERRA, 2020).

The COVID-19 pandemic posed a significant challenge for governments, requiring policies aimed at reducing human and economic activity, along with limitations on civil freedoms, with clear but potentially unquantifiable trade-offs. Such situation claimed for multidisciplinary decision making (NORHEIM et al., 2021) whilst also opening avenues for populist responses (LASCO, 2020). Given the novelty of the virus and its correlated disease SARS-COV2, as well as the resulting uncertainty regarding the subject, reasonable levels of scientific disagreement were expected on proposals to allocate resources (WASSERMAN; PERSAD; MILLUM, 2020). Nonetheless, debate concerning COVID-19 related policies started to occupy mainstream avenues in politics and grew stronger as more information was catered to support divergent worldviews (WILLIAMS; KESTENBAUM; MEIER, 2020).

In the early stages of the pandemic, during a period of intense political polarization (JUSTO et al., 2020), Brazil held mayor elections in November 2020. According to its legal and administrative framework, Brazilian cities bear responsibilities regarding public health and had to implement non-pharmaceutical interventions (NPIs) intended to reduce the circulation of the virus, alongside state level government (SANTOS et al., 2021). Considering the unwillingness from the federal government in adopting national social distance policies and mask mandates (FERIGATO et al., 2020) and its consequences related to the spread of the virus (CASTRO et al., 2021), mayors and governors became important actors in tackling the pandemics in Brazil (LANCET, 2020).

Mayoral elections in Brazil have two rules: a plurality system for cities with less than 200,000 electors and a two-round majority system for larger cities[1]. In both frameworks, an incumbent running for reelection possesses incentives to adopt policies matching the preferences of the biggest number of voters[2]. Therefore, it is reasonable to suppose incumbents may have aimed to calibrate its policies according to electoral motives.

Several questions arise from this observation. Firstly, considering the trade-off between short-term economic activity and the adoption of NPI, electors might disagree on which policies to adopt, if any. In Brazil, this discussion became ideologically motivated from the start after its right-wing President, Jair Bolsonaro, used an official pronouncement in national television to claim that the disease was a mere flu and daily life should remain as usual (AJZENMAN; CAVALCANTI; MATA, 2020).[3]

Mayors intending to sign ideology or proximity with the federal government could be encouraged not to adopt measures such as social distancing or businesses closures. The opposite could also be expected: local governments adopting NPIs even though no cases were reported in their cities. In any case, an upcoming election and information regarding the voters preferences might have influenced policy making pertaining to the pandemics. On the other hand, mishandling the health crisis may indicate low levels of competence, which can hurt the electoral results of incumbents seeking reelection (FRENKEL, 2014). Existing evidence suggests that electoral incentives have impacted COVID-19 policies in other countries (PULEJO; QUERUBÍN, 2021), and Giommoni e Loumeau (2022) observed that stricter lockdowns were correlated with higher vote shares for incumbents in the 2020 French municipal elections.

Building on these observations, we present a framework consisting of three components: *i*) ideology, *ii*) policy regarding NPIs, *iii*) and office rent. Following that idea, we build a signaling model to indicate how each component affect optimum strategy for incumbents seeking reelection given Brazilian institutional framework, their ideology

[1] If no candidate wins more than fifty percent of valid ballots in the first round, a runoff between the two most voted candidates occurs.

[2] Winning more than half the votes is a necessary and sufficient condition for reelection in majority rule. Although it is not a necessary condition in plurality frameworks, it is a sufficient one. Following these , it is possible to reason that there are incentives to please the majority of the voters in either case.

[3] The entire official pronouncement, broadcasted nationally on 03/24/2020, can be read in Portuguese at: <https://noticias.uol.com.br/politica/ultimas-noticias/2020/03/24/leia-o-pronunciamento-do-presidente-jair-bolsonaro-na-integra.htm>

and the political preferences of the local electors. It states that right-wing pragmatic incumbents may calibrate their policies related to COVID-19 pandemics following electoral incentives, especially in right-leaning cities. On the other hand, left-wing incumbents may not act in the same way, even if the constituents are right-leaning, considering that implementing policies became associated with left-wing ideology.

The model was empirically tested using a regression discontinuity design (RDD), comparing responses adopted by mayors who were elected by a small margin in 2016[4], therefore able to run for reelection, with second term mayor, hence unable to compete for a new term. The data was combined with 2018 election results in each city as a proxy for the ideology of voters, as well as sociodemographic, economic, institutional and social features of cities and personal characteristics of candidates. The results indicate that right-wing incumbents adopted less stringent non-pharmaceutical policies during election year, but only when mandates for business closures are included in the stringency index. Electoral incentives did not modify the policies adopted by center and left-wing incumbents, even in cities with a majority of righ-leaning voters.

These findings, as well as the empirical limitations and ideas for future works, will be later discussed on the basis set by the related literature and the signalling model displayed in the following sections.

2.1.1 Literature Review

As mentioned in the introduction, this study is located in the field of political economy and focuses on estimating electoral incentives and incumbency effects. This work builds on microeconomic models such as principal-agent, signaling, and public choice, among others. There has been growing interest in this subject within economic literature, using game theoretic and social choice frameworks.

In the theoretical front, the canonical formal model linking policy decisions and electoral outcomes is the Hotteling-Downs model (DOWNS et al., 1957). Political competition is assumed to be analogous to firm competition given that each party must maximize its share of voters – in the same sense as each business aim to maximize its consumers. The model assumes a two-party election where each party aims to maximize their probability of winning and policy implementation is credible. If policy is one-dimensional and there is perfect information regarding to the preferences of sincere voters, it leads both parties to implement similar policies close to the median point.

4 As it will be explained in further details throughout the paper, politicians elected by a large margin of votes may not respond to electoral incentives once they might possess intrinsic characteristics that guarantees the support of the majority of voters, such as political background and/or popular charisma. Restricting the sample based on voting difference is the most used way to avert biases caused by non-observable factors (LEE, 2008; SONG, 2018).

Dewan e Shepsle (2011) presents a review of formal models of voting and elections. The authors show that models depict elections as having multiple roles and provide analytical tools to investigate how they relate to political phenomena. Two of the main tools provided by elections are preferences/information aggregation and incentive mechanisms. The introduction of models considering asymmetric information presents new evidences on incumbency effects, policy signaling and commitment.

Razin (2003) purposes a model of imperfect information where candidates make policy choices considering exogenous factors. Diverging from the initial results, it is shown that signaling motivations can lead to polarization and, given a set of general conditions, equilibria are inefficient regarding to the implemented policy.

Heidhues e Lagerlöf (2003) argue that, in the face of uncertainty about the true state of the world, candidates have incentives to follow popular beliefs, represented by voters' prior beliefs, rather than information gathered on the subject. This result arises from the fact that politicians must suggest a policy to voters and anticipate that competitors will propose a platform that is aligned with that of the electors. In that sense, each candidate ought to convince the electorate that their policy suggestion is more likely to lead to the intended outcome. The result stresses that even in the face of information suggesting the another policy is expected to produce better outcomes, the candidate commits the the policies preferred *a priori* by the voters, producing a suboptimal result in terms of general welfare.

Another important aspect of elections is the evaluation of incumbent actions. Ferejohn (1986) first proposed that voters have an incentive to base their votes on incumbents actual performance when holding offices. Politicians anticipate that behavior when choosing which policies to implement, resulting in a dynamic framework where the focus is located less in campaign promises and more in actual performance.

Recognizing that citizens might not accurately evaluate implemented policies, the author further developed a model to propose conditions that would induce the agent (the incumbent) to implement accountability mechanisms (FEREJOHN, 1999). It concludes, however, that if electorate is sufficiently heterogeneous and policies and performance are judged in multiple dimensions there may not be effective control tools for voters to exert.

The integration of theoretical and empirical investigations has been a common practice, even in early works such as Rattinger (1991) and BESLEY e CASE (1995), when econometric methods were less advanced. As these works indicate, the initial interest was estimating electoral advantages of being in office, as was also the case for the first studies applying methods to access causal inference.

Lee (2008) proposed that the discontinuity observed in close races could be used as a randomized experiment in a regression discontinuity design (RDD). Applying this method in US congressional elections, the author found that House Representatives first elected in close races experienced a significant electoral advantage from incumbency. Further studies strengthened the results (ERIKSON; TITIUNIK et al., 2015) and found similar effect for Senate races (CATTANEO; FRANDSEN; TITIUNIK, 2015) as well as mayor (KESSNER, 2018).

Given the two party system in the United States, the approach could be inappropriate for Brazil and other democracies. At city-level, early studies applying RDD found a big electoral advantage for incumbents barely elected for city council (BOAS; HIDALGO, 2011) in Brazil.

Pertaining mayors, Brambor e Ceneviva (2011) estimated a significant incumbency disadvantage, a result later corroborated by Klašnja e Titiunik (2017) using the same method as Lee (2008). However, DeMagalhaes (2015) proposes that, unlike the US, where almost all incumbents run for reelection, in Brazil a significant number of mayors chose not to try a second term. Defining incumbency advantage as the probability of being reelected unconditional on running for a second term, the study finds no significant (dis)advantage in statistical terms for incumbents who won close elections in 1996.

Novaes e Schiumerini (2021) finds that commodity shocks help explain incumbency effects for mayors, while Owen (2019) obtains similar results when investigating the impact of announcements of foreign direct investments on incumbency in Brazilian cities.

Regarding broader effects in public policy, Besley e Case (1995) investigated whether policies implemented by governors who were subject to binding one-term limits differed from those implemented by governors who were eligible to run for reelection. The study found evidence that the presence or absence of term limits affected taxes, spending, and other policy instruments, particularly when the governor was a Democrat. Building on those ideas, several studies applied RDD in close elections to estimate in-office behavior.

Until this point, the literature review highlighted a growing interest in the relationship between electoral incentives and policy decisions. Theoretical models and empirical studies provide evidence of incumbency effects and the influence of electoral incentives on policy choices. The studies discussed in this review range from formal models of voting and elections, to the evaluation of incumbent actions and the effects of binding one-term limits on public policy.

We now continue by investigating COVID-19 responses, as several recent studies examine the impact of the pandemic on political behavior, government response, and voting preferences. The COVID-19 crisis has generated debates about whether incumbents should prioritize lives, livelihoods, jobs or the general economy, with politicians' decisions potentially affecting their re-election chances. Chmel, Klimova e Savin (2023) conducted two experiments in Russia to examine the trade-off between saving lives and saving the economy for incumbent support. They found that while both healthcare-driven and economy-driven policies encouraged support, the economy-driven policy had a larger effect on voting.

Pulejo e Querubín (2021) investigates how electoral concerns impact the implementation of restrictive measures in response to the COVID-19 outbreak. Their findings reveal that incumbents who can run for re-election implement less stringent restrictions when the election is closer in time. Similarly, Bel, Gasulla e Mazaira-Font (2021) present a theoretical model and empirical strategy to analyze the drivers of policy-response agility during the outbreak, showing that policy responses were delayed due to concerns about healthcare system capacity and economic costs. Shvetsova et al. (2021) examine the policy response of federal and regional governments in federations to the COVID-19 crisis, finding that public health measures are at least as stringent as those in non-federations.Ferraresi et al. (2020) identifies the role of political, economic, and institutional factors in explaining the differential timing and intensity of stringency measures undertaken by countries on the same pandemic trajectory. A key result was that fiscally decentralised economies have been slow to react.

Engler et al. (2021) analyzed the degree to which COVID-19 policies interfered with democratic principles in 34 European countries. They found that the variation in policy responses could not be solely explained by pandemic-related factors, and argued that strong protection of democratic principles in normal (crisis-less) times made governments more reluctant to opt for restrictive policies during the pandemic.

Next, Giommoni e Loumeau (2022) studies the impact of the lockdown policy on voting behavior during the COVID-19 pandemic in France, using a Spatial Regression-Discontinuity-Design model. Their results suggest that lockdown regulations significantly affected electoral outcomes, with incumbents and Green parties gaining more vote shares in localities under a harder lockdown.

Leininger e Schaub (2023) investigated the impact of the COVID-19 pandemics on electoral choice in Germany, specifically in the state of Bavaria. They found that the crisis significantly benefited the dominant regional party, the CSU, and its candidates. The authors attributed this to a strategic-alignment mechanism, whereby voters supported candidates that they deemed most likely to be able to solicit support from higher levels of government.

Pertaining to Brazil, Menezes-Filho e Komatsu (2021) found no incumbency effect on the adoption of non-pharmaceutical interventions (NPIs) by Brazilian municipal governments in response to COVID-19. However, unlike the present study, their work posited that electoral incentives would act in the same direction for both right-wing and left-wing incumbents, which may help explain their results. In a related study, Bruce et al. (2022) investigated mayoral measures to combat the pandemic in Brazil and found evidence that female incumbents performed better in terms of total cases and deaths.

In the context of citizens' evaluation of government measures, Altiparmakis et al. (2021) examined the determinants of the public's evaluations of health and economic measures taken by governments to address the COVID-19 crisis. The study found that the public's approval of the measures depends strongly on their trust in national leaders, an effect augmented for voters of the opposition. Bol et al. (2021) investigated the political effect of the enforcement of a strict confinement policy in response to the COVID-19 pandemic, revealing that lockdowns have increased vote intentions for the party of the Prime Minister/President, trust in government, and satisfaction with democracy.

Baccini, Brodeur e Weymouth (2021) investigated the effect of the COVID-19 pandemic on the 2020 US presidential election, focusing on the change in county-level voting for Donald Trump between 2016 and 2020. They found that COVID-19 cases negatively affected Trump's vote share, with the effect being strongest in urban counties, states without stay-at-home orders, swing states, and states that Trump won in 2016. A counterfactual analysis suggested that Trump might have won re-election if COVID-19 cases had been 5 percent lower.

Lastly, Vries et al. (2021) examined how the response to the COVID-19 outbreak in one country affected incumbent support in other countries. Their results indicate a crisis signal effect of Italy's COVID-19 lockdown, as support for the incumbent increased domestically in other European countries. This finding highlights the importance of developments abroad for incumbent approval and the difficulty facing citizens seeking to disentangle performance signals from exogenous shocks.

In conclusion, the related literature indicate that COVID-19 pandemic has had significant effects on political behavior and electoral outcomes. The studies in this literature review provide insights into the complex relationship between the pandemic, political decisions, and the functioning of democracy during times of crisis, including impacts on mayoral responses. This interplay calls for empirical investigations, especially in frameworks that allows for causal inference. Following these findings, this literature review sets the stage for a more in-depth analysis of the relationship between electoral incentives and policy decisions in Brazil, focusing on COVID-19 related non-pharmaceutical interventions during local elections season.

2.1.2 Outline

The current paper is built as follows. After this introduction and review of the relevant literature, the following section presents the signaling model considering the legal features of Brazilian public health framework and local election rules. An empirical investigation will be presented, based on data from 2016 and 2020 municipal elections combined with datapapers and public databases. Finally, after discussing the implications of the empirical findings for the theoretical predictions, concluding remarks and ideas for future research will be offered.

2.2 THE MODEL

The following sections present the context and conceptualize the formal model and its solutions.

2.2.1 Legal framework

The legal framework in Brazil is characterized by its federate configuration, with three government levels: federal, state, and municipal. The Federal Constitution provides general rules for each level, including their legal and policy competencies, tax system, administrative organization, and other areas.

Elections in Brazil are conducted by Regional Electoral Courts (TRE), which are subordinate bodies of the Superior Electoral Court (TSE) and thus follow national rules. As already stated, mayoral elections in Brazil have two rules: plurality for cities with less than 200,000 electors, and two-round majority[5] for cities with more than 200,000 electors. In both cases, incumbents running for re-election have incentives to adopt policies that align with the preferences of voters.

In terms of public health, the Federal Constitution states that health is a right of all citizens and a duty of the State, and it should be guaranteed through social and economic policies[6]. Even though the three government levels have responsibilities concerning the subject, the roles are complementary and coordinated to constitute an unified and universal health care system (*Sistema Único de Saúde*, SUS). The cities are primarily responsible for basic care, but they can also participate in more complex activities in cooperation with the state and federal governments.

In response to the COVID-19 pandemic, the Brazilian Supreme Court ruled that each government level could adopt stricter rules compared to the upper levels, but could not loosen restrictions. For example, the federal government could determine business closures, which would then be necessarily enforced by the state and local governments. However, if a state government imposed restrictions, the federal government could not

[5] A second round occurs when the most voted candidate does not obtain more than half of valid votes (excluding blanks and nulls) in the first round.

[6] Article 196. Health is a right of all and a duty of the State and shall be guaranteed by means of social and economic policies aimed at reducing the risk of illness and other hazards and at the universal and equal access to actions and services for its promotion, protection and recovery (BRASIL, 1988).

erase these measures, and cities would have to abide by them.(ABBOUD; SCAVUZZI; FERNANDES, 2020)[7]

This ruling was significant, as then-President Jair Bolsonaro had publicly opposed non-pharmaceutical interventions such as stay-at-home orders and business closures, which created uncertainty around the national stance on pandemic response measures (PECI; GONZÁLEZ; DUSSAUGE-LAGUNA, 2023). Despite the President's public statements, the Brazilian government adopted various policies to combat the virus. It highlighted the contradictions between the President's public stance and some of the government's actions, resulting in the firing of two health ministers during the first months of the health crisis.

Given the novelty of the pandemic, there was a reasonable doubt regarding the most effective course of action, which could have further complicated decision-making processes for local leaders. However, the natural complexity of Brazilian political and governmental landscape gained another component: the polarization between federal government's supporters and critics (BORGES; RENNÓ, 2021).

Bolsonaro's public narratives, while not necessarily reflecting the government's actions, could still have influenced local decision-makers and voters. It may have incentivized mayors to avoid adopting policies against the virus to align with the President public stance and that of his supporters. In such a scenario, local leaders might have felt encouraged to prioritize political alignment with the President over policies to combat the pandemic (PECI; GONZÁLEZ; DUSSAUGE-LAGUNA, 2023). This highlights the potential consequences of political narratives in shaping local policy responses, even when the legal framework prevents the president from directly interfering with state and municipal governments formal decision-making processes.

Disregarding initial differences, every state in Brazil implemented mask-wearing and business closure legislation (TOUCHTON et al., 2021). Cities had limited margins to affect the behavior of their citizens, consequently the introduction of stricter rules would possibly have a reduced impact on the spread of the virus. On the other hand, proposing rules to override state-level restrictions did not produce practical effects, as the judiciary would quickly overrule such legislation following the Supreme Court ruling. These features are translated into a signaling model that will be detailed in the following section.

2.2.2 Basic setting

Let us consider a city where each voter is indexed by $j \in \{l, r\}$. The share $\mu \in (0, 1)$ of voters is r. The incumbent mayor running for re-election has a type $\theta \in \{L, R\}$, which is

[7] The Supreme Court was asked to rule in the matter after Brazilian President Jair Bolsonaro edited executive orders aiming to erase state government competencies to adopt restrictions and masking mandates. It was ruled unconstitutional: <https://portal.stf.jus.br/noticias/verNoticiaDetalhe.asp?idConteudo=440055&ori=1>

the incumbent's private information even though the voters possess a prior belief $p \in [0, 1]$ that the mayor is of type R. As can be deduced from the letters denoting the chosen variables, $j = l$ and $\theta = L$ represent left-wing voters and incumbents, respectively, while $j = r$ and $\theta = R$ indicate right-wing ones.

Given the health emergency that was happening during the election season, incumbents had to decide whether to adopt NPIs, denoted by $x_\theta \in \{0, 1\}$, where 1 represents the adoption of such policies. Considering the general awareness around the subject and the widespread fear of contagion in a period when vaccines were not yet available, we suppose that among the voters, a share $\chi \in (0, 1)$ votes for the incumbent if and only if $x_\theta = 1$. The remaining voters (share $1 - \chi$), on the other hand, choose to re-elect the mayor if they believe they share the same ideology. While χ is unknown to the mayor, we assume that it is a random variable with a probability distribution function with cumulative distribution denoted by the function $F(\cdot)$, which is common knowledge.

As highlighted in the previous section, the Supreme Court ruled that cities (or states) could implement stricter COVID-19 regulations than those imposed by state (or federal) guidelines but could not relax these measures. This legal framework created an environment in which mayors faced restrictions due to governor mandates, ultimately leading to the decision to utilize a signaling model to analyze political behavior in this context.

The signaling model can help identifying the incentives mayors faced when introducing or refraining from promoting additional COVID-19 measures. For left-leaning mayors in cities where the majority of the population shares their political orientation, adopting more stringent measures than those imposed by the respective governor could signal a commitment to prioritizing public health and addressing the pandemic. This action could potentially resonate with their left-leaning constituents and enhance their electoral appeal.

On the other hand, right-leaning mayors in cities with a predominantly right-leaning electorate may have chosen not to introduce additional mandates, signaling their adherence to right-wing beliefs. By not adopting more stringent measures than those enforced by the state, these mayors could demonstrate their support for a more relaxed approach to pandemic management, which could appeal to their right-leaning constituents. It is important to note that in this scenario, cities would still have to enforce state mandates regardless[8], meaning that the decision not to introduce additional measures was somewhat symbolic.

By employing the following model, we can better understand the political motivations of mayors during the pandemic and how their decisions to implement or not implement

[8] Even though the effort to adopt these policies was relegated to state-level officials, their decisions were centralized in what became known as "Council of Health Secretaries,"which helps explain the similar level of stringency observed by Petherick et al. (2020)

additional COVID-19 measures served as signals to their respective constituents, thus influencing their political behavior and electoral outcomes. This framework is represented by a two-period model. In the first period, the incumbent must choose x_θ, while in the second, the constituents decide whether to vote for the incumbent. The extensive form of such game is presented in figure 2.1.

2.2.3 Incumbent's problem

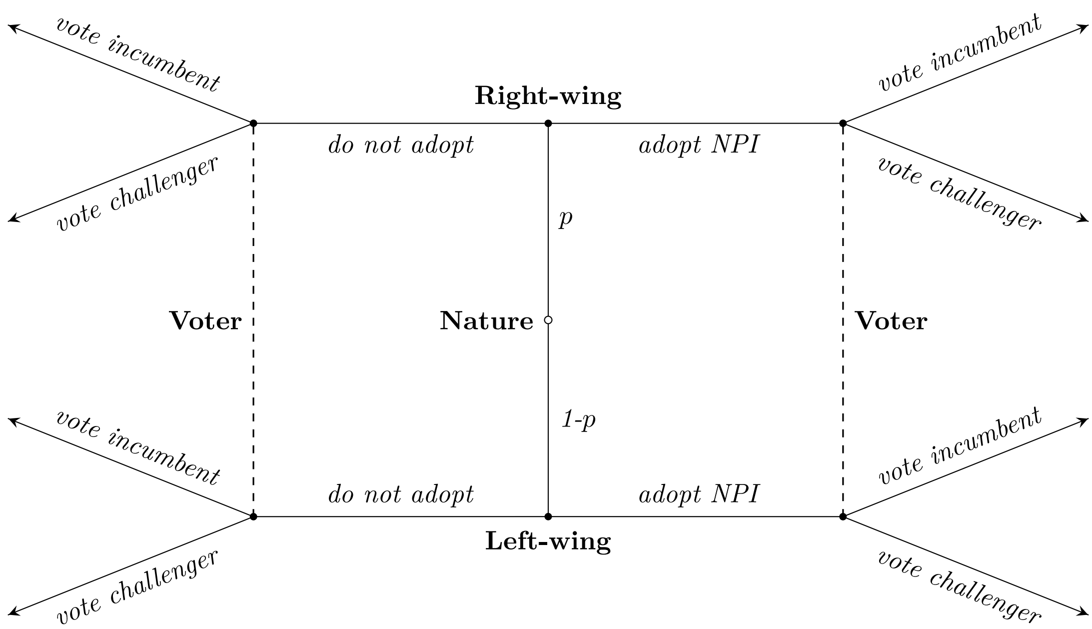
Based on the framework previously described, the expected utility of the incumbent is expressed by

$$\mathbb{E}[U_\theta(x_\theta)] = T(1 - x_\theta)A_R + (1 - T)x_\theta A_L + W \Pr(v_\theta \geq 1/2 \mid x_\theta), \tag{2.1}$$

where: T is an indicator variable such that $T = 1$ if $\theta = R$, $T = 0$ otherwise; $A_R > 0$ represents the (ideology) benefit for a right-wing incumbent from not adopting NPIs and $A_L > 0$ is the (ideology) benefit that a left-wing mayor exerts from implementing NPIs; W denotes the net benefit obtained from being in office, representing the product of wages, ego-rents, policy setting, among other general political gains; finally, v_θ is the share of votes[9] for incumbent θ given her choice of x_θ.

[9] As stated in section 2.2.1, mayoral elections follow plurality rule for cities with less than 200k voters, which is the case for the vast majority ($\approx$ 98%) of cities in Brazil. However, we chose to represent the odds of reelection as if the incumbent must win the majority of votes, a sufficient condition, although not a necessary one. It is intended to greatly simplify the analyses while also considering that most municipal elections present only two viable candidates. Election results showed that the two most voted candidates in 2020 elections accounted for more than 92% of valid ballots on average, which indicates that the simplification is close enough to reality.

Figure 2.1 – Signaling game in extensive form.



Source: author's preparation.

The proposed utility assumes that a right-wing incumbent experiments utility gains when fails to adopt NPIs, following the political discourse against these measures produced by Brazilian President at the time. In contrast, left-wing mayors increase their utility by introducing such policies, once mask wearing and business closures became linked with left-leaning policies.

In short, the expected utility of the incumbent is expressed in equation 2.1. The problem of the incumbent is to maximize the expected utility, modelling the trade-off between ideology costs or benefits of implementing NPIs and the expected probability of winning the election given the choice of x_θ. The utility function takes into account the type of the incumbent (right-wing or left-wing), the cost or benefit of implementing NPIs, and the general political gains from being in office. The next step is to examine how voters behave.

2.2.4 Voters' behavior

As indicated in the previous section, it will be assumed that voters care only about two factors whilst deciding whether or not to support the incumbent. A proportion χ of constituents will vote to reelect the incumbent if and only if she implements NPIs ($x_\theta = 1$). The remaining $1 - \chi$ voters will vote for the incumbent if they believe the incumbent shares their ideology.

In mathematical terms, this means that the voting share can be expressed as $v_\theta = (1-\chi)(\mu p + (1-\mu)(1-p)) + \chi x_\theta$. Therefore, the actual total voting will depend on which equilibria the voters believe they are in and the adopted policy.

For an incumbent $\theta = R$, the expected voting shares are:

$$v_R = \begin{cases} \mu(1-\chi) & \text{for } (x_l^*, x_r^*) = (1,0) \\ \mu(1-\chi)+\chi & \text{for } (x_l^*, x_r^*) = (0,1) \\ (1-\chi)(\mu p + (1-\mu)(1-p)) + \chi & \text{for } (x_l^*, x_r^*) = (1,1) \\ (1-\chi)(\mu p + (1-\mu)(1-p)) & \text{for } (x_l^*, x_r^*) = (0,0), \end{cases} \tag{2.2}$$

while a $\theta = L$ incumbent expects to obtain voting as follows:

$$v_L = \begin{cases} \mu(1-\chi)+\chi & \text{for } (x_l^*, x_r^*) = (1,0) \\ \mu(1-\chi) & \text{for } (x_l^*, x_r^*) = (0,1) \\ (1-\chi)(\mu p + (1-\mu)(1-p)) + \chi & \text{for } (x_l^*, x_r^*) = (1,1) \\ (1-\chi)(\mu p + (1-\mu)(1-p)) & \text{for } (x_l^*, x_r^*) = (0,0). \end{cases} \tag{2.3}$$

The voting behavior of constituents indicates that the expected votes for both types of incumbents are the same in pooling equilibria. That is expected once voters are unable to differentiate the candidates based on their choice of public policy and the result is mostly affected by their prior belief about the incumbent's ideology and the share of constituents who want the adoption of NPIs. The next section will investigate the conditions and consequent feasibility regarding each equilibrium.

2.2.5 Equilibria

The solutions of the proposed signaling game constitute Perfect Bayesian Equilibria (PBE). In these frameworks, an equilibrium is represented by a pair of optimal strategies (x_R^*, x_L^*) and beliefs $Pr(\theta = R \mid x_\theta) = p \in [0,1], \theta \in \{L, R\}, x_\theta \in \{0,1\}$ that voters share regarding the ideology of the incumbent given the chosen policy.

The first solution to be explored is the separating equilibrium where the right-wing incumbent does not implement the policies while the left-wing does: $(x_R^* = 0, x_L^* = 1)$ with $Pr(\theta = R \mid x_\theta = 0) = p = 1$, and $Pr(\theta = L \mid x_\theta = 1) = 1 - (p-1) = 1$. Let us first observe what it represents for a right-wing incumbent. In accordance to (2.2), she is expected to receive $\mu\,(1-\chi)$ share of the votes and is thus reelected if $\mu\,(1-\chi) \geq 1/2$. As χ is the only random variable in the setting and its cumulative distribution is denoted by $F(\cdot)$, isolating χ results in

$$Pr(v_R \geq 1/2 \mid x_R = 0) = Pr\left(\chi \leq \frac{2\mu - 1}{2\mu}\right) = F\left(\frac{2\mu-1}{2\mu}\right). \tag{2.4}$$

Nonetheless, in order for a right-wing incumbent not to defect, it is necessary that $\mathbb{E}[U_R(x_R = 0)] \geq \mathbb{E}[U_R(x_R = 1)]$. Given the set of beliefs for this equilibrium, an incumbent who implements NPIs is expected to be left-wing ($p = 0$), resulting in a vote share of $\mu(1-\chi) + \chi$ following (2.3) and a probability of being elected of

$$Pr(v_R \geq 1/2 \mid x_R = 1) = 1 - F\left(\frac{2\mu-1}{2\mu}\right), \tag{2.5}$$

which is the complement of (2.4).

Substituting (2.4) and (2.5) in (2.1) and applying to the necessary condition expressed above yields

$$\begin{aligned} A_R + WF\left(\frac{2\mu-1}{2\mu}\right) &\geq W\left(1 - F\left(\frac{2\mu-1}{2\mu}\right)\right), \\ \frac{A_R}{W} &\geq \left(1 - 2F\left(\frac{2\mu-1}{2\mu}\right)\right). \end{aligned} \tag{2.6}$$

Regarding a left-wing incumbent and following the same steps, the condition for the equilibrium to hold, which relies on $\mathbb{E}[U_L(x_L = 1)] \geq \mathbb{E}[U_L(x_L = 0)]$, is represented by

$$\frac{A_L}{W} \geq \left(2F\left(\frac{2\mu-1}{2\mu}\right) - 1\right). \tag{2.7}$$

At a first glance, both equations (2.6) and (2.7) state that the equilibrium will hold if and only if the rate between ideology (A_θ) and office rent (W) is greater than a function of the probability of being elected dependent on the proportion of right-leaning constituents in the city (μ). Aiming to allow for more insightful interpretations of the results, it is useful to propose the following definitions:

Definition 2.1. ${}^{A_\theta}/_{W} \in [1, 0)$ *represents 'pragmatic' incumbents, and* ${}^{A_\theta}/_{W} > 1$ *denotes 'ideological' incumbents.*

The definition is designed to be straightforward. If $A_\theta > W$, the incumbent values ideology more highly than the utility gained from being in office. Such a politician is commonly labeled *ideological.* On the other hand, whenever a mayor does not favor ideology in comparison to political gains ($A_\theta \leq W$), they are often referred to as *pragmatic.*

In order to analyze whether (2.6) and/or (2.7) are feasible in a plausible environment, we will define χ as a random variable with distribution $F(\cdot)$ that satisfies certain conditions. A basic condition is that $F(\cdot)$ is continuous, strictly increasing, and defined on the interval $[0, 1]$ in order for it to be a cumulative distribution function. Apart from that, one desired condition is that $\mathbb{E}(\chi > 0.5) \approx 0$. This condition ensures that the incumbent does not expect to be reelected simply by adopting NPIs ($x_\theta = 1$).[10] One way to guarantee this result is restricting the support of $F(\cdot)$ to the in the interval $[0, 0.5)$[11]. Consequently, it also means that the median of the distribution, $F(1/2)$, is less than 0.5.

Considering this distribution and the fact that $\mu \in (0, 1)$, from (2.6) and (2.7) we can see that

$$F\left(\frac{2\mu - 1}{2\mu}\right) = \begin{cases} 0, & \text{if } \mu \leq 1/2, \\ \in (0, 0.5), & \text{if } \mu > 1/2. \end{cases} \tag{2.8}$$

This result shows that if $\mu \leq 1/2$, representing a city where the majority of voters are left-leaning, the expected χ share of the population that votes for the incumbent if and only if she implements NPIs is not relevant. That is the case because the left-leaning voters also choose to reelected the incumbent if and only if she chooses $x_\theta = 1$, given that it would make them believe that the incumbent is left-wing ($1 - p = 1$) with certainty. On the other hand, if $\mu > 1/2$, the majority of the constituents is right-leaning, therefore the positive $F(\cdot)$ highlights the effect of the parameter μ (the share of right-wing voters) on the political calculation heuristically executed by the incumbent when deciding whether to implement NPIs or not.

Noticing the right hand-side of both conditions, it can be observed that one equals the negative of the other. Therefore, we can conclude that one of conditions will

[10] It implies that if the incumbent implements NPIs ($x_\theta = 1$), their expected chance of winning re-election is not significantly greater than 50%. If it were, the analysis would not be entirely believable and could produce unrealistic results based on the fact that implementing NPIs alone would guarantee W.

[11] In formal terms, we let $\text{supp}(F) \subseteq [0, 0.5)$.

automatically be satisfied. Appendix 2.6.1 shows that the condition that holds is 2.7, hence the left-wing incumbent will not defect. It is based on the definitions of $F(\cdot)$, once it is limited to the interval $(0, 0.5)$ for all values of $\mu \in (0, 1)$. It therefore represents a sufficient condition for 2.7 to hold regardless of the relation between A_L and W.

Considering a right-wing incumbent, a sufficient but not necessary condition for (2.6) to be true and the equilibrium to hold is $A_R > W$, which happens whenever the right-wing incumbent is ideological. Appendix 2.6.1 also presents the demonstration, which is expected given the definition of the support of $F(\cdot)$.

The combination of these results constitute the first proposition:

Proposition 2.2. *A sufficient condition for a separating equilibrium where the right-wing incumbent does not adopt NPIs ($x_R = 0$) and the left-leaning does ($x_L = 1$) to happen is $A_R > W$, which is the case if the former is ideological.*

The logic behind the result is elementary. Whenever the incumbents favor ideology over office rent, the equilibrium is expected to hold once the types are adopting the policies that each prefers. However, once the $1 - \chi$ share of constituents decide their votes based on the expected ideology of the incumbent and believe that it determines the chosen policy, pragmatic mayors may calibrate their response based on the constituents' preferred policies.

Next, let us evaluate the possibility of a separating equilibrium where the right-wing mayor implements NPIs, but the left-wing does not: $(x_R^* = 1, x_L^* = 0)$, where $Pr(\theta = R \mid x_\theta = 0) = p = 0, Pr(\theta = L \mid x_\theta = 1) = 1 - p = 1$. For this arrangement to exist, the following conditions must be met:

$$\frac{A_R}{W} \leq 1 - 2F\left(\frac{1 - 2\mu}{2(1 - \mu)}\right), \tag{2.9}$$

$$\frac{A_L}{W} \leq 2F\left(\frac{1 - 2\mu}{2(1 - \mu)}\right) - 1. \tag{2.10}$$

The opposite of equation (2.8) is observed. Now, whenever $\mu > 0.5$, $F(\cdot) = 0$ as right-leaning voters support the incumbent if and only if she adopts NPIs, once they would believe she is also right-wing. Therefore, they act in the same way as the χ share of voters, making the $F(\cdot)$ distribution and $\mathbb{E}(\chi)$ irrelevant. However, if $\mu < 0.5$, $F(\cdot) > 0$ and the electoral trade-offs are present.

Nonetheless, given that $F(\cdot)$ is defined in the interval $[0, 0.5)$, it implies that condition (2.10) can not be met, once the right hand-side of the equation is negative and both A_L and W are positive.[12] The intuition regarding this result is clear: even if a

[12] See Appendix 2.6.2

pragmatic right-wing incumbent chooses to adopt NPIs in a left-leaning city, the left-wing incumbent in a similar situation would deviate. By enacting the policy, it would match the probability of reelection of the right-wing candidate, while also obtaining A_L. It allows for the second proposition:

Proposition 2.3. *There does not exist an equilibrium where a right-wing incumbent adopts NPI while a left-wing incumbent does not.*

This is because any left-wing incumbent will possess incentives to defect when a right-wing expects sufficient electoral gains from adopting the policy, as it would match the probability of winning the election while also experimenting utility gains from implementing NPIs.

A separating equilibrium where a left-wing incumbent adopts NPIs and a right-wing incumbent chooses not to implement the policies has been demonstrated to be feasible under certain conditions. A sufficient one is that both types are ideological ($A_\theta > W$ for $\theta = \{L, R\}$). However, the opposite scenario, where a right-wing incumbent adopts NPIs while a left-wing incumbent does not implement the measures has been shown not to be feasible even when both types are pragmatic ($A_\theta \leq W$ for $\theta = \{L, R\}$). We now investigate the possible pooling equilibria.

First, let us focus on the equilibrium where both implement the policy: $(x_R^* = 1, x_L^* = 1), (Pr(\theta = R \mid x_\theta = 1) = p, (Pr(\theta = R \mid x_\theta = 0) = q)$. As both types choose the same policy, the voters' posteriors are equal to their priors. Let us define $p \in (0, 1)$ as the probability that the incumbent is right-wing given that she acted according to the equilibrium, $1 - p$ that she is left-wing given the same conditions. Additionally, $q \in (0, 1)$ refers to the probability that the incumbent is right-wing when she defects, $1 - q$ that she is left-wing.

Once again, in order for the equilibrium to hold, it is necessary that $\mathbb{E}[U_R(x_R = 1)] \geq \mathbb{E}[U_R(x_R = 0)]$ and $\mathbb{E}[U_R(x_L = 1)] \geq \mathbb{E}[U_L(x_R = 0)]$ hold simultaneously. Isolating χ in equation (2.2) shows that

$$Pr(v_R \geq 1/2 \mid x_R = 1) = 1 - F\left(\frac{1/2 - (p\mu + (1-p)(1-\mu))}{1 - (p\mu + (1-p)(1-\mu))}\right) \equiv 1 - F(\psi_p), \tag{2.11}$$

$$Pr(v_R \geq 1/2 \mid x_R = 0) = F\left(\frac{2(q\mu + (1-q)(1-\mu)) - 1}{2(q\mu + (1-q)(1-\mu))}\right) \equiv F(\psi_q). \tag{2.12}$$

Applying this logic to $\theta = L$ yields the same share of votes, once the constituents are not able to differentiate both types. Substituting (2.11), (2.12) in equation (2.1) results in the conditions for the equilibrium to hold:

$$\frac{A_R}{W} \leq 1 - F(\psi_p) - F(\psi_q), \tag{2.13}$$

$$\frac{A_L}{W} \geq F(\psi_p) + F(\psi_q) - 1. \tag{2.14}$$

It can be show that condition (2.13) will not hold for right-wing ideological incumbents (for a formal demonstration, see Appendix 2.6). As both $F(\cdot)$ are equal or greater than zero, the right hand-side of the inequality will not be greater than 1. Therefore, if $A_R > W$, the condition can not be met and the right-wing incumbent always defect. It is expected since she favors ideology gains and this pooling equilibrium means that she would have to adopt an undesired policy. From this result follows the next proposition. It implies that there can exist a pooling equilibrium where both types of incumbents adopt NPIs if and only if $A_R < W$, i.e. if the right-wing mayor is not ideological.

Regarding left-wing incumbents, the fact that $F(\cdot)$ is defined in the interval $[0, 0.5)$ implies that condition 2.14 always holds (see Appendix 2.6). It also makes sense once $x_L = 1$ produces utility gains regardless of the electoral results. As voters can not differentiate the types based on their choice of policy in pooling equilibrium, there are no incentives for the left-wing incumbent to act strategic.

Combining the previous observations brings us the next proposition:[13]

Proposition 2.4. *There exists a pooling equilibrium where both types of incumbents implement NPIs. Left-wing incumbents will always adopt the policy. Pragmatic right-wing incumbents will calibrate their response based on voters' ideology and beliefs.*

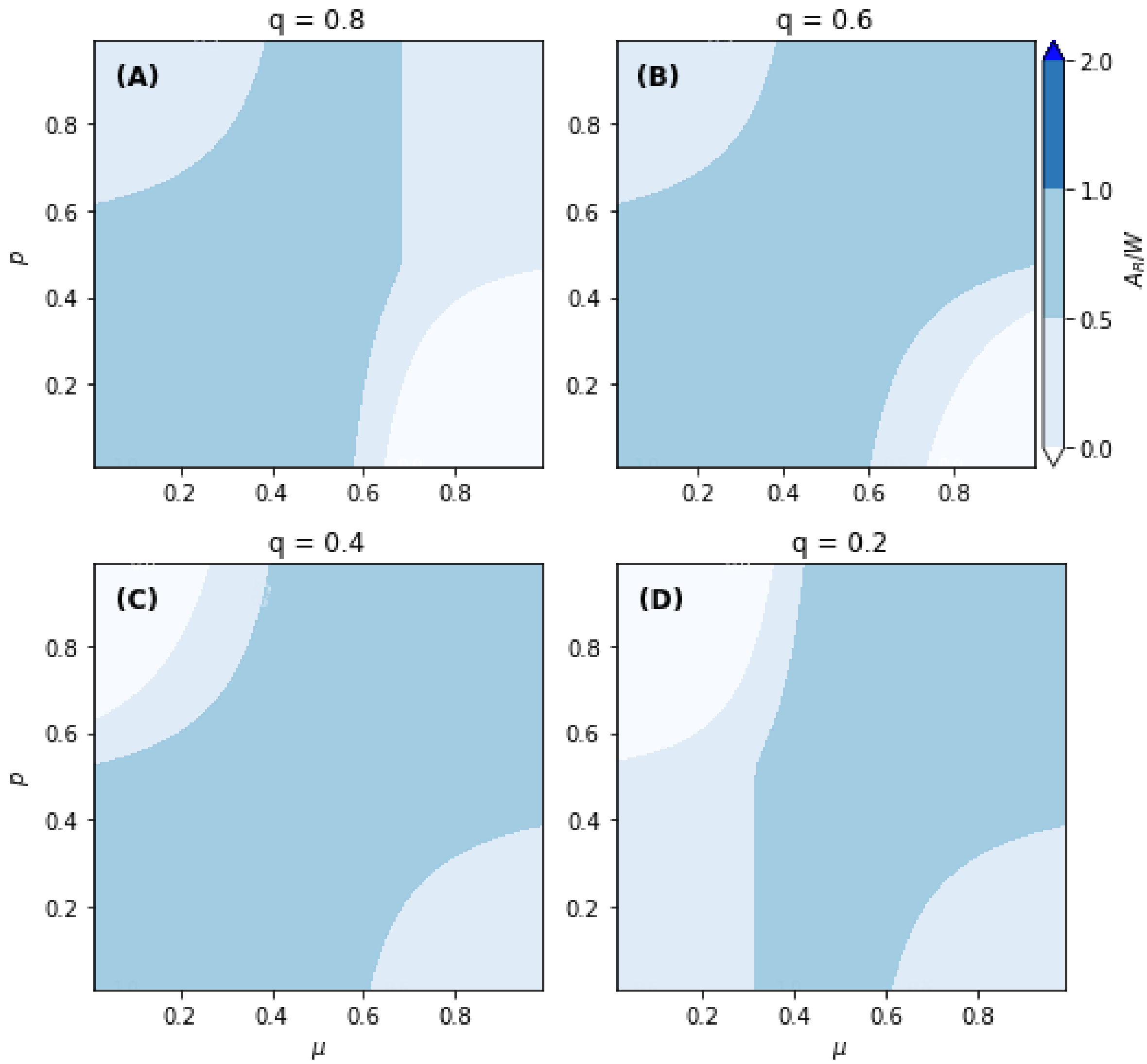
Considering that right-wing pragmatic incumbents will rely on the combinations of μ, p and q to make their policy decisions, it will be easier if we visually evaluate the results. If there exists a distribution $F(\cdot)$ that fulfills the conditions mentioned earlier, the insights derived from the model would hold for the general case as well. The Beta(a, b) is an example of a distribution that may serve as a suitable choice for analyzing the equilibrium conditions in the signaling game.

The results obtained using the distribution can be considered general if $F(\cdot)$ represents the real proportion χ and satisfies the desired conditions. To show that it might be the case, we can further discuss its properties. With parameters $(2, 8)$, the expected value of χ is 0.2, which means that an incumbent can expect 20% of the population to vote for her if she adopts NPIs. Moreover, the probability of $\chi \geq 0.5$ is approximately 0, avoiding the unrealistic situation where adopting NPIs would guarantee reelection. As its cumulative distribution function matches the general conditions, the following results will assume $F(\cdot) \sim$ Beta$(2, 8)$ without loss of generality.

Aiming to show how different values of q affect the feasible areas, figure 2.2 presents two dimensional contour plots where $q = 0.8, 0.6, 0.4, 0.2$. Plot (A) shows that when the proportion of right-wing voters (μ) is high, the prior belief that the incumbent is right-wing (p) is low, and the belief that a mayor who does not adopt NPIs is right-wing (q) is high, pragmatic incumbents ($A_R \leq W$) may defect.

[13] For the mathematical proof, see appendix 2.6.3

Figure 2.2 – Pooling equilibrium ($x_R^* = 1, x_L^* = 1$) - feasible area



Source: author's preparation.

Pragmatic right-wing mayors choose $x_R = 0$ when p and q are both high and μ is low. It states that, if the probability of being reelected is already low, once most voters believe that the incumbent is right-wing (high p and q) whilst the electors are left-leaning (low values of μ), the mayor will defect following her ideology regardless of electoral incentives even though she may be pragmatic.

Finally, right-wing pragmatics also defect when p is low while μ is high and $q > 0.5$, as can be seen in the top plots in figure 2.2. If the majority of the population is right-wing and believes the incumbent is left-wing if she adopts NPIs, the pragmatic incumbent will opt for $x_R = 0$ following electoral incentives only if the majority of population regards the defector as right-wing. The next proposition summarizes these findings.

Proposition 2.5. *Pragmatic right-wing incumbents may defect in two scenarios: (*i*) when the voters believe that an incumbent who does not adopt NPIs is right-wing ($q > 0.5$),* *she defects ($x_R = 0$) if the vast majority of voters are right-leaning ($\mu > 0.5 + \epsilon$, where $\epsilon > 0$) and believe that the incumbent is left-wing ($p < 0.5 - \epsilon$); or* (ii) *when $q < 0.5$, if $\mu < 0.5 - \epsilon$ and $p > 0.5 + \epsilon$).*

The proposition states that the pragmatic right-wing incumbent may deviate from the equilibrium whenever she expects significant electoral gains from choosing $x_R = 0$ or she expects to loose the election regardless of her actions. Considering that office rent can produce a higher utility than ideology ($W \geq A_R$) for this politician, she calibrates her policy depending on the preferences of the constituents. It is formally demonstrated in appendix 2.6.4

The final pooling equilibrium considers $(x_R^* = 0, x_L^* = 0), (Pr(\theta = R \mid x_\theta = 0) = p, (Pr(\theta = R \mid x_\theta = 1) = z)$. The expected share of votes are the opposite as what was presented in the following equilibrium. In order for $\mathbb{E}[U_R(x_R = 0)] \geq \mathbb{E}[U_R(x_R = 1)]$ and $\mathbb{E}[U_R(x_L = 0)] \geq \mathbb{E}[U_L(x_R = 1)]$ to hold, the next conditions[14] are necessary:

$$\frac{A_R}{W} \geq 1 - F(\omega_p) - F(\omega_z), \tag{2.15}$$

$$\frac{A_L}{W} \leq F(\omega_p) + F(\omega_q) - 1. \tag{2.16}$$

Condition (2.16) states that A_L/W must be less than a negative number for the equilibrium to be feasible. It results from the properties of both $F(\omega_p)$ and $F(\omega_q)$, once they possess support in the interval $[0, 0.5)$, therefore their sum will never surpass 1. As both A_L and W are positive, there is no combination of the parameters that allows the condition to hold, implying that the equilibrium in not possible.[15]

Proposition 2.6. *There does not exist a pooling equilibrium where left-wing and right-wing incumbents choose not to adopt NPIs.*

The reason for this result is similar to the one applied for ideological right-wing incumbents regarding proposition 2.4, once a left-wing mayor will always have incentives to defect regardless of the values of other parameters. If voters can not differentiate both types by their policies, left-wing incumbents will be better off deviating and guaranteeing utility gains (A_L) from adopting her desired policy ($x_L = 1$) than betting on possible electoral gains based on a choice of policy ($x_L = 0$) that does not meet their ideology. Also, by doing so she would gain the χ share of votes.

In conclusion, the analysis of the political equilibria shows that the adoption of NPIs by incumbents depends on various factors, including the beliefs of voters and the type of incumbent. In practical terms, it is expected that left-wing mayors will adopt NPIs,

[14] Where $\omega_p \equiv F\left(\frac{2(p\mu+(1-p)(1-\mu))-1}{2(p\mu+(1-p)(1-\mu))}\right)$ and $\omega_z \equiv 1 - F\left(\frac{1/2-(z\mu+(1-z)(1-\mu))}{1-(z\mu+(1-z)(1-\mu))}\right)$.

[15] For a formal demonstration, see Appendix 2.6.5.

while right-wing non-ideological incumbents may have incentives to remain in a separating equilibrium where they choose $x_R = 0$ or a pooling equilibrium with $x_R = 1$. The beliefs (p, q) and ideology (μ) of voters play a relevant part in the right-wing politician decision regarding the adoption of NPIs. Therefore, the results suggest that implementing such measures is more likely when the proportion of left-wing voters is high, and when the incumbent is not a right-wing ideological politician.

The next section will evaluate whether this insights are supported by the data, using real-world results from the 2020 mayoral elections that occurred in Brazil as laboratory.

2.3 EMPIRICAL STRATEGY

This section displays the data and statistical analyses applied in order to evaluate the theoretical predictions, as well as the empirical results.

2.3.1 Data Description

The study was performed using public data from Brazil and information from publicly available scientific data paper (SANTOS et al., 2021). The data on the adoption of NPIs was complemented with election results, information on cadidates, and a set of socioeconomic and demographic variables.

In the country, mayors serve a four-year term and they can be reelected once for another same-length term. In cities where a run off happened, solely second round results were considered. Data on election final results were collected from Superior Electoral Court (TSE) database. Information on whether the candidate was running for reelection were presented in the candidates profiles and was combined with 2016 and 2020 results. Further data about the candidates – i.e. education level, former profession, skin color, age – were gathered from the same source. Additionally, the results of the 2018 presidential elections at city level were also collected and used as a proxy of the constituents' ideology. We utilized the final valid share of votes received in the second round run-off by right-wing and eventual President Jair Bolsonaro and subtracted the share of ballots for left-wing opponent Fernando Haddad.

Pertaining to municipal measures against COVID-19, data surveyed and arranged by Santos et al. (2021) was utilized as well as information collected by Brazilian Bureau of Geography and Statistics (IBGE). Both relate to surveys comprising prohibition of social gatherings and mandatory use of face masks, while only the first possesses a dummy indicating the closure of non-essential services. The IBGE database also indicates social protection measures enacted by local governments against health risks and economic downturns related to the pandemics, such as distributing masks and personal hygiene products, as well as the creation of cash transfer programs and food banks.

With these information, we created three main variables of interest which will constitute the target of the empirical evaluation: (*i*) $NPI\_index \in \{0, 1, 2, 3\}$, representing the sum of dummy variables that indicate whether the city implemented mask mandates, social distancing and/or non-essential business closures according to Santos et al. (2021); (*ii*) $NPI\_IBGE \in \{0, 1, \cdots, 5\}$, denoting the adoption of mask mandates, social distancing, stay-at-home orders, and/or fines against private citizens or business that did not follow the rules; and (*iii*) $social\_protection \in \{0, 1, \cdots, 22\}$ indicating the sum of 22 dummies[16] where each represents social protection policy to alleviate the health and economic burden exerted by the pandemics.[17]

The ideological classification of political parties followed the survey executed by Tarouco e Madeira (2015). One possible concern in identifying political ideology in Brazil is that its multiparty system favors heterogeneity among parties and politicians (SCHEEFFER, 2018a) and make it difficult for governments to execute policies related to their core ideas (CAREY, 2007). This problem will be further presented in the discussion section.

The descriptive statistics of the target variables is presented in Table 3.7. The data displays separate statistics for cities where the incumbent is center, right- or left-wing, according to his party's ideology. It also presents the data sorted by left- and right-leaning cities, based on the 2018 presidential run-off results.

In addition to the core data, we collected a set of geographic, demographic and socioeconomic data at municipal level, as well as candidates and mayors characteristics. IBGE is also responsible for the latter, while TSE once again is the source for the former. Final dataset, including information collection and data cleaning and wrangling steps, as well as full analyses and results, are available on GitHub. [18]

[16] The measures consisted of maintaining school cafeterias opened while schools were closed (Mcov0511); the distribution of: personal hygiene kits (Mcov061), general hygiene kits (Mcov062), masks (Mcov063), basic-needs groceries for "Bolsa Família"recipients (Mcov064), basic-need groceries for other families in need (Mcov066); the creation of: shelters for homeless population (Mcov066), hygiene locations for homeless population (Mcov067), general host spaces for homeless population (Mcov068), and food banks (Mcov069); registration of: families to receive "Bolsa Família"(Mcov0610), individuals to receive the federal government financial aid (Mcov0611), individuals in a local cash transfer program (Mcov0612); enlarged (Mcov0613) and enabled (Mcov0614) specific benefits regarding the COVID-19 pandemics; hept open: social assistance centers (Mcov0615), previously existing shelters (Mcov0616), elderly facilities (Mcov0617), health facilities focused on cronic diseases (Mcov0618); monitored domestic violence (Mcov0619); kept psicosocial facilities open (Mcov0620); and adopted other policies (Mcov0621). The codes in parentheses indicate the variable name in IBGE database.

[17] For complete details, the full python code to collect, clean, wrangle the data, and create the variables is available at <https://github.com/hssitja/PhD-Dissertation/blob/Chapter-1/Chapter3.ipynb>.

[18] <https://github.com/hssitja/PhD-Dissertation/tree/Chapter-1>

Table 2.1 – Descriptive statistics

	Observations	Mean	St. Dev.	Min	Max
Incumbent: left-wing					
Social distancing	924	0.979	0.142	0.0	1.0
Business closures	923	0.775	0.418	0.0	1.0
Mask mandates	920	0.964	0.186	0.0	1.0
NPI index	920	2.718	0.505	0.0	3.0
Mask mandates (IBGE)	1309	0.945	0.228	0.0	1.0
Social distancing (IBGE)	1309	1.785	0.448	0.0	2.0
Sanctions (IBGE)	1308	1.153	0.848	0.0	2.0
NPI IBGE	1308	3.883	1.071	0.0	5.0
Incumbent: right-wing					
Social distancing	1583	0.978	0.147	0.0	1.0
Business closures	1579	0.782	0.413	0.0	1.0
Mask mandates	1582	0.958	0.200	0.0	1.0
NPI index	1578	2.718	0.498	1.0	3.0
Mask mandates (IBGE)	2142	0.940	0.237	0.0	1.0
Social distancing (IBGE)	2143	1.787	0.443	0.0	2.0
Sanctions (IBGE)	2141	1.171	0.844	0.0	2.0
NPI IBGE	2141	3.898	1.041	0.0	5.0
Incumbent: center					
Social distancing	1407	0.979	0.142	0.0	1.0
Business closures	1408	0.766	0.424	0.0	1.0
Mask mandates	1402	0.956	0.204	0.0	1.0
NPI index	1401	2.702	0.507	0.0	3.0
Mask mandates (IBGE)	1941	0.949	0.220	0.0	1.0
Social distancing (IBGE)	1941	1.790	0.437	0.0	2.0
Sanctions (IBGE)	1939	1.163	0.854	0.0	2.0
NPI IBGE	1939	3.903	1.045	0.0	5.0
City: left-leaning					
Social distancing	1612	0.987	0.113	0.0	1.0
Business closures	1612	0.803	0.398	0.0	1.0
Mask mandates	1606	0.968	0.177	0.0	1.0
NPI index	1606	2.758	0.463	0.0	3.0
Mask mandates (IBGE)	2700	0.937	0.242	0.0	1.0
Social distancing (IBGE)	2701	1.797	0.435	0.0	2.0
Sanctions (IBGE)	2698	1.102	0.854	0.0	2.0
NPI IBGE	2698	3.837	1.060	0.0	5.0
City: right-leaning					
Social distancing	2302	0.973	0.162	0.0	1.0
Business closures	2298	0.754	0.431	0.0	1.0
Mask mandates	2298	0.953	0.212	0.0	1.0
NPI index	2293	2.680	0.526	0.0	3.0
Mask mandates (IBGE)	2692	0.952	0.214	0.0	1.0
Social distancing (IBGE)	2692	1.778	0.448	0.0	2.0
Sanctions (IBGE)	2690	1.226	0.838	0.0	2.0
NPI IBGE	2690	3.955	1.036	0.0	5.0

Notes: (*i*) Social distancing (IBGE) $\in \{0, 1, 2\}$, where 1 denotes prohibition of social gatherings and 2, stay-at-home orders. (*ii*) Sanctions (IBGE) $\in \{0, 1, 2\}$, where sanctions for individuals and/or business from breaking isolation orders are added to form the variable. Ideology of the mayor is defined by their political party. (*iii*) Mayors' ideology according to their parties. (*iv*) Ideology of the city is determined by the results of the 2018 presidential election's run-off (cities where Jair Bolsonaro got more than 50% of the votes were labeled as right-leaning.
Source: author's preparation.

2.3.2 Data Analysis

The study investigated whether Brazilian mayors running for reelection in 2020 elections responded differently to the COVID-19 pandemics considering their ideology and the expected policy preference of local voters. The outcome variables includes NPIs at city-level and it was evaluated whether the response to the COVID-19 pandemics was influenced by electoral incentives and whether different strategies considering political preferences were observed.

The central hypothesis is that incumbent mayors fighting for reelection will adopt looser – or stricter – measures in comparison to lame duck mayors inside the same political spectrum observing whether the majority of electors favor such measures. In order to perform such investigation, the two last Brazilian local election – 2016 and 2020 – will be analyzed in combination with Santos et al. (2021), official government datasets concerning NPIs at city-level and results from the 2018 federal election.

As NPI measures were heavily politicized at the time of local elections in Brazil, an incumbent mayor in a city where the majority of the population voted for then-Brazilian President Jair Bolsonaro in the 2018 general election could adopt looser policies in order to please the majority of electors. Conversely, if Fernando Haddad, the runner up in '18 elections, received the most votes in a given city, its mayor would have incentives to impose more stringent measures. As the formal model proposes, such policy strategies can be regarded as signaling efforts, once severe state-levels restrictions were already being adopted.

The main issue pertaining empirical analyses of incumbent effects is the fact that second term mayors may not be comparable to first term ones. Once reelected officials might possess intrinsically different characteristics that lead to their political and electoral advantages, the main empirical strategy currently applied to infer causality between reelection status and public policy is utilizing regression discontinuity design (RDD) (ERIKSON; TITIUNIK et al., 2015; SONG, 2018).

Not without its critiques (DELACUESTA; IMAI, 2016; HYYTINEN et al., 2018) but with increasing evidence on its validity (EGGERS et al., 2015), the strategy specified by Lee (2008) relies on comparing policies implemented by incumbents who were reelected by a small margin with those implemented by second term mayors[19]. The logic states that second term mayors elected in close contests are comparable to first time mayors in all characteristics except for the fact that, as they are in a second term and, they are not able to run for reelection.

Using the common terminology applied in these contexts, it will be assumed that a treatment status $\tau \in \{0, 1\}$ is assigned to a city i if the share of votes that the incumbent

[19] Which implies that they cannot run for another term according to Brazilian electoral rules.

received v_i was above the cutoff c, which represents the voting margin in relation to the runner up in the election. That means that τ is a deterministic function where $\tau = 1$ if $v_i - c \geq 0$, $\tau = 0$ otherwise. Therefore, it represents a sharp RDD and the local average treatment effect ($LATE$) can be estimated through the following regression:

$$\Delta Y_i = \alpha + LATE(\tau_i) + f(v_i - c) + \gamma_s + \epsilon_i, \tag{2.17}$$

where $F(\cdot)$ is a polynomial function of the interactions between the margin of victory and the treatment status, γ_s is a vector of state fixed effects[20], and ϵ_i is an error term. As the causal effect identified by this method only refers to close elections, optimal bandwidth were selected following Calonico, Cattaneo e Farrell (2020).

Considering the hypothesis extracted from the model presented in section 2.2, the equation (2.17) will be estimated separately for incumbents according to their ideology – center, left or right. The idea is that the electoral incentives would exert different effects across the political spectrum. Next section summarizes the main results, while descriptive statistics, balance, and robustness checks are found in the appendix 2.6. Full regression results can be visualized online.[21]

2.3.3 Theoretical Predictions

Considering the signaling model and the available data, the following predictions will be tested:

1. Adoption of NPIs by left-wing incumbents: the model predicts that left-wing incumbents are more likely to adopt NPIs, regardless of the values of the parameters. It is expected no incumbent effect on this group.

2. Adoption of NPIs by right-wing incumbents: the model predicts that the adoption of NPIs by right-wing incumbents depends on the values of p, q, μ, and the type of incumbent. Non-ideological right-wing incumbents may have incentives to adopt NPIs in a pooling equilibrium or remain in a separating equilibrium where they choose not to adopt. It is expected statistical significant incumbent effect indicating that right-wing incumbents adopt looser policies.

3. The role of voters' beliefs: the model predicts that the beliefs (p, q) and ideology (μ) of voters play a role in the adoption of NPIs by right-wing incumbents. The adoption is more likely when the proportion of left-wing voters is high.

The following sections display the main empirical findings.

[20] As state-level policies applied for the cities, this step is central to the empirical validity of the findings. But these dummies also intend to capture regional and cultural differences that could cause endogeinity problems.

[21] <https://github.com/hssitja/PhD-Dissertation/blob/Chapter-1/Chapter3_empirical.ipynb>

2.3.4 Results

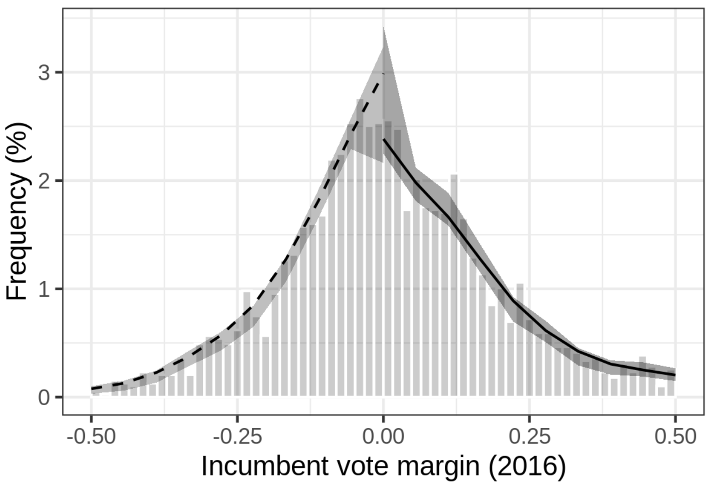
Initially, it is important to verify if the running variable runs smoothly around the cutoff point. It is essential that the assignment of the treatment status is similarly distributed for values just below and above the cutoff, otherwise it could indicate that the main assumption behind the regression discontinuity design would not be met. In the current study, if the mass of observation around zero was not continuous, it could mean, for instance, that incumbents may influence close elections or election official could purposely harm their odds of reelection. As figure 2.3 indicates, it is not the case for the collected dataset.

Another indication on the validity of the RDD is the graphical representation of the variable of interest around the cutoff point. In this study, the first variable is the adoption on non-pharmaceutical interventions, which consisted of an index regarding whether the city adopted mask mandates, business closures and social distancing regulations. The variable can assume values from 0 to 3, where each of the policies counts as a dummy variable and the final index results from their sum. The visual representation in figure 2.4 indicates that right-wing incumbents, when facing reelection, adopt stricter policies than second term mayors. Pertaining left-wing and center mayors, no impact was observed.

Figure 2.5, on its turn, show the discontinuity around the cut-off point pertaining NPIs measured by IBGE, among which there are no business closure mandates. No impact was observed. Finally, Figure 2.6 indicates that incumbency status does not appear to have impacted the adoption of social relief measures when the full sample is evaluated.

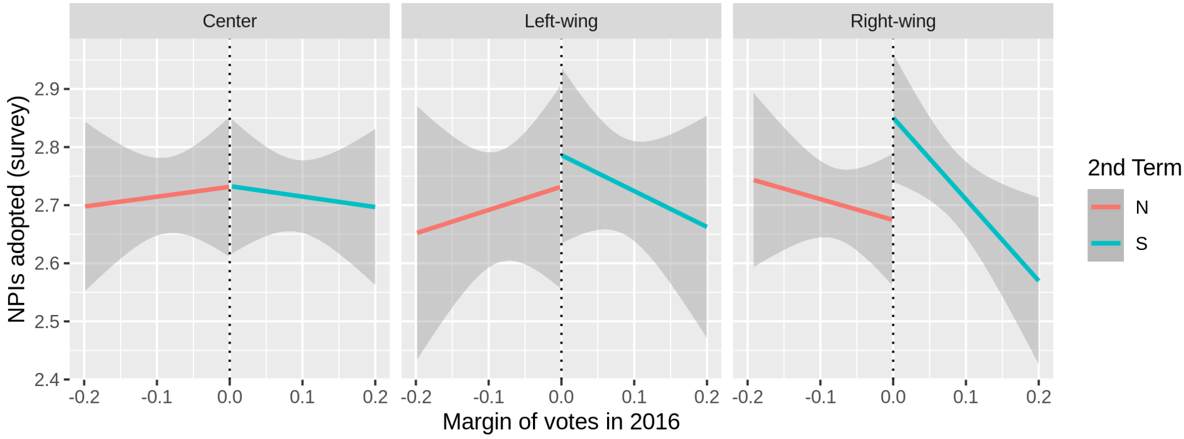
A final validation test consists in comparing the distribution of other variables among the treated (second term mayors) and control groups (first term incumbents). It

Figure 2.3 – Mass of observations around the cutoff point



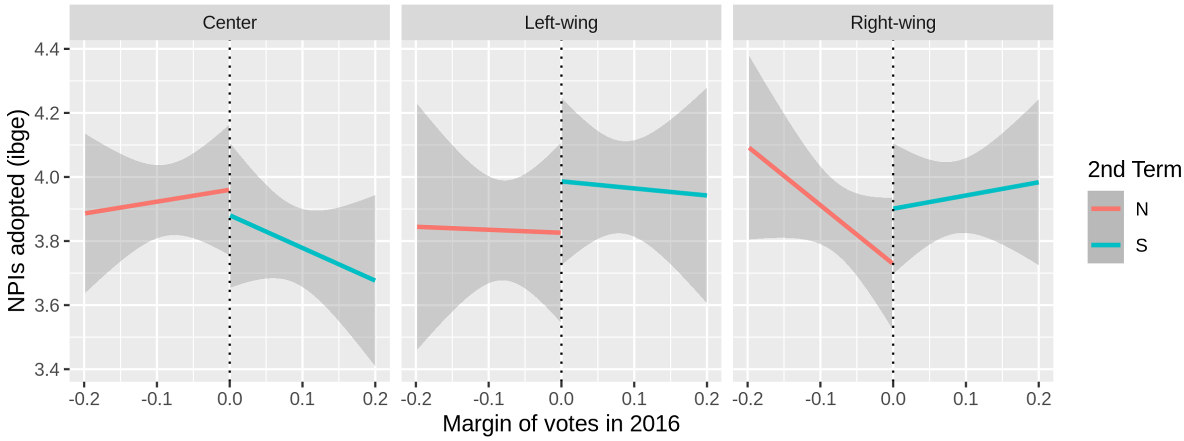
Source: author's preparation.

Figure 2.4 – NPI index around discontinuity for different incumbent ideologies.



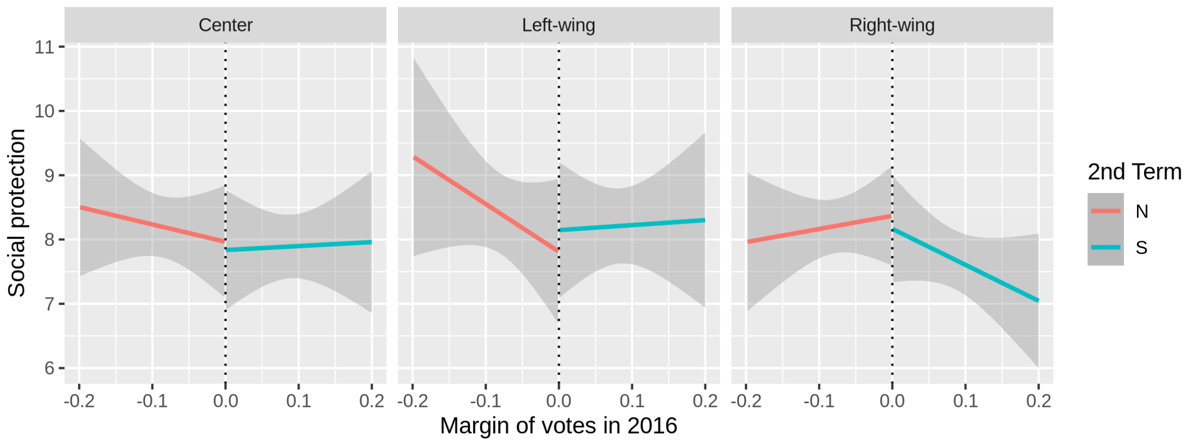
Source: author's preparation.

Figure 2.5 – NPI IBGE index (no business closure mandates) around discontinuity



Source: author's preparation.

Figure 2.6 – Social protection policies around discontinuity



Source: author's preparation.

also serves as descriptive statistics for possible covariates. Table 2.2 shows that all variables related to the city or the incumbent are well balanced at five percent significance, meaning that there is no need to include covariates in the models.

Table 2.2 – Balance Table

	Control			Treated			
Variable	N	Mean	SD	N	Mean	SD	Test
Bolsonaro_share	1176	0.436	0.218	1223	0.462	0.226	F= 7.939***
Ideology	1176			1223			χ^2 = 10.847***
center	445	37.8%		435	35.6%		
right-wing	474	40.3%		450	36.8%		
left-wing	257	21.9%		338	27.6%		
Age	1176	49.389	11.076	1223	49.164	9.811	F= 0.278
Sex	1176			1223			χ^2 = 0.533
Female	141	12%		134	11%		
Male	1035	88%		1089	89%		
Race	1176			1223			χ^2 = 1.288
Yellow	9	0.8%		6	0.5%		
White	832	70.7%		851	69.6%		
Native	2	0.2%		2	0.2%		
Brown	319	27.1%		348	28.5%		
Black	14	1.2%		16	1.3%		
Instruction	1176			1223			χ^2 = 8.312
Elementary	80	6.8%		73	6%		
Elementary incompl	76	6.5%		63	5.2%		
High School	303	25.8%		320	26.2%		
Incomplete HS	33	2.8%		31	2.5%		
Write and read	16	1.4%		7	0.6%		
Superior	595	50.6%		661	54%		
Superior incompl	73	6.2%		68	5.6%		
GDP	1176	1470.865	22547.5	1223	1321.438	5524.774	F= 0.051
Net taxes	1176	213.625	3916.126	1223	185.461	930.929	F= 0.06
Agriculture	1176	57.763	101.75	1223	51.388	86.861	F= 2.731*
Industry	1176	218.017	1883.191	1223	280.778	1394.116	F= 0.865
Services	1176	813.947	15551.9	1223	608.423	2843.169	F= 0.206
Population	1176	38381.76	363917.9	1223	42500.586	170247	F= 0.128

Significance markers: *p<0.1; **p<0.05; ***p<0.01.
Source: author's preparation.

It is worth noting that even though there appears to be statically significant differences in the share of right-wing voters and ideology of incumbents, the discrepancies in means and standard deviations are not large. Also, as different specifications of the model separating the dataset according to ideology will be analysed, these facts are not supposed to interfere with the results.

Finally, Table 2.3 presents the results fo the NPI index obtained with the data collected by Santos et al. (2021). The RDD estimation indicates that second term mayors adopted stricter policies in comparison to incumbents that could run for reelection. This result becomes clearer when the analysis is performed considering the ideology of the mayor. It then shows that the result was driven only by right-wing mayors, once left-wing and centrist incumbents adopted the same level of NPIs regardless of their ability to run for another term. These results corroborate the hypothesis extracted from the model, showing that right-wing incumbents would possess the strongest electoral incentives to modulate their responses to the pandemics in order following their preferred policy.

The results were obtained using a local linear estimator for discontinuity, a triangular kernel to weight observations around the cutoff and the coefficient was estimated with robust bias-corrected confidence intervals, while optimal bandwidth was selected using minimum squared errors (CALONICO; CATTANEO; TITIUNIK, 2014; CALONICO et al., 2019; CALONICO; CATTANEO; FARRELL, 2020). The results were the same for other kernels and bandwidths as displayed in Table 2.8. Table 2.7 shows placebo tests with different cut-off points, which resulted in non-significant coefficients for all estimations, further strengthening the findings as show in the Appendix 2.6.8.

Table 2.3 – Results – y = NPI index

	All ideologies	Right-wing	Left-wing	Centrist
Robust	0.142**	0.259**	0.183	0.026
SD	(0.069)	(0.118)	(0.146)	(0.116)
p-value	(0.041)	(0.028)	(0.210)	(0.823)
Obs. left	494	187	78	165
Obs. right	464	150	95	147

i) Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; *iii)* optimal bandwith mserd, local linear estimator, triangular kernel. (*iv*) Mayors' ideology according to their parties.
Source: author's preparation.

Next, Table 2.4 presents the finding for NPI and social protection indices built from the official IBGE survey on measures to contain the pandemics during 2020. It shows that the incumbency effect was not observed in relation to NPIs. However, right-wing incumbents adopted a higher level of social relief measures when running for re-election. Once again, no electoral impact was estimated concerning the policies adopted by left-wing and centrist mayors.

Table 2.4 – Results – IBGE variables

	y = NPI IBGE			*y = social protection*		
	Rightwing	Leftwing	Centrist	Rightwing	Leftwing	Centrist
Robust	-0.133	-0.119	-0.075	-2.783***	-0.801	-0.698
SD	(0.234)	(0.308)	(0.204)	(1.017)	(1.087)	(0.896)
p-value	(0.570)	(0.700)	(0.713)	(0.006)	(0.461)	(0.436)
Obs. left	243	146	241	187	153	263
Obs. right	191	154	200	141	169	227

i) Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; *iii)* optimal bandwith mserd, local linear estimator, triangular kernel. (*iv*) Mayors' ideology according to their parties.
Source: author's preparation.

The next table presents the local average treatment effect for cities where the majority voted for right-wing candidate Jair Bolsonaro ($\mu > 0.5$) or left-wing Fernando Haddad ($\mu leq 0.5$) in the 2018 general elections. It also divides the sample according to the ideology of the incumbent. The results further corroborate the theoretical model. Table 2.6 shows that right-wing mayors implemented less stringent NPIs only in cities where the majority of voters are right-leaning. Nonetheless, they also implemented a higher level of social protection measures regardless of the municipality's voting profile. Considering the theoretical model and its predictions, the following section will discuss their implications and how they relate to the empirical findings given the available data and the econometrics strategy employed.

Table 2.5 – Results - Ideology of incumbents and voters

	Right-leaning cities			*Left-leaning cities*		
y =	NPI index	NPI IBGE	social protection	NPI index	NPI IBGE	social protection
Incumbent: right-wing						
Robust	0.498**	0.073	-3.615**	-0.005	-0.400	-2.519**
SD	(0.207)	(0.316)	(1.658)	(0.147)	(0.274)	(1.131)
p-value	(0.016)	(0.817)	(0.029)	(0.972)	(0.145)	(0.026)
Obs. left	82	129	83	59	123	118
Obs. right	66	103	66	40	93	84
Incumbent: left-wing						
Robust	0.381	0.098	-0.985	-0.180	-0.350	-0.552
SD	(0.237)	(0.526)	(1.595)	(0.208)	(0.428)	(1.503)
p-value	(0.107)	(0.852)	(0.537)	(0.386)	(0.413)	(0.713)
Obs. left	24	43	47	51	84	96
Obs. right	32	50	56	64	86	98

i) Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; *iii)* optimal bandwith mserd, local linear estimator, triangular kernel. (*iv*) Mayors' ideology according to their parties. (*v*) Ideology of the city is determined by the results of the 2018 presidential election's run-off (cities where Jair Bolsonaro got more than 50% of the votes were labeled as right-leaning.
Source: author's preparation.

2.4 DISCUSSION

Before commenting on results, it is important to discuss a possible caveat that could arise from the complexities of party ideology and its impact on political actors' behavior in Brazil. Previous studies have highlighted competing pressures that politicians face due to institutional factors and how it influences the commitments with their party's preferred policies. Suggesting that a right-wing politician would follow then-President Bolsonaro's stance on COVID-19 may be a strong assumption.

However, relevant studies suggest that our decision is valid. Hicken e Stoll (2011) argue that presidential elections exert influence especially as they shape the incentives of candidates to coordinate across electoral districts under a common party banner. Additionally, Borges e Lloyd (2016) empirically test a similar hypothesis for Brazil: whether concurrent presidential and gubernatorial elections affect electoral coordination and coattails voting between national and subnational levels of government. Using individual-level survey data and time-series cross-sectional electoral data, they find congruence between national and subnational elections occur when the effective number of presidential candidates is low. The political polarization observed in Brazil before and during the pandemic years ultimately reduced the relevant candidates in the past two elections, indicating that the conditions may hold for such congruence to happen.

Finally and also using data from Brazil, Scheeffer (2018b) demonstrates that ideology still plays a significant role shaping parliamentary behavior, particularly when there is a clear ideological content in the issues being debated. Following these studies and in the context of the current work, we can argue that the ideological difference or proximity between the mayor and the voters might affect municipal policy considering electoral incentives.

However, it should also be stressed that the terminology of right- and left-wing in this study does not imply specific ideas or beliefs associated with each political spectrum. The study does not assume that conservative or liberal ideologies necessarily determine voters' preferences for stricter or looser COVID-19 related policies. Rather, we posit that each political group was invested in a particular stance during the health crisis. That means that incumbent politicians with incentives to signal their ideology must adjust their policies to align with the prevailing position within their political spectrum.

In light of these acknowledgments, our study aimed to analyze the role of mayors' and voters' ideology in shaping COVID policy responses in relation to electoral incentives in Brazil. We argue that the interplay between political ideology, institutional factors, and national and subnational political dynamics could have had implications for policy-making during the pandemic. Even taking into account the limitations and nuances presented in the literature, we propose that our analysis of political ideology is valid.

We now turn our focus back to the predictions and their empirical evaluation. The results show the impact of electoral incentives on the adoption of non-pharmaceutical interventions (NPIs) by incumbent mayors during the COVID-19 pandemic. The theoretical model predicted that left-wing incumbents would adopt NPIs regardless of the electoral context, while right-wing incumbents would be influenced by the beliefs and ideology of voters and their own type of incumbency. The empirical results confirmed these predictions, showing that right-wing incumbents running for reelection adopted less stringent NPIs when business closures are considered. It suggests that they may have followed then-President Bolsonaro's focus on aiming to reduce economic losses resulting from mandates.

However, when only mask mandates and social distancing measures are considered, no electoral impact is observed. This suggests that even if the model indicates that the level of ideology must be higher for the separating equilibrium to be feasible, it applied more to pragmatic matters such as the local economy than to discussions regarding civil liberties. More importantly, the estimations indicated that right-wing incumbents shaped their policies depending on the voter profile. Once again, these results were significant only when the NPIs analyzed included restrictions to non-essential businesses. Two findings base this proposition. First, the local average treatment effect on NPIs measured through the dataset produced by Santos et al. (2021) showed statistical significance only for cities where the majority of the voters supported the right-wing candidate in the last presidential election. Right-wing incumbents also followed electoral incentives when implementing social protection policies regarding the economic impacts of COVID-19. Nonetheless, in this case, the results presented statistical significance regardless of the voters' preferences.

The findings suggest that the adoption of NPIs by incumbent mayors was shaped through two channels: i) their own political ideology; and ii) the beliefs and preferences of voters. Right-wing incumbents were found to be sensitive to the beliefs and ideology of voters, who tended to focus more on the negative impacts of NPIs on the local economy. This result can be highlighted by the lack of significant effect when the NPI measure did not include business closures. However, the social protection policies adopted by right-wing mayors seeking reelection were also affected by electoral incentives. Therefore, the results can be regarded as corroborating the second theoretical prediction. The empirical results indicate the importance of considering the incumbent's ideology as well as their preferences between office rent (W) or public policy (A_θ) in analyzing political incentives. The finding that right-wing incumbents running for reelection adopted less stringent NPIs supports the hypothesis that incumbents may act pragmatically while responding to electoral incentives to increase their chances of re-election. It adds another factor to consider, which is not explicitly expressed in previous studies designed to assess the impact of re-election status on public policy.

On the other hand, left-wing and centrist incumbents were similarly likely to adopt NPIs or social assistance policies, notwithstanding their candidacy status. It arguably reflects a broader commitment to public health measures and empirically validates the first prediction. It can also serve as a statement on the polarization around the President's position, given that centrist incumbents reacted in the same way as leftists. It strengthens our choice not to include only two types of incumbents in the theoretical models. The right-wing incumbent reflects, ultimately, those who supported then-President Jair Bolsonaro, while left-wing represents the opposition in a broader sense.

It is important to acknowledge the limitations of the research design and available data. The study used a regression discontinuity design to assess the impact of incumbency on the adoption of NPIs, which provides strong internal validity for the results but only applies to close elections. Another point to highlight is that the analyses did not directly measure the incumbency effects or the related policies on the spread of the virus. Our decision not to perform regressions evaluating infections and casualties related to COVID-19 was based on the realization that the main contagious wave hit the country just in 2021. Therefore, the results of empirical investigations concerning the impacts of the health crisis based in the first months of the pandemic would be strongly influenced by omitted or non-quantified factors, lending reduced explanatory power to statistical inferences.

Finally, we must emphasize that the target variables were build following surveys performed by academics and by the Bureau of Geography and Statistics. The fact that both datasets present similar descriptive statistics is one step towards strengthening the findings. However, surveys are always subject to several potential biases, such as non-response[22] or desirability[23] bias (SANTESSO et al., 2020). Further data collection would be needed to confirm and expand the findings of this study and to better understand the impact of political incentives on public health policy during an emergency.

2.5 CONCLUDING REMARKS

This study offers evidence that electoral incentives influenced the policies adopted by incumbent mayors during the COVID-19 pandemic. The theoretical model and empirical analysis demonstrate that right-wing incumbents running for re-election tended to adopt less stringent NPIs in response to voter beliefs and ideology, while left-wing and centrist incumbents implemented NPIs regardless of their re-election prospects. In essence, our research enriches the understanding of the interaction between ideology and policy-making during the COVID pandemic. By recognizing the potential impact of institutional factors, national and subnational political dynamics, and ideological differences on policy responses and electoral incentives in Brazil, our analysis of political ideology proves to be valid.

These findings emphasize the importance of considering political ideology as well as voter beliefs and preferences when examining political incentives during a crisis. The results contribute to the literature on the impact of incumbency on public policy and offer valuable insights for future investigations in this area. However, subsequent research should strive to address the limitations of the current study and explore additional factors that may influence the relationship between electoral incentives and public health policy. One possible avenue is introducing social media political discourse as a proxy to indicate if the politician is ideological or pragmatic.

[22] It was basically null in the IBGE survey, but it was higher in the dataset produced by Santos et al. (2021).

[23] When respondents answer the questions based on what they think should be the correct answer, not how they actually acted. If that was the case, the NPIs indices would reflect, at least in part, the preferred policy of each incumbent, not necessarily which measures were adopted by the city.

In conclusion, this study sheds new lights on the politics of pandemics and highlights the tendency for policymakers to account for electoral incentives when making decisions related to public policy during unexpected circumstances. The findings can guide and inspire future research and policy discussions at the intersection of public health, politics, and health economics to ultimately promote better policy outcomes in the face of public health crisis and other imminent challenges.

2.6 APPENDIX

In this appendix, we offer proof of the results stated in sections 2.2.5

2.6.1 Proof of proposition 2.2

In order to proof proposition 2.2, let us state the first lemma.

Lemma 2.7. *Condition* (2.7) *holds for left-wing incumbents where* A_L *and* W *are positive,* $F(\cdot)$ *has support on the interval* $[0, 0.5)$*, and* $\mu \in (0, 1)$*.*

Demonstração. First, let's analyze the function $g(\mu) = \frac{2\mu-1}{2\mu}$. As μ varies in $(0, 1)$, the range of $g(\mu)$ will be:

$$\lim_{\mu \to 0^+} g(\mu) = -\infty, \quad \lim_{\mu \to 1^-} g(\mu) = 1. \tag{2.18}$$

Now, let's find the maximum value of the function inside the inequality (2.7). We have the function:

$$h(\mu) = 2F(g(\mu)) - 1. \tag{2.19}$$

The maximum value of $h(\mu)$ occurs when $F(g(\mu))$ is at its maximum, i.e., $F(g(\mu)) = 0.5$. This gives us:

$$\max_{\mu \in (0,1)} h(\mu) = 2(0.5) - 1 = 0. \tag{2.20}$$

Now, given that A_L and W are positive, we have:

$$\frac{A_L}{W} > 0 \geq \max_{\mu \in (0,1)} h(\mu). \tag{2.21}$$

Thus, the inequality (2.7) holds for all $\mu \in (0, 1)$, given that A_L and W are positive, and $F(\cdot)$ has support on the interval $[0, 0.5)$. $\square$

Continuing, we demonstrate that condition (2.6) holds for ideological right-wing incumbents.

Lemma 2.8. *A sufficient but not necessary condition for the inequality* (2.6) *to hold is* $A_R > W$*.*

Demonstração. Recall the function $g(\mu) = \frac{2\mu-1}{2\mu}$ analyzed in the previous proof. As μ varies in $(0,1)$, the range of $g(\mu)$ will be $(-\infty,1]$ according to (2.18).

Now, consider the function inside the inequality (2.6):

$$k(\mu) = 1 - 2F\left(g(\mu)\right). \tag{2.22}$$

We can see that the maximum value of $k(\mu)$ occurs when $F(g(\mu))$ is at its minimum, i.e., $F(g(\mu)) = 0$. This gives us:

$$\max_{\mu\in(0,1)} k(\mu) = 1 - 2(0) = 1. \tag{2.23}$$

We have shown that the maximum value of the function $k(\mu)$ is 1. If $A_R > W$, then we have:

$$\frac{A_R}{W} > 1 \geq \max_{\mu\in(0,1)} k(\mu). \tag{2.24}$$

Thus, if $A_R > W$, the inequality (2.6) holds for all $\mu \in (0,1)$, given that $F(\cdot)$ has support on the interval $[0, 0.5)$. This proves that a sufficient but not necessary condition for (2.6) to be true is $A_R > W$. □

Therefore, we have formally demonstrated the validity of proposition 2.2.

2.6.2 Proof of proposition 2.3

To proof proposition 2.3, we must show that either conditions (2.9) or (2.10) will not hold. It is the case for the latter.

Theorem 2.9. *The condition 2.10 does not hold.*

Demonstração. First, let us restate that $F(\cdot)$ has support on the interval $[0, 0.5)$, A_L and W are positive, and $\mu \in (0,1)$. Then, we can analyze the right-hand side of condition (2.10):

$$2F\left(\frac{1-2\mu}{2(1-\mu)}\right) - 1. \tag{2.25}$$

Note that the function $F(\cdot)$ is defined on the interval $[0, 0.5)$. Given that its maximum value is 0.5, it implies that the maximum value of the right-hand side of condition (2.10) is $2(0.5) - 1 = 0$.

Considering that both A_L and W are positive, we have:

$$\frac{A_L}{W} > 0. \tag{2.26}$$

As the maximum value of the right-hand side of condition (2.10) is zero and the left-hand side is strictly positive, the condition (2.10) can not hold. $\square$

2.6.3 Proof of proposition 2.4

To show that proposition 2.4 is valid, the following conditions must be demonstrated to hold:

$$\frac{A_R}{W} \leq 1 - F(\psi_p) - F(\psi_q), \frac{A_L}{W} \geq F(\psi_p) + F(\psi_q) - 1.$$

First we analyze the condition for the left-wing incumbent to maintaing the equilibrium.

Lemma 2.10. *Condition* (2.14) *always holds for left-wing incumbents.*

Demonstração. Given that $F(\cdot)$ is defined in the interval $[0, 0.5)$, it implies that:

$$0 \leq (F(\psi_p), F(\psi_q)) < 0.5. \tag{2.27}$$

Considering the extreme case where both $F(\psi_p)$ and $F(\psi_q)$ are at their maximum value (which is still less than 0.5), we have:

$$F(\psi_p) + F(\psi_q) - 1 < 0.5 + 0.5 - 1 = 0. \tag{2.28}$$

As both A_L and W are positive:

$$\frac{A_L}{W} > 0. \tag{2.29}$$

Thus, we have:

$$\frac{A_L}{W} > 0 > F(\psi_p) + F(\psi_q) - 1, \tag{2.30}$$

showing that condition (2.14) always holds for left-wing incumbents. $\square$

Lemma 2.11. *Condition* (2.13) *does not hold for ideological right-wing incumbents.*

Demonstração. Given that $F(\cdot)$ is defined in the interval $[0, 0.5)$, it implies that inequality (2.27) is true.

Considering the extreme case where both $F(\psi_p)$ and $F(\psi_q)$ are at their minimum value (0), we have:

$$1 - F(\psi_p) - F(\psi_q) = 1 - 0 - 0 = 1, \tag{2.31}$$

which represents the maximum value the right hand-side of condition (2.13) can achieve.

For ideological right-wing incumbents, $A_R > W$. In this case, the left-hand side of condition (2.13) is always greater than 1:

$$\frac{A_R}{W} > 1. \tag{2.32}$$

It was shown that the maximum value of the right-hand side of condition (2.13) is 1, thus condition (2.13) never holds for ideological right-wing incumbents. $\square$

Lemma 2.12. *Condition* (2.13) *can hold for pragmatic right-wing incumbents.*

Demonstração. Once again, the result is based on (2.27). For pragmatic right-wing incumbents, $A_R \leq W$. In this case, the left-hand side of condition (2.13) can be less than or equal to 1:

$$0 < \frac{A_R}{W} \leq 1. \tag{2.33}$$

As the maximum value of the right-hand side of condition (2.13) is 1, there exists a range of A_R and W values such that the inequality holds for pragmatic right-wing incumbents. Furthermore, there are combinations of parameters $(\mu, p, q) \in (0, 1)$ such that result in $F(\psi_p)$ and $F(\psi_q)$ satisfy condition (2.13) if equation (2.33) is valid. $\square$

Combining these lemmas implies that proposition 2.4 is true.

2.6.4 Proof of proposition 2.5

Scenario (i): Let's assume $q > 0.5$, $\mu > 0.5 + \epsilon$, and $p < 0.5 - \epsilon$ for some $\epsilon > 0$. Recall that:

$$\psi_p = \frac{1/2 - (p\mu + (1-p)(1-\mu))}{1 - (p\mu + (1-p)(1-\mu))}, \psi_q = \frac{2(q\mu + (1-q)(1-\mu)) - 1}{2(q\mu + (1-q)(1-\mu))}. \tag{2.34}$$

We need to show that under these conditions it exists situations where the inequality in condition (2.13) can hold. It means that there are situations where the pragmatic right-wing incumbent does not defect.

Demonstração. Suppose $q > \frac{1}{2}$. Without loss of generality, let $q = \frac{1}{2} + \epsilon$ for some $\epsilon > 0$. We define $\mu = \frac{1}{2} + \epsilon$ and $p = \frac{1}{2} - \epsilon$, and assume $q, \mu \in (0.5, 1)$ and $p \in (0, 0.5)$ such that $\epsilon \in (0, 0.5)$. Next, substituting the values of q, μ and p into ψ_p and ψ_q results in:

$$\psi_p = \frac{1/2 - ((\frac{1}{2} - \epsilon)(\frac{1}{2} + \epsilon) + (\frac{1}{2} + \epsilon)(\frac{1}{2} - \epsilon))}{1 - ((\frac{1}{2} - \epsilon)(\frac{1}{2} + \epsilon) + (\frac{1}{2} + \epsilon)(\frac{1}{2} - \epsilon))} = \frac{-2\epsilon}{1 - 2\epsilon},$$

and:

$$\psi_q = \frac{2((\frac{1}{2} + \epsilon)(\frac{1}{2} + \epsilon) + (\frac{1}{2} - \epsilon)(\frac{1}{2} - \epsilon)) - 1}{2((\frac{1}{2} + \epsilon)(\frac{1}{2} + \epsilon) + (\frac{1}{2} - \epsilon)(\frac{1}{2} - \epsilon))} = \frac{2\epsilon}{1 + 2\epsilon}.$$

Substituting these values into the inequality, we have:

$$\begin{aligned} \frac{A_R}{W} &\leq 1 - F(\psi_p) - F(\psi_q) \\ &= 1 - F\left(\frac{-2\epsilon}{1 - 2\epsilon}\right) - F\left(\frac{2\epsilon}{1 + 2\epsilon}\right) \end{aligned}$$

If we denote $F\left(\frac{2\epsilon}{1+2\epsilon}\right) \equiv F(x)$ it would imply that $F\left(\frac{-2\epsilon}{1-2\epsilon}\right) = -F(x)$. We can then use the fact that $F(\cdot)$ is continuously defined on $[0, 0.5)$, to get:

$$\frac{A_R}{W} \leq 1 + F\left(\frac{-2\epsilon}{1-2\epsilon}\right) - F\left(\frac{2\epsilon}{1+2\epsilon}\right) \leq 1,$$

which proofs that the condition holds for some $\epsilon \in (0, 0.5)$ if $A_R \leq W$. Therefore, pragmatic right-wing incumbents can maintain the equilibrium in those situations if $\mu \geq 0.5 + \epsilon$ and $p \leq 0.5 - \epsilon$. □

The same result can be obtained for $q = \frac{1}{2} - \epsilon$, $\mu = \frac{1}{2} + \epsilon$, and $p = \frac{1}{2} - \epsilon$, assuming $q, \mu \in (0, 0.5)$ and $p \in (0.5, 1)$, $\epsilon \in (0, 0.5)$ if $\mu \leq 0.5 - \epsilon$ and $p \geq 0.5 + \epsilon$. As it portrays the scenario (*ii*) in Proposition 2.5, it completes the proof of its validity when combined with Lemma 2.10.

2.6.5 Proof of proposition 2.6

In order to proof proposition 2.6, it suffices to show that of the following conditions does not hold:

$$\frac{A_R}{W} \geq 1 - F(\omega_p) - F(\omega_z), \frac{A_L}{W} \leq F(\omega_p) + F(\omega_q) - 1.$$

The next theorem demonstrates that the left-wing incumbent always defects.

Theorem 2.13. *Condition* (2.16) *does not hold.*

Demonstração. Given that $F(\cdot)$ is defined in the interval $[0, 0.5)$, it implies that:

$$0 \leq (F(\omega_p), F(\omega_q)) < 0.5. \tag{2.35}$$

Considering the extreme case where both $F(\omega_p)$ and $F(\omega_q)$ are at their maximum value (0.5), we have:

$$F(\omega_p) + F(\omega_q) - 1 < 0.5 + 0.5 - 1 = 0. \tag{2.36}$$

As both A_L and W are positive:

$$\frac{A_L}{W} > 0. \tag{2.37}$$

Thus, we have:

$$\frac{A_L}{W} < F(\psi_p) + F(\psi_q) - 1 < 0, \tag{2.38}$$

which directly contradicts (2.37). This shows that condition (2.16) never holds for left-wing incumbents, thus completing this proof. □

2.6.6 Results - Centrist incumbent

Table 2.6 – Results - Ideology of incumbents and voters

	Right-leaning cities			*Left-leaning cities*		
y =	NPI index	NPI IBGE	social protection	NPI index	NPI IBGE	social protection
Incumbent: centrist						
Robust	0.169	-0.166	-1.534	-0.313	0.059	-0.495
SD	(0.130)	(0.255)	(1.360)	(0.263)	(0.304)	(1.732)
p-value	(0.192)	(0.515)	(0.259)	(0.234)	(0.847)	(0.775)
Obs. left	108	133	123	42	83	100
Obs. right	114	139	119	33	55	63

i) Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; *iii)* optimal bandwith mserd, local linear estimator, triangular kernel. (*iv*) Mayors' ideology according to their parties. (*v*) Ideology of the city is determined by the results of the 2018 presidential election's run-off (cities where Jair Bolsonaro got more than 50% of the votes were labeled as right-leaning.
Source: author's preparation.

2.6.7 Placebo Tests

Table 2.7 – Placebo tests

	y = NPI index, sample = rightwing incumbent			
	c = -0.15	c = 0.15	c = -0.1	c = 0.1
Robust	-0.345	-0.040	-0.309*	-0.083
SD	(0.248)	(0.177)	(0.176)	(0.099)
p-value	(0.165)	(0.820)	(0.079)	(0.401)
Obs. left	34	127	48	113
Obs. right	86	66	97	60

i) Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; *iii)* optimal bandwith mserd, local linear estimator, triangular kernel.
Source: author's preparation.

2.6.8 Robustness checks

Table 2.8 – Robustness checks

	y = NPI index, sample = rightwing incumbent			
	kernel = uniform	kernel = epanechnikov	bw = cerrd	bw = 0.2
Robust	0.302**	0.267**	0.282**	0.205**
SD	(0.121)	(0.118)	(0.125)	(0.087)
p-value	(0.013)	(0.024)	(0.024)	(0.019)
Obs. left	150	177	150	332
Obs. right	108	140	111	286
kernel	Uniform	Epanechnikov	Triangular	Triangular
bwselect	mserd	mserd	cerrd	Manual

Notes: *i)* Significance markers: *p<0.1; **p<0.05; ***p<0.01; *ii)* covariates representing state fixed-effects; (*iii*) Mayors' ideology according to their parties.
Source: author's preparation.

2.6.9 Optimum Bandwidth Selection Algorithms

Table 2.9 – Estimated Bandwidths

	BW est. (h)		*BW bias (b)*	
mserd	0.176	0.176	0.329	0.329
msetwo	0.183	0.189	0.311	0.394
msesum	0.188	0.188	0.348	0.348
msecomb1	0.176	0.176	0.329	0.329
msecomb2	0.183	0.188	0.329	0.348
cerrd	0.122	0.122	0.329	0.329
certwo	0.126	0.130	0.311	0.394
cersum	0.130	0.130	0.348	0.348
cercomb1	0.122	0.122	0.329	0.329
cercomb2	0.126	0.130	0.329	0.348

Notes: triangular kernel.
Source: author's preparation.

3 MAY THE CHOICE BE WITH YOU? INDIVIDUAL AND SOCIAL DETERMINANTS OF VACCINE HESITANCY IN BRAZIL

This chapter explores the factors influencing vaccine hesitancy as the number and the interval between COVID-19 vaccine doses in Brazil, highlighting the importance of addressing vaccine hesitancy and promoting vaccine uptake. The findings provide important insights into the complexities and heterogeneity of the COVID-19 pandemic in Brazil and have implications for the development of evidence based public health policies and interventions aimed at addressing vaccine hesitancy and other challenges imposed by health crises.

Key-words: COVID-19, health economics, vaccine hesitancy, Brazil.

3.1 INTRODUCTION

Increase in vaccine hesitancy has been observed worldwide in the past years (DUBÉ et al., 2013), a trend that has became more explicit and relevant given the COVID-19 pandemics (SALLAM, 2021). Several studies aim to identify determinants as means to understand such behavior – for instance, Bendau et al. (2021), Cascini et al. (2021), Kerr et al. (2021), Lindholt et al. (2021), Machingaidze e Wiysonge (2021), and Spinewine et al. (2021).

Initially, it is convenient to define vaccine hesitancy. According to the Strategic Advisory Group of Exports on Immunization (SAGE), which works with the World Health Organization (WHO) on global policies pertaining vaccination, vaccine hesitancy refers to delay in acceptance or refusal of vaccination despite availability of vaccination services. As it is related to individual decision-making, this phenomenon is complex and context specific, varying across time, place and vaccines.

Similar patterns have been happening in Brazil, a country that used to report high vaccine coverage rates (CÉSARE et al., 2020), even before the global pandemic (SATO, 2018; BROWN et al., 2018). Although hesitancy appears to be at a lower rate when compared to the United States and several European countries (CALVO; VENTURA, 2021), it is heavily affecting children and teenage immunization in particular (BAGATELI et al., 2021; FERNANDEZ; MATTA; PAIVA, 2022). Similarly once again to what was witnessed in other countries, COVID-19 vaccination has become deeply politicized in Brazil (FONSECA; SHADLEN; BASTOS, 2021; ARGOTE et al., 2021; EBELING et al., 2021). It prompted a research agenda focused on the linkage between confidence in politicians and behavior towards the sanitary crisis (SHAO; HAO, 2020).

This paper intends to build on this knowledge by utilizing available public data to evaluate vaccination hesitancy among Brazilian population. The research will combine vaccination and election data in order to investigate whether socioeconomic characteristics and political preferences correlates with postponement or refusal in getting immunized against COVID-19. Building on expected utility models for risk-benefit assessment, a simple framework representing the decision process of getting the COVID-19 vaccine will be introduced. The framework intends to show how expected health risks related to individual characteristics and information pertaining the effectiveness and safeness of the vaccines can influence individual decision-making through the subjective probabilities held by each person regarding safeness and effectiveness of immunizations. The next step will comprise deriving behavior hypothesis based on political ideology. Supposing information is available for each individual, only a sample will reach and/or be processed by a particular individual. It is then expected that agents with similar characteristics and backgrounds may form similar subjective probabilities about states of the world and the consequences of their actions.

In order to evaluate these ideas, public information on individual COVID-19 vaccines doses applied in Brazil was combined with other public data to construct a novel dataset that allows for an empirical investigation on determinants behind vaccine acceptance. As a result, the study presents an estimate of how individual characteristics – such as age, health status, socioeconomic variables and political preferences – correlate with vaccine hesitancy among Brazilian population during the COVID-19 pandemic.

3.1.1 Literature Review

Current section portraits an overview of scientific literature linking individual characteristics, political preferences and vaccination, with an special focus on inoculations against COVID-19. It explores various studies on the topic which addressed the subject in different contexts worldwide. The research field of vaccine hesitancy in economics has seen several studies conducted in recent years, focusing on the prominent themes about refusal on social media, the factors that contribute to hesitancy, and the impact of political partisanship on physical distancing and vaccine uptake. From an economic perspective, the impact of vaccine hesitancy on public health is significant, as outbreaks of vaccine-preventable diseases can result in increased healthcare costs and a loss of productivity.

Several papers investigate the determinants of vaccination acceptance and hesitancy in different countries, allowing for systematic review of motives behind this trend (SALLAM, 2021). Khan et al. (2021) illustrate the importance of such an effort highlighting that only 61 percent of respondents in a worldwide sample agreed or strongly agreed that they would take a COVID-19 vaccine if available. It is influenced by factors such as complacency, convenience and confidence (MACDONALD et al., 2015). However, Machingaidze e Wiysonge (2021) highlighted the limited data available on vaccine hesitancy in low- and middle-income countries. The study emphasized the need for more research to be conducted in these regions to understand the reasons behind vaccine hesitancy.

Dubé et al. (2013) provides a comprehensive overview of the subject. The authors suggest that the increase in vaccine hesitancy can be attributed to a combination of emotional, cultural, social, spiritual, political, and cognitive factors. Additionally, they highlight the complex nature of individual decision-making regarding vaccination, which involves a variety of factors that can impact an individual's trust and confidence in vaccines. The study concludes that, despite the increasing trend towards vaccine hesitancy, it is difficult to quantify the exact proportion of the population that can be categorized as vaccine-hesitant. However, it is widely acknowledged that there is a need for greater understanding of the drivers behind this phenomenon and how to effectively address it. (BURKE; MASTERS; MASSEY, 2021) explored the psychological beliefs that may act as enablers or barriers to vaccine uptake. The study found that factors such as individual variables (income, age, religion, altruism, and collectivism) and health beliefs (risks and severity of the disease) played a significant role in vaccine hesitancy.

On a social level, (WEISEL, 2021) found that vaccinated participants in a study reduced their generosity towards non-vaccinated individuals compared to vaccinated individuals. This result supports the hypothesis that vaccination can be seen as a social contract and this effect was not dependent on group membership.

While some socioeconomic and demographic variables are found to be statically significant (KHUBCHANDANI et al., 2021) and differ across countries (BURKE; MASTERS; MASSEY, 2021), political preferences were estimated to be the most important factor in many studies (BAUMGAERTNER; CARLISLE; JUSTWAN, 2018). Before the global pandemics, Kennedy (2019) found evidences that vaccine hesitancy in Western Europe was linked with supporting populist parties. Partisanship divergence was also found in the United States during the H1N1 pandemic of 2009-2010 (MESCH; SCHWIRIAN, 2015).

Related to COVID-19, studies found correlation between ideology and vaccine acceptance in France(GAGNEUX-BRUNON et al., 2022), Hong Kong (YUEN, 2022), Italy(PALAMENGHI et al., 2020), Jordan and Kuwait (SALLAM, 2021), New Zealand (WINTER et al., 2022), Norway (WOLLEBÆK et al., 2022) South Korea (PARK et al., 2021), Spain (SERRANO-ALARCON et al., 2022), and the United States (VISWANATH et al., 2021; TRAVIS et al., 2021; FARHART et al., 2022).

Studies focused on Latin America countries did not estimate similar results (URRUNAGA-PASTOR et al., 2021; BATES et al., 2022). However, political preferences were found to be significant determinants of willingness to get vaccinated in Brazil (GRAMACHO et al., 2021).

It is worth noting that even before the pandemics, Brown et al. (2018) emphasized that vaccine hesitancy was a growing concern in Brazil and, as a complex phenomenon that varies over time, location, and type of vaccine, the authors highlighted the importance of communication and engagement with the public to combat vaccine hesitancy. However, when compared to other countries, Brazil still presents a low hesitancy rate among the Brazilian population, with only 10.5% of respondents reporting a reasonable level vaccine hesitancy (MOORE et al., 2021).

Regarding determinants of vaccine hesitancy in Brazil, several factors have been described in the past years. Gramacho et al. (2021) conducted a national survey in Brazil to measure the role of political preferences in knowledge and misinformation about the coronavirus and its illness, COVID-19. The findings show that political preferences play a significant role in explaining differences in knowledge about the coronavirus and COVID-19, with supporters of then-President Jair Bolsonaro, who has systematically downplayed the risks associated with the virus, having significantly less knowledge about the virus and being more likely to believe in conspiracy theories.

Gramacho e Turgeon (2021) examine the effect of the country of origin of the vaccine on vaccination acceptance in Brazil. The results show that vaccination uptake and intention to vaccinate are generally high in Brazil, but that vaccine acceptance decreases when the country of origin is mentioned, with Chinese and Russian developed-vaccines being the most rejected, adding another variable behind immunization acceptance. Rejection of the Chinese-developed vaccine is particularly strong among those with positive evaluations of President Bolsonaro. Similar results were found pertaining other Latin American countries Argote et al. (2021), where citizens preferred Western-produced vaccines.

Ajzenman, Cavalcanti e Mata (2020) help better understating these findings. The authors investigated the impact of the anti-scientific rhetoric of modern populists on followers' behavior during the COVID-19 pandemic. The study used electoral information, credit card expenses, and geo-localized mobile phone data for approximately 60 million devices in Brazil to assess the relationship between the president's public statements on the pandemic and the level of social distancing and credit card expenses in pro-government and anti-government localities. The results showed a significant decrease in social distancing and an increase in in-person credit card expenses in pro-government municipalities following the president's visible events. However, the study could not estimate the effect of the president's speech on the levels of mobility or differentiate between pro-government and anti-government municipalities.

Similar trends are also observed in other countries. Shao e Hao (2020) propose that risk perception is influenced by ideology. The authors find that liberals and moderates perceived a greater risk on COVID-19 in comparison to conservatives. One possible explanation links political preferences and attention to news about the pandemics as well as perceived quality of media coverage. Conservatives reported higher distrust in media which can reduce the risk perception given the extensive coverage diploid by traditional news outlets regarding the outbreaks.

Differences in prior beliefs about the severity of the pandemics are found to correlate with partisanship, according to a series of studies (BHANOT; HOPKINS et al., 2020; GADARIAN; GOODMAN; PEPINSKY, 2021). Building on divergent beliefs, pandemic related misinformation was found to be more commonly believed and pushed through social media by political conservatives in the United States (HAVEY, 2020) and Turkey (KÜÇÜKALI et al., 2022).

Calvo e Ventura (2021) reported that individual perception of risk was affected by partisanship in Brazil. Pro-government respondents tended to undermine health risks in comparison to opposition partisans, especially after the speech in national television where the president underscored the severity and dismissed the risks associated with the pandemics. Ajzenman, Cavalcanti e Mata (2020) found that stay-at-home compliance decreased after the presidential public address, an effect that was stronger in cities with a bigger proportion of government supporters.

Studies revealed that political preferences relate to compliance with non-pharmaceutical interventions intended to deter the spread of the virus. In the US, state level adherence to stay-at-home orders correlated negatively with the proportion of republicans/leaning republicans even after adjusting for urbanization and other relevant variables (ALLCOTT et al., 2020; HSIEHCHEN; ESPINOZA; SLOVIC, 2020).

In that same direction, partisanship was found to be the most important predictor of mask mandates compliance in the same country (MILOSH et al., 2021). These facts may have led to higher COVID-19 infection and fatality rates in counties where former president Donald Trump received a majority of the votes in 2016 election (GOLLWITZER et al., 2020), since counties that voted Republican exhibited 14% less physical distancing compared to those that voted for Democrat.

In the study by Soares et al. (2021), the researchers aimed to assess and identify the factors associated with COVID-19 vaccine hesitancy in Portugal. The study found factors including distrust in the government and the media, misinformation, and personal beliefs contributed to vaccine hesitancy in the Portuguese population.

The studies presented in this section stress the relevance of investigating the relationship between individual variables and vaccine acceptance. In conclusion, the literature review suggests that vaccine hesitancy is a complex phenomenon influenced by various factors, including political ideology, health beliefs, and individual variables. Understanding these factors and their impact on vaccine uptake is crucial to facilitate vaccine acceptance and ensure public health. The next sections detail the theoretical and empirical strategies to further understand this relationships.

3.1.2 Outline

The study is built as follows. After the introduction and literature overview, next section introduces the base model and the main hypothesis derived from its framework combined with the existing studies and evidences. In the sequence, the empirical model is estimated, based on the dataset related to different Brazilian cities. Final sections present the concluding remarks and ideas for further studies.

3.2 A CONCEPTUAL FRAMEWORK FOR VACCINATION DECISION

Intending to extract theoretical hypotheses about determinants of vaccine acceptance, current section presents a general expected utility setting to assess choice under uncertainty with subjective probabilities over the risks and effectiveness of COVID-19 vaccination.

Following the framework proposed by Courbage e Peter (2021), we analyze an individual's decision-making process concerning vaccination. The authors develop a model based on a two-argument von Neumann-Morgenstern utility function, denoted by $u(C, H)$. There, C denotes the consumption of an aggregate good, and H represents health. They assume that health can be captured by a single variable, although it could represent a vector of weighted factors without altering their propositions. Both consumption and health should be positively valued, with partial derivatives $u_C > 0$ and $u_H > 0$ representing the marginal utility from increasing consumption and health, respectively.

To accommodate subjective probabilities in the vaccination decision model, we generalize the probabilities of effectiveness and side effects by introducing individual beliefs about the probability distribution of states of the world, denoted by $p : \mathcal{S} \to \mathbb{R}_+$. We also generalize the consequences of vaccination by introducing an individual's utility function over consequences in the form of the aforementioned model, denoted by $u : \mathcal{X} \to \mathbb{R}$.

The inclusion of subjective probabilities allows for a more nuanced analysis of individual decision-making and the role of individual beliefs in vaccine acceptance. It becomes clearer when we present an illustrative set of states of the world $\mathcal{S} = \{s_1, s_2, s_3, s_4\}$ such that:

- s_1: High vaccine effectiveness, low transmission, and low side effects,
- s_2: Low vaccine effectiveness, high transmission, and low side effects,
- s_3: High vaccine effectiveness, low transmission, and high side effects,
- s_4: Low vaccine effectiveness, high transmission, and high side effects;

and the set of consequences $\mathcal{X} = \{x_1, x_2, x_3, x_4\}$ as follows:

- x_1: Healthy, no COVID-19 infection,
- x_2: Mild COVID-19 infection and retransmission to closer ones,
- x_3: Severe COVID-19 infection and retransmission to several others,
- x_4: Adverse vaccine side effects.

In this context, the vaccination decision is a choice between two possible acts: taking the vaccine, represented by a function $f_v : \mathcal{S} \to \mathcal{X}$; or not taking the vaccine,[1] $f_n : \mathcal{S} \to \mathcal{X}$. Each act maps the states of the world to the corresponding consequences in terms of health and consumption.

The individual's expected utility when not vaccinated is:

$$U^n = \sum_{s \in \mathcal{S}} p(s) u(C_{s,n}, H_{s,n}), \tag{3.1}$$

where $u(C_{s,n}, H_{s,n}) \equiv u(f_n(s))$, $C_{s,n}$ and $H_{s,n}$ are consumption and health levels in state s when not vaccinated.

The individual's expected utility when vaccinated is:

$$U^v = \sum_{s \in S} p(s) u(C_{s,v}, H_{s,v}), \tag{3.2}$$

where $u(C_{s,v}, H_{s,v}) \equiv u(f_v(s))$, $C_{s,v}$ and $H_{s,v}$ are consumption and health in state s when vaccinated.

In this framework, individuals base their vaccination decision on their subjective beliefs about the probability distribution of states of the world and their preferences over the consequences according to equation 3.2. If the individuals are deciding between taking the vaccine (f_v) or refusing it (f_n), the relevant comparison that makes them getting vaccinated relies on the following necessary and sufficient condition:

$$f_v \succeq f_n \Longleftrightarrow \sum_{s \in \mathcal{S}} p(s) u(f_v(s)) \geq \sum_{s \in \mathcal{S}} p(s) u(f_n(s)), \tag{3.3}$$

so that the vaccine is expected to raise utility.

It formally represents a setting where an act denotes an individual's decision to take the vaccine or not, given their beliefs about vaccine safety and effectiveness. It assumes that individuals have preferences over acts based on their subjective beliefs about the probability distribution of states of the world and their utility function over consequences. It allows us

[1] The same logic applies when comparing the decision between taking a shot or delaying the decision, or delaying the next dose or ultimately not taking it. Therefore both types of hesitance could be modeled following this framework.

to propose another assumption: that individuals with similar information, health status, and risk aversion will have similar subjective probabilities and utility functions. This implies that they would make similar decisions regarding vaccination.

This framework allows for the exploration of how information dissemination and public health campaigns may influence subjective beliefs and consequently vaccination decisions. By identifying patterns in the data such as correlations between individual characteristics (i.e. age, skin color, neighborhood of residence, and sociodemographic or voting patterns) with the number of doses taken or the interval between shots, researchers and government officials can better understand vaccine hesitancy and potentially develop targeted interventions to address it.

The common prior assumption suggests that if individuals are subject to similar contexts and receive and process the same information, they will form common subjective probabilities. However, we should treat this assumption with some skepticism, as it is a weak point in the economics of uncertainty. Once we can derive the existence of such subjective probabilities from real-world data, assuming that the actions that individual take are informative of their preferences, it claims for empirical investigations in order to collect evidences for or against this hypothesis. That is precisely the objective of the next chapter.

3.3 EMPIRICAL STRATEGY

The current section portrays the data collection and analyses applied in the study.

3.3.1 Data Description

Information on every vaccine dose administered in Brazil until the 28th of February, 2023, was collected from public database. It possesses more than 400 million entries with an unique id for every citizen ($\approx$ 180 million individuals with at least one dose). The microdata presents individual features – age, race, postal code of residence, and group for immunization – as well as details on the supplier, and where and when the vaccines were applied. The interval between every dose was then calculated and combined with the correspondent vaccine supplier to form the base dataframe for this study.

One relevant note on this data is the fact that there is information pertaining only to those individuals who accepted at least one dose of a vaccine against COVID-19. The implications of this fact will be thoroughly discussed after the presentation of the results. One clear caveat and arguably the biggest limitation of this study is that the population who ultimately displayed the highest level of vaccine hesitancy were excluded from the analyses.

A set of twenty municipalities was draw among those with more than 250k inhabitants (150K for the Northern region). The sample was designed to select four cities from each of the five geographical regions in Brazil (Center-West, North, Northeast, South and Southeast), where two must be state capitals. After the random drawing, nine cities had to be manually substituted for neighboring cities with similar population, when postal code data was not properly informed for at least forty per cent of its population. [2] The list of municipalities and its general statistics are presented in table 3.1. Although the sampling can not be considered formally representative of the Brazillian population, its final size, comprising 17,926,966 individuals, represented roughly eight percent of the country's entire population. Furthermore, as vaccination calendars were defined by each municipality, the decision to sample cities and consider the entirety of its citizens intended to avoid bias from city-level vaccination programs.

Small municipalities were excluded from the study once they only present one postal code. It would not allow to use average neighborhood features as independent variable in the model. Given that every city had a different vaccination calendar, introducing cities where average voting patterns and socioeconomic variables would not vary among its population would ultimately evaluate the municipality vaccination effort, not individual determinants.

Brazilian postal code possesses eight digits in total. Among bigger cities, it allows for the identification of the street of residence. In compliance with personal data protection legislation regarding health information, the available database indicates only the first five digits, which informs the neighborhood where every patient lives. It is worth noting that the postal code information is up to date once every citizen were obligated to present documentation on their current living address in order to get a COVID-19 shot, as the Federal Government was distributing doses based on local population.

Postal code data is not publicly available in Brazil, therefore the connection between every five-digit postal code and the neighborhood (*bairro*, in Brazilian Portuguese) was collected through web-scrapping. It resulted in a list of (at least one) *bairro* for every postal code. Public data on socioeconomic indicators and voting patterns in the 2018 general election related to every neighborhood was averaged between the neighborhoods related to each postal code and included in the final dataframe matching the residential information of each individual.

Election results and voting locations were obtained from Superior Electoral Court (TSE) public database. The difference between the voting share on congresspeople who ran for Jair Bolsonaro's then-party (PSL) and the left-wing Worker's Party (PT) was used as ideology proxy. Considering that the former Brazilian President ran in the 2018 election

[2] Individual information was collected and forwarded by local authorities, which may explain the differences in missing values among cities.

as opposition to the party who had won the past four general polls (PT), the share of his votes included not only his supporters but also the anti-PT voters (NICOLAU, 2020). On the other hand, PSL was an irrelevant party that elected only one congressman in the 2014 election. However, in 2018, it elected fifty two congresspeople as it became known solely as Bolsonaro's party. Therefore, it is expected that this strategy presents a sufficiently reliable measure of ideological supporters of the Brazilian former President.

Table 3.2 displays descriptive statistics for the continuous features. Table 3.6 shows the same data separated by regions. Table 3.3 portrays the data grouped by the vaccine supplier of the first dose. Further descriptive statistics are displayed in the appendix 3.6.1 Full coding to extract the final database from Google Cloud and full empirical analyses using Python are available on GitHub. [3]

3.3.2 Data analysis

Aiming to evaluate the determinants of vaccination against COVID-19 among the designed sample, a series of regressions were performed to investigate how individual, socioeconomic and political variables interact with vaccination data.

Two forms of hesitancy were analyzed. Considering that there is no information on individuals who refused to get vaccinated, there could be three categories according to the number of doses received. It allowed the estimation of ordinal multinomial logistic regressions, considering the probability of each vaccination status as the categorical dependent variable as follows:

$$\begin{aligned} P(Y_i = k) &= \frac{e^{\sum_{j=1}^{J} \beta_{k,j} x_{i,j}}}{1 + \sum\limits_{k=1}^{2} e^{\sum_{j=1}^{J} \beta_{k,j} x_{i,j}}}, \text{for } k = \{1, 2, 3\}, \\ P(Y_i = 0) &= \frac{1}{1 + \sum\limits_{k=1}^{2} e^{\sum_{j=1}^{J} \beta_{k,j} x_{i,j}}}, \text{for } k = \{0\}, \end{aligned} \tag{3.4}$$

where $k \in \{1, 2, 3\}$ denotes the number of doses individual i has accepted, while $k = 0$ represents four or more doses, and x_j is each of the J explanatory variables.

Next, hesitancy was regarded as postponing second and booster shots. Therefore, the dependent variable is the number of days between each dose taken. Its determinants were estimated through linear regression against the set of individual characteristics, as well as the estimated political preferences.

$$Y_i = \alpha + \sum_{j=0}^{J} \beta_j x_{i,j} + \epsilon_i, \tag{3.5}$$

3 <https://github.com/hssitja/PhD-Dissertation/tree/Chapter-2>

Table 3.1 – Summary statistics - sample of municipalities

City	State	Region	Population	Avg. Doses	Avg. Age	Avg. Income
Abaetetuba	PA	North	160,439	1.84	36.71	2250.80
				(0.53)	(17.22)	(1.57)
Campo Grande*	MS	Center-West	916,001	2.25	41.35	3307.81
				(0.67)	(18.18)	(2181.17)
Caxias do Sul	RS	South	523,716	2.12	42.72	3125.33
				(0.61)	(18.28)	(764.63)
Cuiabá*	MT	Center-West	623,614	1.97	41.05	3104.58
				(0.60)	(17.46)	(1477.75)
Curitiba*	PR	South	1,963,726	2.19	43.01	3823.70
				(0.58)	(18.35)	(1620.66)
Feira de Santana	BA	Northeast	624,107	1.81	41.28	1965.18
				0.64	18.00	661.62
João Pessoa*	PB	Northeast	825,796	1.98	41.99	2704.27
				(0.60)	(18.23)	(1993.39)
Londrina	PR	South	580,870	2.12	43.16	3255.08
				(0.62)	(18.54)	(2587.76)
Macapá*	AP	North	522,357	1.70	37.31	3007.46
				(0.62)	(17.03)	(691.81)
Manaus*	AM	North	2,255,903	1.93	37.84	2485.41
				(0.57)	(17.05)	(1556.09)
Paulista	PE	Northeast	336,919	1.86	42.23	1618.15
				(0.61)	(18.02)	(556.76)
Porto Alegre*	RS	South	1,492,530	2.20	44.35	3747.20
				(0.65)	(19.28)	(1985.33)
Recife*	PE	Northeast	1,661,017	1.97	43.17	2699.92
				(0.63)	(18.47)	(2184.45)
Rio de Janeiro*	RJ	Southeast	6,775,561	2.15	43.64	3199.06
				(0.64)	(19.20)	(2235.37)
Rondonópolis	MT	Center-West	239,613	1.92	40.20	2314.77
				(0.60)	(17.51)	(1022.27)
Santarém	PA	North	308,339	1.74	37.88	2016.65
				(0.59)	(17.84)	(714.98)
Santo André	SP	Southeast	723,889	2.14	43.70	3438.06
				(0.65)	(18.72)	(1466.76)
São Gonçalo	RJ	Southeast	1,098,357	1.91	43.28	1765.57
				(0.65)	(18.46)	(389.85)
Vitória*	ES	Southeast	369,534	2.25	43.74	4161.10
				(0.64)	(18.65)	(3332.22)
Várzea Grande	MT	Center-West	290,383	1.92	40.12	1822.36
				(0.61)	(17.22)	(436.51)

Notes: (*i*) State capitals identified with *. (*ii*) Standard deviation between parenthesis. (*iii*) Doses and age refers to the average value among individuals who took at least one dose of a COVID-19 vaccine. (*iv*) Income, literacy and family size refer to the average value in the neighborhood where each individual who took vaccine lives.
Source: author's preparation.

where once again x_j is each of the J explanatory variables and ϵ_i is normally distributed with mean equals to zero.

Separate models for geographic regions were estimated, given the continental size of Brazil and the socioeconomic heterogeneity among such regions. Considering the propositions based on the theoretical framework, specifications for vaccination groups

Table 3.2 – Descriptive statistics of variables - full sample

	Observations	Missing values	Mean	St. Dev.	Min	Max
Nbr. doses	17,926,966	0	2.07	0.64	1	4
Diff. dose1-dose2	14,494,789	3,432,177	70.90	42.57	1.00	30445.00
Diff. dose2-dose3	3,672,308	14,254,658	165.56	41.50	1.00	354.00
Age	17,926,966	0	42.40	18.63	-16	221
Avg. Income	15,625,791	2301175	3057.54	2012.02	567.34	18553.01
Avg. Literacy	15,625,791	2301175	96.43	2.54	75.6	99.8
Avg. Family size	15,625,791	2301175	3.14	0.41	1.73	4.72
Vote diff. PSL-PT	15,046,357	2880609	0.09	0.11	-0.35	0.56

Notes: 1. Doses, interval between doses, and age refers to the average value among individuals who took at least one dose of a COVID-19 vaccine. 2. Difference between doses displays the average number of days. 3. Income and voting results refer to the average value in the neighborhood where each individual who took vaccine lives.
Source: author's preparation.

based on health[4] and professional status[5,6] were also tested. The final set of covariates was selected aiming to avoid collinearity. Therefore, one feature was selected when pairs of variables showed covariance greater than 0.5. Full correlation matrix and empirical estimations are available in the online appendix.[7]

3.3.3 Theoretical Predictions

Following the relevant studies on the subject and the theoretical framework presented in the former sections, a set of predictions can be introduced:

1. COVID-19 vaccine hesitancy will not be estimated as high in Brazil, considering the country's tradition and institutional capabilities pertaining to immunization;
2. older individuals and individuals with preexisting conditions will present higher number of doses and shorter intervals between shots; females will display similar, yet weaker, results;
3. proxies for individual characteristics such as political preference and income will be statically significant, but not strongly related to the two forms of hesitancy.

[4] Population with previous medical conditions included those with: Sickle cell anemia, Neoplasms, Diabetes Mellitus, Chronic Obstructive Pulmonary Disease, Chronic Kidney Disease, Cardiovascular and cerebrovascular diseases, Hypertension with complications or organ damage, Solid Organ Transplant recipients, Severe Obesity (BMI >= 40), Down Syndrome, Other Immunocompromised conditions, Liver Cirrhosis, Chronic Neurological Diseases, Cardiovascular Disease.

[5] Health professional included: Biomedical scientist, Elderly caregiver, Doula/Midwife, Nurse, Pharmacist, Physiotherapist, Speech therapist, Funeral system employee with potentially contaminated cadavers, Doctor, Ambulance driver, Nutritionist, Dentist, Psychologist, Social worker, Nursing technician, Occupational therapist, Nursing auxiliary, Dental technician, Endemic combat agent - ACE, Community Health Agent - ACS, Dental health assistant - ASB, Dental health technician.

[6] Security forces included: Brazilian Army - EB, Brazilian Air Force - FAB, Civil Firefighter, Military Firefighter, Municipal Guard, Civil Police, Federal Police, Military Police.

[7] <https://github.com/hssitja/PhD-Dissertation/blob/Chapter-2/Chapter2.ipynb>

Table 3.3 – Descriptive statistics

variable	Observations	Missing	Mean	SD	Min	Max
Dose 1: Astrazeneca						
Nbr. doses	6618744	0	2.13	0.57	1	4
Diff. dose1-dose2	5910150	708594	87.31	37.72	1.00	30445.00
Diff. dose2-dose3	1475029	5143715	142.16	30.48	1.00	345.00
Age	6618744	0	48.12	14.73	-16	170
Avg. Income	5799578	819166	3,099.15	2036.72	567.34	18553.01
Vote diff. PSL-PT	5572129	1046615	0.09	0.11	-0.35	0.56
Dose 1: Janssen						
Nbr. doses	499404	0	3.00	0.02	3	4
Diff. dose1-dose2	109826	389578	170.42	17.81	1.00	477.00
Diff. dose2-dose3	481	498923	81.04	63.60	1.00	196.00
Age	499404	0	41.05	8.61	0	121
Avg. Income	428689	70715	3,097.48	2052.49	567.34	18553.01
Vote diff. PSL-PT	421550	77854	0.08	0.11	-0.35	0.56
Dose 1: Coronavac/Sinovac						
Nbr. doses	4745484	0	2.32	0.66	1	4
Diff. dose1-dose2	4223203	522281	36.08	34.17	1.00	23086.00
Diff. dose2-dose3	1954167	2791317	188.12	35.69	1.00	354.00
Age	4745484	0	50.62	21.14	0	129
Avg. Income	4151934	593550	3,161.60	2091.27	567.34	18553.01
Vote diff. PSL-PT	4011901	733583	0.09	0.11	-0.35	0.56
Dose 1: Pfizer						
Nbr. doses	6063334	0	1.75	0.53	1	4
Diff. dose1-dose2	4251610	1811724	80.11	33.39	1.00	20228.00
Diff. dose2-dose3	242631	5820703	126.25	34.24	1.00	277.00
Age	6063334	0	29.84	13.65	-5	221
Avg. Income	5245590	817744	2,925.90	1907.60	567.34	18553.01
Vote diff. PSL-PT	5040777	1022557	0.09	0.11	-0.35	0.56

Notes: (*i*) Doses, interval between doses, and age refers to the average value among individuals who took at least one dose of a COVID-19 vaccine. (*ii*) Difference between doses displays the average number of days. (*iii*) Income and voting results refer to the average value in the neighborhood where each individual who took vaccine lives.
Source: author's preparation.

Next, the results will be presented and discussed.

3.3.4 Results

The current section presents the overall results of the empirical investigation. Table 3.4 displays the results of the linear models considering the entire population of the twenty cities included in the study. Given that every coefficient was significant at 1% level, coefficients can be directly compared in order to suggest the most important factors correlated to the endogenous variables.

Model (1) was estimated via ordered logistic regression, where the number of doses was the dependent variable[8]. The set of independent variables is presented in the table.

[8] Although the number of doses represents a count variable, Poisson regression was not used for two

Table 3.4 – Results - entire population

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		86.734***	71.413***	139.572***	154.858***
		(0.017)	(0.019)	(0.047)	(0.052)
dose1 Pfizer	-0.591***	-5.589***		-14.510***	
	(0.002)	(0.020)		(0.079)	
dose1 Sinovac	0.636***	-51.555***		44.976***	
	(0.001)	(0.019)		(0.040)	
Black	0.047***	1.523***	0.305***	-1.543***	-2.565***
	(0.003)	(0.036)	(0.047)	(0.087)	(0.106)
Brown	-0.034***	1.028***	0.582***	-1.123***	-1.603***
	(0.001)	(0.020)	(0.026)	(0.051)	(0.062)
White	0.308***	-0.944***	-2.027***	-0.593***	-0.836***
	(0.001)	(0.019)	(0.025)	(0.044)	(0.053)
Age	0.908***	1.561***	-3.547***	1.414***	9.202***
	(0.001)	(0.009)	(0.010)	(0.022)	(0.026)
Avg. Income	0.219***	-1.421***	-1.513***	0.224***	-0.010
	(0.001)	(0.008)	(0.010)	(0.017)	(0.021)
Vote diff. PSL-PT	0.158***	1.124***	0.989***	-7.393***	-9.225***
	(0.001)	(0.008)	(0.010)	(0.020)	(0.024)
Female	0.192***	0.103***	-0.548***	4.352***	5.937***
	(0.001)	(0.016)	(0.020)	(0.038)	(0.046)
Observations	14,097,711	11,733,790	11,733,790	3,098,474	3,098,474
Adjusted R^2	0.170	0.420	0.015	0.385	0.085
Residual Std. Error	1.000	26.337	34.307	32.461	39.589

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

The results seem to validate the theoretical propositions, once age presents the higher coefficient (0.908). Considering that, in average, older people experiments lower health status when compared to the general population, it is expected that they would accept a bigger number of doses.

The next features in order of importance where Sinovac (0.636) and Pfizer (-0.591) as suppliers of dose 1. Income (0.219) and the proxy for right-wing ideology (Vote difference PSL-PT for congresspeople, 0.158) were positively correlated to the number of doses, although at lower values. It indicates that supporting right-wing candidates did not correlate with vaccine hesitancy when measured as the reluctance to get further doses.

reasons. The practical reason related to the unavailability of data on those who did not get a vaccine (zero count), which would violate the hypothesis for this type of analysis. The more theoretical reason is that there are steep decreasing utility gains from getting extra doses. A Poisson regression framework assumes that the distance between each step is equal, while a person with two doses of vaccine does not possess twice the protection in comparison to another individual who only received one shot.

Among the dummy variables, black (0.047) and brown (-0.034) skin color presented negligible coefficients, while white (0.308) was correlated to a higher number of doses. Female (0.192) was positively correlated, as expected, but at a moderate rate.

Models (2) until (5) were estimated through ordinary least squares (OLS) and evaluated the correlation between the number of days between doses and the same set of features. Models (2) and (3) regarded the interval between doses 1 and 2. The first model included the supplier of the first dose as independent variable, while the second did not. Once recommended interval between shots of Sinovac was four weeks, Pfizer started with eight but was reduced to four, while Astrazeneca (omitted from the model to avoid perfect collinearity) indicated up to eight weeks interval (BRASIL, 2022), their significance is expected. Nevertheless, the R^2 falls from 0.42 (2) to 0.015 (3) when the dummies representing the supplier of dose 1 is excluded[9], showing that most of the variations in the dependent variable is correlated to the type of vaccine taken by the individuals.

Regarding the importance of each feature, the values of the coefficient illustrate the same result. Sinovac as dose 1 (-51.555) presented a negative coefficient ten times larger than Pfizer (-5.589)[10]. The latter, by its turn, was more than three times the magnitude of coefficients regarding the next variables (1.561 for age, 1.523 for black person).

Models (4) and (5) presented the interval between second and third doses as dependent variable. The latter possessed the supplier of the first dose as explanatory variable, as it was almost perfectly correlated with second dose supplier, and the former did not. Once again, the explanatory power of the vaccine supplier was the most important feature, although in a less steep way[11]. It is worth noting that the right-wing ideology proxy became the most important factor – -7.393 for model (4), -9.225 for model (5) – related to a shorter interval, differently than what was obtained in the previous models.

Pertaining to other variables, models (2) and (3) point that income correlated negatively with the interval between doses 1 and 2, and the ideology proxy was positively correlated. When compared to models (4) and (5), the second relation is reversed, and income becomes negligible.

Age and female patients are strongly correlated with a bigger interval between doses 2 and 3 when vaccine supplier is not included as explanatory variable. As both relations become reversed in relation to model (3), it can be assumed that the bigger interval is at least in part related to the calendar of availability for third dose.

[9] Given that the coefficient of determination measures the proportion of variance in the dependent variable that is explained by the independent variable, R-squared of 0.42 indicates that 42% of the variability in the dependent variable is accounted for by the independent variable included in the model. The same applies to an R^2 of 0.015, implying that only 1.5% of the changes in the endogenous variable are correlated with variation in the features.

[10] As single dosed Janssen was excluded from models evaluating the interval between doses, Astrazeneca represents the baseline.

[11] R^2 drops from 0.385 pertaining to model (4) to 0.085 related to model (5).

Table 3.5 shows the results when the population is restricted to people with comorbidities. Most of the coefficients remain similar. One important exception is brown skin color, which was negative (-1.603) in model (5) and positive (4.652) in model (10).

Table 3.5 – Results - population with comorbidities

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(6)	(7)	(8)	(9)	(10)
const		86.310***	82.708***	130.729***	134.239***
		(0.073)	(0.074)	(0.138)	(0.138)
dose1 Pfizer	0.074***	-2.824***		-1.066***	
	(0.005)	(0.085)		(0.147)	
dose1 Sinovac	0.697***	-51.817***		45.920***	
	(0.010)	(0.167)		(0.260)	
Black	0.247***	0.251***	1.863***	3.925***	1.689***
	(0.010)	(0.152)	(0.161)	(0.265)	(0.282)
Brown	0.011***	0.707***	-1.164***	1.793***	4.652***
	(0.006)	(0.092)	(0.098)	(0.171)	(0.182)
White	0.404***	-1.475***	-0.060	0.439***	-1.835***
	(0.006)	(0.087)	(0.092)	(0.152)	(0.161)
Age	0.445***	-0.945***	-0.970***	9.518***	10.050***
	(0.004)	(0.063)	(0.066)	(0.117)	(0.125)
Avg. Income	0.122***	-0.984***	-0.852***	-1.785***	-2.215***
	(0.002)	(0.036)	(0.038)	(0.063)	(0.067)
Vote diff. PSL-PT	0.160***	2.303***	4.234***	-1.223***	-3.972***
	(0.002)	(0.037)	(0.039)	(0.068)	(0.071)
Female	1.664***	1.513***	0.598***	-0.054***	0.452***
	(0.005)	(0.072)	(0.076)	(0.126)	(0.134)
Observations	844,424	786,501	786,501	239,676	239,676
Adjusted R^2	0.0195	0.124	0.016	0.162	0.049
Residual Std. Error	1.000	31.325	33.191	30.413	32.410

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Regarding the coefficients of determination, it is worth highlighting that they were consistently lower in the models evaluating the population with previous diseases (table 3.5) in comparison to the general population (table 3.4). It is specially significant when comparing models (1), with an R^2 of 0.170 and (6), 0.0195.

In the following section, we will discuss the implications of these results, specifically in comparison to the predictions derived from the microeconomic model.

3.4 DISCUSSION

When analyzing the results of the empirical investigation, one important caveat to keep in mind is the fact that arguably the most impactful type of hesitancy, that of people who refused to get vaccinated, could not be directly evaluated. Also, the interval between doses is calculated only for those who took at least two shots. Therefore, the general results relate to the part of the population with a moderate to low level of hesitancy, not reaching the most reluctant individuals. It may help explain some of the results that appear at odds with surveys and other empirical studies.

The microeconomic framework suggests that prior subjective probabilities on vaccine safety and effectiveness plays a role in shaping individual decisions pertaining to vaccination. However, there still is an ongoing argument in the economics field in particular and broadly in science about the existence of such probabilities. We will not enter in this ontological debate. Our reasoning follows what has been developed since the seminal work of Savage (1954). In short, our approach assumes that choices-based subjective probabilities can be observed in settings that calls for decision making under uncertainty. We propose that it is the case when agents must decide whether to take a new vaccine for an ongoing pandemics.

The naive social scientist could argue that, following the results of a randomized controlled trial that asserts the safeness and effectiveness of the immunization, the expected utility theory should conclude that every agent concerned with their health status would get a vaccine. Nonetheless, assuming health status positively affects one's utility, the agents must *believe* that their expected health condition would be benefited from this action. This belief can be interpreted as a prior subjective probability about states of the world regarding the effects of taking the shot. Even if the science community and government official can guarantee, based on controlled trials, that individual would be better off getting vaccinated, people must trust in them and their conclusions in order to follow the technical advises.

Given that vaccination possesses well known medical but also economic beneficial consequences for the individual and also for the community (BLOOM; FAN; SEVILLA, 2018), presenting information such that the subjective probabilities reflect the objective probability of a healthier status after accepting the shot becomes the challenge. However, the cost of accessing reliable sources and correctly interpreting information is not explicitly displayed in the framework, once the process that generates the subjective probabilities is not usually present as an endogenous variable in classical microeconomic models. Notwithstanding this debates and limitations regarding the theoretical framework, we are confident that analyzing data patterns on vaccination, especially with individual-level information, can enhance our understanding about the vaccine hesitancy phenomenon.

It leads us to the empirical investigation. The results indicate that older individuals (0.908), white individuals (0.308), higher income individuals (0.219), females (0.192), and individuals with right-wing ideology (0.158) are positively correlated with a higher number of COVID-19 shots. The most important factor was age, while the others were presented in decreasing order. Apart from the proxy for right-wing (expected to be negatively correlated in accordance with the studies referred to in section 3.1.1) and skin color (no hypothesis), the other results appear to corroborate the model. Similar results were observed when evaluating only the population with previous diseases. The main difference regarded black skin color, which displayed a negligible coefficient for the general population (0.047), but positive regarding people with previous diseases (0.247).

Regarding the result related to the right-wing proxy, several caveats may explain this outcome. As previously mentioned, the database consists of individuals who received at least one dose of the COVID-19 vaccine. Our chosen proxy measures electoral results for congresspeople in the 2018 general election, where we collected ballots located in each neighborhood and calculated the vote share by subtracting the share received by left-wing party PT candidates from that of Jair Bolsonaro's then party PSL candidates. We opted for legislative ballots as presidential results would not enable us to distinguish between Bolsonaro's supporters and those rejecting PT candidate Fernando Haddad. We believe that this choice accurately represents right-leaning neighborhoods in Brazil.

Nevertheless, our results may be influenced by a self-selection bias among the data concerning right-leaning neighborhoods. The existing literature and evidences suggest that the most ideologically driven right-wing individuals could have opted against vaccination, leading to this bias. If this hypothesis holds, our findings would suggest that agents living in right-leaning neighborhoods who received at least one vaccine dose were, on average, less hesitant than their counterparts living in left-leaning places. However, the data used in this study does not allow for testing this hypothesis, which highlights the need for further research on the subject.

It is noteworthy that the dummies representing the supplier of the first dose presented the second (Sinovac, 0.636) and third (Pfizer, -0.591) most relevant coefficients in table 3.4. In regards to the population with comorbidities, the Chinese supplier was once again the second-highest predictor (0.697), while the North American drug company displayed a negligible coefficient (0.074). It could be explained in part by Gramacho et al. (2021) findings that the public discourses casting doubts on the Chinese supplier reduced public trust in the vaccine. However, a more practical reason may be linked to the fact that it was primarily applied to the elderly and health professionals, which may also correlate to a higher number of doses. Once again, the data and empirical strategy do not allow for these hypotheses to be ultimately tested.

Pertaining to the second type of hesitancy, the postponement of second and booster shots, the results are less clear. Coefficient values in models (2) and (7) suggest that the interval between doses 1 and 2 is determined mostly by the supplier of the doses. Models (4) and (9) indicate that this relation is not as strong regarding second and third doses, although it is also observed. This conclusion is supported by the comparison concerning the coefficients of determination of the aforementioned models with specifications (3), (5), (8), and (10). Since most of the interval between shots is determined by the vaccine supplier, the results showing that those vaccines with shorter intervals were highly negatively correlated to the number of days allow for such a statement. Additionally, that would be in accordance with the findings of Calvo e Ventura (2021), proposing that Brazil perceives lower hesitancy than most of the developed countries.

Nonetheless, analyzing the variables' coefficients gives even stronger support for this claim. None of the explanatory variables presented a consistent coefficient among the eight models tested. Some of the results were reversed from doses 1 to 2 when compared to the interval between 2 and 3. It is the case for the ideology proxy, which presented a positive correlation among the four specifications pertaining to the first two doses and negative regarding the four models that evaluated hesitancy in getting the third shot. It can suggest that some of the people who delayed the second shot did not take the third dose, representing another self-selection bias in the data. Table 3.4 shows that models (2) and (3) evaluated 11,733,790 observations while (4) and (5) considered only 3,098,474 individuals. In that sense, there is a reasonable chance that the eight million people who did not accept the third dose were mostly constituted by those who needed a longer interval to accept the second dose. Once again, these questions may inform future studies aiming to investigate more thoroughly the implications of these results.

In general, the model can be considered as supported by the evidence, considering that the effort made by the press and local authorities supposedly made the general population confident in the vaccines. However, further investigations can be performed to evaluate other aspects of vaccine hesitancy. The next section will conclude presenting the main results of this study, as well as the implications for future works.

3.5 CONCLUDING REMARKS

This study aimed to investigate the factors influencing vaccine refusal and the interval between doses in Brazil regarding vaccination against COVID-19. The findings suggest that age, skin color, income, gender, and political ideology are correlated with the number of vaccine shots received. Moreover, the interval between doses is mainly determined by the vaccine supplier, indicating that a reasonable portion of the Brazilian population complied with health authorities concerning COVID-19 vaccination.

These results have important implications for public health policies and interventions aimed at addressing vaccine hesitancy. As highlighted by Rutten et al. (2021), hesitancy threatens the success of vaccination programs, particularly in the context of the COVID-19 pandemic. Therefore, it is critical to implement multilevel, evidence-based strategies to address vaccine hesitancy and increase vaccine uptake. At the policy and community level, efforts must focus on ensuring equitable access to vaccines, providing accurate information on vaccine safety and efficacy, and addressing misinformation and distrust (ISLAM et al., 2021). At the healthcare system level, interpersonal, individual-level, and organizational interventions can play a crucial role in addressing vaccine hesitancy and promoting vaccine uptake (BELLANTI, 2021).

However, the limitations of this study, such as the potential for self-selection bias and the scope of the data, call for further research to better understand the complexities of vaccine hesitancy. In particular, future studies should explore different levels of analysis, such as city-level data, to provide a more comprehensive understanding of the factors influencing vaccine hesitancy and immunization coverage. This approach can complement the findings of the current study and contribute to a more nuanced understanding of the interplay between individual and community-level factors in shaping vaccine-related behaviors.

Overall, this study provides insights into the factors contributing to vaccine hesitancy in Brazil and emphasizes the importance of trustworthy information and public knowledge in promoting vaccine uptake and protecting public health. Continued research and evidence-based interventions are vital to address this critical issue, especially in developing countries.

3.6 APPENDIX

This section presents the appendix to chapter 2.

3.6.1 Descriptive Statistics

Table 3.6 – Descriptive statistics of variables - regions

	Observations	Missing values	Mean	St. Dev.	Min	Max
Region: South						
Nbr. doses	3,674,829	0	2.17	0.62	1	4
Diff. dose1-dose2	3,170,890	503,939	68.70	32.37	1	477
Diff. dose2-dose3	940,181	2,734,648	173.28	38.53	1	337
Age	3,674,829	0	43.46	18.71	0	129
Avg. Income	3,218,122	456,707	3,660.20	1832.25	1277.48	13229.38
Vote diff. PSL-PT	3,053,702	621,127	0.02	0.08	-0.20	0.25
Region: Northeast						
Nbr. doses	2,773,588	0	1.94	0.63	1	4
Diff. dose1-dose2	2,064,380	709,208	70.89	78.84	1	30445
Diff. dose2-dose3	365,381	2,408,207	181.75	41.53	1	344
Age	2,773,588	0	42.51	18.32	-16	170
Avg. Income	2,354,895	418,693	2,534.85	1962.08	567.34	9481.84
Vote diff. PSL-PT	2,003,752	769,836	-0.02	0.08	-0.35	0.29
Region: Center-West						
Nbr. doses	1,617,560	0	2.09	0.65	1	4
Diff. dose1-dose2	1,285,143	332,417	67.83	33.77	1	8435
Diff. dose2-dose3	337,553	1,280,007	158.68	40.03	1.00	354
Age	1,617,560	0	40.97	17.78	0	129
Avg. Income	1,094,578	522,982	2,905.85	1740.44	1026.72	11329.68
Vote diff. PSL-PT	1,223,440	394,120	0.08	0.05	-0.04	0.21
Region: North						
Nbr. doses	2,337,468	0	1.87	0.59	1	4
Diff. dose1-dose2	1,727,204	610,264	73.20	30.69	1	465
Diff. dose2-dose3	223,868	2,113,600	189.20	40.35	1.00	336
Age	2,337,468	0	37.71	17.14	0	221
Avg. Income	1,766,712	570,756	2,484.75	1388.11	571.02	17281.59
Vote diff. PSL-PT	1,627,698	709,770	-0.02	0.06	-0.21	0.50
Region: Southeast						
Nbr. doses	7,523,521	0	2.13	0.64	1	4
Diff. dose1-dose2	6,247,172	1,276,349	72.01	33.43	1	563
Diff. dose2-dose3	1,805,325	5,718,196	156.61	40.48	1	351
Age	7,523,521	0	43.61	19.07	0	170
Avg. Income	7,191,484	332,037	3,122.81	2181.37	766.00	18553.01
Vote diff. PSL-PT	7,137,765	385,756	0.17	0.07	-0.14	0.56

Notes: (*i*) Doses, interval between doses, and age refers to the average value among individuals who took at least one dose of a COVID-19 vaccine. (*ii*) Difference between doses displays the average number of days. (*iii*) Income and voting results refer to the average value in the neighborhood where each individual who took vaccine lives.
Source: author's preparation.

Table 3.7 – Descriptive statistics - Supplier of dose 3

variable	Observations	Missing	Mean	SD	Min	Max
Dose 3: Astrazeneca						
Nbr. doses	214070	0	3.08	0.28	3	4
Diff. dose1-dose2	199525	14545	70.34	35.25	1.00	11443.00
Diff. dose2-dose3	187547	26523	136.25	41.32	1.00	351.00
Age	214070	0	48.50	13.63	0	123
Avg. Income	181707	32363	3,118.86	1995.99	567.34	18553.01
Vote diff. PSL-PT	191328	22742	0.13	0.09	-0.35	0.50
Dose 3: Janssen						
Nbr. doses	22030	0	3.01	0.11	3	4
Diff. dose1-dose2	21805	225	71.34	27.25	1.00	477.00
Diff. dose2-dose3	21746	284	148.84	40.81	1.00	333.00
Age	22030	0	44.61	11.94	13	108
Avg. Income	20513	1517	3,365.55	2264.79	766.00	18553.01
Vote diff. PSL-PT	20652	1378	0.15	0.08	-0.34	0.36
Dose 3: Coronavac/Sinovac						
Nbr. doses	73071	0	3.32	0.47	3	4
Diff. dose1-dose2	56769	16302	35.49	27.44	1.00	402.00
Diff. dose2-dose3	50895	22176	106.47	77.66	1.00	336.00
Age	73071	0	55.95	21.47	1	122
Avg. Income	66443	6628	3,224.72	1896.72	567.34	18553.01
Vote diff. PSL-PT	64084	8987	0.10	0.10	-0.35	0.36
Dose 3: Pfizer						
Nbr. doses	3426985	0	3.00	0.07	3	4
Diff. dose1-dose2	3410402	16583	53.06	38.61	1.00	30019.00
Diff. dose2-dose3	3412120	14865	168.16	39.39	1.00	354.00
Age	3426985	0	60.13	16.15	0	170
Avg. Income	3075721	351264	3,599.57	2316.38	567.34	18553.01
Vote diff. PSL-PT	3002670	424315	0.10	0.10	-0.35	0.56
Refused dose 3						
Nbr. doses	14190810	0	1.82	0.46	1	3
Diff. dose1-dose2	10806288	3384522	76.72	42.32	1.00	30445.00
Diff. dose2-dose3	0	14190810				
Age	14190810	0	37.96	16.51	-16	221
Avg. Income	12281407	1909403	2,919.46	1904.44	567.34	18553.01
Vote diff. PSL-PT	11767623	2423187	0.08	0.11	-0.35	0.56

Notes: (*i*) Doses, interval between doses, and age refers to the average value among individuals who took at least one dose of a COVID-19 vaccine. (*ii*) Difference between doses displays the average number of days. (*iii*) Income and voting results refer to the average value in the neighborhood where each individual who took vaccine lives.
Source: author's preparation.

3.6.2 Full Results

Table 3.8 – Results - Health Professionals

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		85.024***	72.175***	146.361***	166.382***
		(0.492)	(0.456)	(0.399)	(0.441)
Dose1 Pfizer	-0.750***	9.964***		-14.004***	
	(0.030)	(1.210)		(1.403)	
Dose1 Sinovac	0.830***	-52.230***		49.483***	
	(0.019)	(0.764)		(0.480)	
Black	0.176***	-0.250	1.005	4.347***	-1.709
	(0.042)	(1.676)	(1.722)	(1.246)	(1.601)
Brown	-0.046**	-0.622	-1.471*	1.709***	1.857**
	(0.019)	(0.771)	(0.791)	(0.629)	(0.809)
White	0.400***	-2.377***	-1.913**	5.570***	1.790***
	(0.019)	(0.760)	(0.781)	(0.539)	(0.692)
Female	0.312***	-0.000	0.895	0.398	-0.176
	(0.021)	(0.828)	(0.850)	(0.570)	(0.734)
Age	0.743***	-5.861***	-16.064***	4.427***	14.974***
	(0.014)	(0.552)	(0.545)	(0.457)	(0.574)
Avg. Income	0.189***	-0.239	0.068	-0.913***	-1.132***
	(0.008)	(0.337)	(0.346)	(0.236)	(0.303)
Vote diff. PSL-PT	-0.042***	0.982***	2.038***	-1.369***	-1.888***
	(0.007)	(0.291)	(0.297)	(0.230)	(0.295)
Observations	97,187	90,212	90,212	16,929	16,929
Adjusted R^2		0.061	0.010	0.421	0.040
Residual Std. Error	1.000	89.821	92.246	29.442	37.892

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.9 – Results - Security Forces

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		97.213***	60.164***	136.623***	164.628***
		(0.198)	(0.214)	(0.163)	(0.164)
Dose1 Pfizer	-3.119***	-13.407***		-44.024***	
	(0.014)	(0.392)		(0.719)	
Dose1 Sinovac	0.944***	-53.743***		28.968***	
	(0.004)	(0.080)		(0.065)	
Black	0.090***	1.438***	-1.424***	-2.742***	-1.815***
	(0.008)	(0.145)	(0.166)	(0.104)	(0.114)
Brown	0.084***	0.287***	2.659***	-1.015***	-2.325***
	(0.005)	(0.084)	(0.096)	(0.062)	(0.068)
White	0.268***	-0.523***	-2.743***	-1.296***	-0.516***
	(0.004)	(0.074)	(0.084)	(0.052)	(0.057)
Female	0.048***	0.282***	-0.192***	0.314***	0.532***
	(0.004)	(0.063)	(0.072)	(0.045)	(0.049)
Age	0.349***	-5.056***	-8.577***	11.941***	9.694***
	(0.006)	(0.119)	(0.135)	(0.094)	(0.103)
Avg. Income	0.230***	-1.603***	-1.897***	-0.893***	-0.880***
	(0.002)	(0.029)	(0.033)	(0.020)	(0.022)
Vote diff. PSL-PT	0.171***	0.563***	-2.854***	-7.191***	-5.923***
	(0.002)	(0.032)	(0.036)	(0.023)	(0.026)
Observations	1,540,956	1,465,049	1,465,049	1,028,787	1,028,787
Adjusted R^2	0.075	0.246	0.013	0.219	0.061
Residual Std. Error	1.000	37.308	42.705	22.332	24.487

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.10 – Results - North

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		82.003***	69.662***	167.782***	191.434***
		(0.073)	(0.093)	(0.326)	(0.339)
Dose1 Pfizer	-0.736***	-1.411***		-76.499***	
	(0.004)	(0.055)		(0.801)	
Dose1 Sinovac	0.862***	-49.344***		37.176***	
	(0.005)	(0.053)		(0.199)	
Black	-0.211***	0.526***	-0.299	-1.710**	-0.520
	(0.016)	(0.193)	(0.260)	(0.793)	(0.919)
Brown	0.015***	0.409***	-0.032	0.068	0.709***
	(0.004)	(0.045)	(0.060)	(0.189)	(0.219)
White	0.280***	-0.244***	-1.121***	1.699***	2.157***
	(0.007)	(0.077)	(0.104)	(0.297)	(0.344)
Female	0.197***	-0.237***	-0.862***	3.657***	4.196***
	(0.004)	(0.042)	(0.056)	(0.176)	(0.204)
Age	0.836***	0.875***	-1.488***	4.191***	-3.604***
	(0.002)	(0.026)	(0.031)	(0.113)	(0.115)
Avg. Income	0.063***	1.051***	0.320***	-2.846***	-0.473**
	(0.004)	(0.051)	(0.069)	(0.196)	(0.226)
Vote diff. PSL-PT	0.226***	-3.226***	-4.104***	5.419***	2.676***
	(0.006)	(0.067)	(0.090)	(0.279)	(0.322)
Observations	1,558,449	1,196,017	1,196,017	159,578	159,578
Adjusted R^2	0.139	0.451	0.007	0.262	0.010
Residual Std. Error	1.000	22.644	30.467	34.433	39.865

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.11 – Results - Northeast

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		87.345***	70.908***	145.852***	175.338***
		(0.095)	(0.094)	(0.195)	(0.214)
Dose1 Pfizer	-0.516***	-3.656***		-46.680***	
	(0.004)	(0.099)		(0.450)	
Dose1 Sinovac	0.914***	-51.607***		50.113***	
	(0.004)	(0.085)		(0.140)	
Black	-0.282***	3.809***	2.507***	0.618*	0.570
	(0.008)	(0.190)	(0.215)	(0.364)	(0.460)
Brown	-0.134***	1.551***	1.037***	-0.732***	-0.126
	(0.004)	(0.085)	(0.095)	(0.152)	(0.192)
White	0.071***	0.876***	0.140	0.789***	1.506***
	(0.005)	(0.117)	(0.132)	(0.190)	(0.240)
Female	0.166***	0.229***	-0.193**	4.501***	6.421***
	(0.003)	(0.074)	(0.083)	(0.131)	(0.165)
Age	0.839***	2.078***	-2.108***	0.296***	4.567***
	(0.002)	(0.042)	(0.042)	(0.072)	(0.089)
Avg. Income	0.217***	-1.438***	-1.547***	-0.412***	-0.962***
	(0.002)	(0.038)	(0.043)	(0.057)	(0.072)
Vote diff. PSL-PT	0.186***	1.322***	1.493***	1.047***	2.657***
	(0.002)	(0.054)	(0.060)	(0.097)	(0.122)
Observations	1,944,042	1,485,483	1,485,483	267,519	267,519
Adjusted R^2	0.157	0.219	0.003	0.386	0.018
Residual Std. Error	1.000	44.237	49.966	32.422	41.004

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.12 – Results - Center-West

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		83.566***	67.943***	147.321***	156.579***
		(0.062)	(0.070)	(0.205)	(0.211)
Dose1 Pfizer	-0.738***	-8.112***		-19.242***	
	(0.006)	(0.064)		(0.285)	
Dose1 Sinovac	0.392***	-46.962***		34.144***	
	(0.006)	(0.062)		(0.172)	
Black	-0.066***	0.351***	-0.318*	-1.432***	-1.418***
	(0.011)	(0.125)	(0.167)	(0.400)	(0.449)
Brown	-0.015***	-0.113*	-0.862***	-2.135***	-2.247***
	(0.005)	(0.065)	(0.087)	(0.217)	(0.243)
White	0.294***	-1.996***	-3.234***	-4.022***	-3.976***
	(0.005)	(0.063)	(0.085)	(0.192)	(0.216)
Female	0.246***	-0.732***	-1.013***	4.306***	5.389***
	(0.004)	(0.051)	(0.067)	(0.156)	(0.175)
Age	0.810***	2.143***	-2.368***	-2.145***	6.534***
	(0.003)	(0.029)	(0.035)	(0.092)	(0.094)
Avg. Income	0.014***	0.817***	1.037***	3.731***	4.094***
	(0.003)	(0.033)	(0.044)	(0.091)	(0.102)
Vote diff. PSL-PT	0.858***	-9.415***	-11.316***	-16.951***	-18.346***
	(0.006)	(0.064)	(0.085)	(0.185)	(0.207)
Observations	942,045	774,800	774,800	208,399	208,399
Adjusted R^2	0.157	0.463	0.041	0.263	0.069
Residual Std. Error	1.000	22.050	29.460	34.825	39.128

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.13 – Results - Southeast

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		87.016***	71.527***	130.219***	144.779***
		(0.024)	(0.030)	(0.069)	(0.079)
Dose1 Pfizer	-0.626***	-3.623***		-10.895***	
	(0.002)	(0.025)		(0.107)	
Dose1 Sinovac	0.497***	-52.169***		47.407***	
	(0.002)	(0.023)		(0.052)	
Black	0.094***	0.956***	-0.072	-0.842***	-2.604***
	(0.003)	(0.040)	(0.056)	(0.103)	(0.128)
Brown	0.145***	0.289***	-0.145***	-2.306***	-4.540***
	(0.002)	(0.024)	(0.033)	(0.064)	(0.079)
White	0.254***	-0.559***	-1.525***	-0.637***	-1.062***
	(0.002)	(0.024)	(0.034)	(0.061)	(0.075)
Female	0.180***	0.368***	-0.090***	4.414***	5.762***
	(0.002)	(0.019)	(0.027)	(0.050)	(0.061)
Age	0.948***	1.544***	-4.450***	0.916***	10.482***
	(0.001)	(0.011)	(0.013)	(0.031)	(0.036)
Avg. Income	0.165***	-1.138***	-1.031***	0.284***	-0.017
	(0.001)	(0.009)	(0.012)	(0.021)	(0.025)
Vote diff. PSL-PT	-0.034***	1.102***	1.469***	0.287***	-0.399***
	(0.001)	(0.015)	(0.021)	(0.040)	(0.049)
Observations	6,938,757	5,881,671	5,881,671	1,714,620	1,714,620
R^2	0.168	0.507	0.023	0.383	0.057
Adjusted R^2		0.507	0.023	0.383	0.057
Residual Std. Error	1.000	22.748	32.030	31.735	39.239

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

Table 3.14 – Results - South

Dependent variable:	Nbr. doses	Diff. dose1-dose2		Diff. dose2-dose3	
	(1)	(2)	(3)	(4)	(5)
const		85.871***	69.939***	144.744***	153.967***
		(0.036)	(0.043)	(0.095)	(0.107)
Dose1 Pfizer	-0.531***	-11.466***		-13.383***	
	(0.004)	(0.036)		(0.125)	
Dose1 Sinovac	0.804***	-52.725***		42.144***	
	(0.003)	(0.035)		(0.075)	
Black	-0.261***	2.888***	1.533***	4.312***	6.264***
	(0.007)	(0.072)	(0.101)	(0.187)	(0.230)
Brown	-0.375***	2.541***	0.844***	2.042***	4.089***
	(0.007)	(0.077)	(0.108)	(0.216)	(0.266)
White	-0.105***	1.092***	-0.527***	1.050***	3.162***
	(0.003)	(0.031)	(0.044)	(0.075)	(0.093)
Female	0.284***	-0.530***	-1.614***	4.385***	6.130***
	(0.003)	(0.028)	(0.040)	(0.071)	(0.087)
Age	0.953***	1.657***	-3.162***	3.007***	11.362***
	(0.002)	(0.016)	(0.020)	(0.041)	(0.048)
Avg. Income	0.185***	-1.280***	-1.774***	0.482***	0.959***
	(0.002)	(0.017)	(0.024)	(0.039)	(0.048)
Vote diff. PSL-PT	0.010***	0.252***	0.873***	-2.833***	-5.172***
	(0.002)	(0.022)	(0.030)	(0.053)	(0.066)
Observations	2,714,418	2,395,819	2,395,819	748,358	748,358
R^2		0.504	0.016	0.399	0.084
Adjusted R^2	0.186	0.504	0.016	0.399	0.084
Residual Std. Error	1.000	21.620	30.441	29.621	36.546

Notes: *i.* Model (1) was estimated via ordered logit; models (2) to (5) via OLS. *ii.* Janssen (single shot) as first dose counted as two doses in model (1), and was excluded in models (2) to (5). *iii.* Difference between doses was measured in days. *iv.* Significance markers: $^{*} = p < 0.1$; $^{**} = p < 0.05$; $^{***} = p < 0.01$. *v.* Standard deviation in parenthesis. *vi.* Pertaining to model (1), table shows pseudo R^2.
Source: author's preparation.

4 THE BALLOT AND THE NEEDLE: INVESTIGATING CORRELATIONS BETWEEN VOTING PATTERNS AND COVID-19 VACCINATION IN BRAZIL

The current chapter examines the relationship between city-level voting patterns and vaccination rates in Brazil, suggesting that voting patterns and political views play a significant role in vaccination decisions. The findings provide important insights into the complexities and heterogeneity of the COVID-19 pandemic in Brazil and have implications for the development of evidence based public health policies and interventions aimed at addressing vaccine hesitancy and other challenges imposed by health crises.

Key-words: COVID-19, health economics, vaccine hesitancy, Brazil.

4.1 INTRODUCTION

The COVID-19 pandemic has highlighted the critical importance of vaccines in safeguarding public health and mitigating the socio-economic impacts of infectious diseases. Vaccines have been shown to significantly reduce morbidity and mortality rates (JUNAIDI et al., 2022), prevent further economic downturns (HOTEZ, 2020), and lower healthcare costs associated with managing COVID-19 (HAGENS et al., 2021). Furthermore, vaccination efforts contribute to achieving sustainable development goals related to poverty, good health, well-being, and reduced inequality (ALAM et al., 2021). Vaccines are often more effective, cost-efficient, and have fewer side effects than other public health interventions (DAS, 1999; SHEPARD et al., 2004; SICILIANI et al., 2020). Epidemiological evidence also supports the positive impact of robust vaccination programs on reducing COVID-19 mortality and improving outcomes in affected regions (ESCOBAR; MOLINA-CRUZ; BARILLAS-MURY, 2020; MARÍN-HERNÁNDEZ; SCHWARTZ; NIXON, 2021).

Despite these benefits, vaccine uptake has declined in various regions, particularly in the developed world (DUBÉ et al., 2013), with the COVID-19 pandemic exacerbating this trend (SALLAM, 2021). Vaccine hesitancy can be attributed to a myriad of factors, including psychological, cultural, and political variables (DUBÉ et al., 2013; MAGUIRE et al., 2022; MOSCARDINO et al., 2022). Misinformation, a likely factor connecting vaccine hesitancy with political preferences, has proliferated during the COVID-19 pandemic (AL-ZAMAN, 2022; LINDEN, 2022; ZOMPETTI; SEVERINO; DELORTO, 2022). Furthermore, questioning scientific expertise has increasingly become part of political rhetoric in recent years (WOLTERS; STEEL, 2017).

In Brazil, researchers have observed a similar phenomenon. Al-Zaman (2022) analyzed online misinformation from 138 countries, identifying India, the United States, Brazil, and Spain as the most affected by misinformation related to vaccine effectiveness and risks. In Brazil, misinformation was particularly focused on CoronaVac, the first vaccine administered in the country (OLIVEIRA et al., 2022). While pre-pandemic surveys indicated that vaccine hesitancy in Brazil was mainly driven by lack of confidence, convenience, and complacency (BROWN et al., 2018), recent studies have found evidence linking political partisanship to vaccine acceptance during the COVID-19 pandemic (BAGATELI et al., 2021; GRAMACHO et al., 2021; GRAMACHO; TURGEON, 2021; PASCHOALOTTO et al., 2021). Despite these challenges, Brazil has maintained a relatively high level of vaccine acceptance compared to developed countries (MOORE et al., 2021).

Considering the novelty and relevance of the subject, along with the wealth of reliable public data available in Brazil, this study aims to investigate the correlations between voting patterns, vaccine uptake, and immunization coverage across Brazil's 5,570 cities. The analysis will also extend to other vaccines, such as those for Polio and BCG, to provide a broader context for understanding the relationship between political preferences and vaccination behavior.

4.1.1 Outline

The study begins with a thorough literature review, followed by a presentation of the collected data, empirical strategy, and relevant hypotheses. The main statistical findings will be discussed in light of the existing literature and the potential limitations of the empirical strategy and database. Finally, concluding remarks will be provided, outlining directions for future research on this critical issue.

4.1.2 Literature Review

The current section presents relevant studies linking political preferences and vaccine acceptance, both worldwide and related to Brazil. But, first, let us introduce a psychological and sociological hypothesis that may help characterize the mechanisms through which this relationship happen.

Social identity theory formulates concepts that intend to characterize how people form identities based on their group membership, including political parties, and how this affects their attitudes and behaviors (GREENE, 2004). This is especially relevant in economics as it can explain how people make decisions based on their group identity, which also involves the categorization and consequently antagonistic behavior of forming "in-group"and "out-group"beliefs and expected actions (CHARNESS; RIGOTTI; RUSTICHINI, 2007). As compared to isolated individuals, people who identify with a group demonstrate distinct behaviors and preferences over outcomes.

In this regard, the study Charness, Rigotti e Rustichini (2007) has shown that group membership affects the saliency of the environment and preferences over outcomes. In order to manipulate group salience in their study, the researchers used two methods. First, they involved a player's own group as a passive audience during decision-making. Second, they made part of the payoff common for members of the group. These strategic environments differed from the minimal-group paradigm and the researchers found that minimal groups alone did not affect behavior. However, they observed that group membership salience had a significant impact on behavior in their study. Specifically, the saliency of group increased the aggressive stance of hosts and tended to reduce the aggressive stance of guests. They concluded that group membership salience presents a strong influence on decision-making in strategic environments.

Following these ideas, Zhai e Yan (2022) argue that the perceived uncertainty and outside threats posed by the COVID-19 virus and the pending COVID-19 vaccine have the potential to affect different groups of the population disproportionately.[1] Aiming to test such hypotheses, a large number of recent studies investigate how different social groups reacted to COVID-19, especially regarding to vaccine acceptance. Arguably the most studied case has been the United States. Samore et al. (2021) found that social conservatism positively associates with COVID-19 precautions among US Democrats but not Republicans, highlighting the strong correlation between political partisanship and behavior in the country. Conservatives, who generally have a greater tendency to support stability and the status quo, were thought to be the group most uneasy with major disruptions such as the pandemics, but it did not hold for Republicans.

Prior to the pandemics, Baumgaertner, Carlisle e Justwan (2018) found that ideology had two mechanisms to affect vaccination attitudes in the US. A direct route would be through ideological prescriptions, while an indirect would be through trust. Once one's ideology impacts who they trust, information can be catered in order to selectively alter the risk-beneficit perception. That poses a challenge for health and science institutions to be able to reach individuals with biased knowledge pertaining to vaccines and its real risks. Nonetheless, Mesch e Schwirian (2015) performed an empirical investigation based on the H1N1 influenza vaccine and concluded that the main factors shaping the decision to accept an immunization was related to confidence in health institutions and the perceived risk of the disease.

Recent studies have reported factors associated with COVID-19 vaccine hesitancy and demonstrated significant differences in vaccine-related behaviors among different groups of individuals. Viswanath et al. (2021) study observed that Republicans who relied in conservatives news outlets were less likely to vaccinate themselves or their children. Gadarian, Goodman e Pepinsky (2021) found strong evidence that partisan

[1] This proposition is in general accordance with the theoretical framework related to chapter 2.

differences in behavior toward COVID-19 were substantively larger than those associated with salient differences in education and income. In addition to those who identified as Republicans, Khubchandani et al. (2021) also estimated a higher prevalence of vaccine hesitancy among African-Americans, Hispanics, those with children at home, individuals with lower education and incomes, rural dweller, and people in the northeastern US.

Study by Weisel (2021) found that group membership did not have a significant impact on vaccine acceptance, despite the perception of vaccines as a social contract and even when the groups are extremely opposed on numerous issues. An experiment was conducted where participants were asked to indicate their willingness to be vaccinated against COVID-19 if a Food and Drug Administration-approved vaccine was available at no cost. Additionally, they were asked to position themselves on a Democrat-Republican scale and complete a social value orientation measure. The measure was administered five times, with the first time serving as a baseline without information about the other person. The remaining four times, participants were presented with another person who either agreed or did not agree to be vaccinated and who supported the Democratic or Republican party, thus creating a contextual orientation. This approach allowed the researchers to examine the impact of social and political context on participants' willingness to be vaccinated.

Arguably the most robust evidence of impact of in-groups and out-groups on the intention to vaccinate against COVID-19 in the US come from the experimental study performed by Pink et al. (2021). Participants (N = 1480) were randomly assigned to either a treatment group or a neutral control group and received the same information about the importance of vaccination for public health and economic concerns. However, the perceived source of information differed among the treatment groups. One group was shown a video of Joe Biden motivating vaccine uptake, while the other was shown a video of Donald Trump doing the same. The participants' intention to vaccinate was measured before and after exposure to the message, and the results demonstrated a statistically significant effect of political identity on vaccine uptake. Participants were more likely to comply with the message when the information came from the leader of their preferred political party.

A theoretical framework intended to estimate the consequences of these evidences was proposed by Allcott et al. (2020). Through a simple model of pandemic response with heterogeneous agents and as empirical test using mobile phone data, the authors proposed that society ends up with more disease transmission at higher economic cost than if people had the same beliefs. They noted that the raw partisan differences partly reflect the fact that Democrats are more likely to live in the dense, urban areas hardest hit by the crisis. However, even after controlling carefully for such factors, the partisan gaps remain statistically and economically significant.

Other Western nations face similar challenges, also starting from before the COVID-19 pandemics. Using national level data, Kennedy (2019) examined the link between political populism and vaccine hesitancy in Western Europe. The author concluded that the support for both movements is driven by distrust in elites and experts, which in turn may be caused by political disenfranchisement and economic marginalisation of large parts of population. The politicization of COVID-19 vaccines started before the shots were available in France (WARD et al., 2020). A survey conducted in European nations while the first COVID-19 vaccines were being developed indicated the magnitude of the phenomenon, showing that as little as 47 % of participants in France and Hungary manifested vaccine acceptance (LINDHOLT et al., 2021).

A series of studies in other countries show that outer-wing supporters, especially far-right partisans, tend to sport higher levels of vaccine reluctance pertaining to COVID-19 immunization. Using panel data, Serrano-Alarcon et al. (2022) concluded that far-right politicians can encourage vaccine hesitancy. Similar results were obtained in Italy (ZOMPETTI; SEVERINO; DELORTO, 2022), New Zealand (WINTER et al., 2022), Norway (WOLLEBÆK et al., 2022), Serbia (ĐORđEVIĆ et al., 2021).

Finally, from a universe of 8,864 studies, a systematic review conducted by Zhao et al. (2023) evaluated 91 observational studies and 11 interventional studies that met the inclusion criteria. The review found that misinformation about COVID-19 vaccines covered a range of topics, including conspiracy theories, concerns about vaccine safety and efficacy, beliefs that vaccines are not needed, morality, liberty, and humor. Belief in misinformation was more prevalent among individuals who were younger, had lower levels of education and economic status, held right-wing and conservative political views, and had psychological problems. The content, format, and source of misinformation influenced its spread. To address vaccine-related misinformation, a 5-step framework was proposed, which included identifying misinformation, regulating producers and distributors, cutting production and distribution, supporting target audiences, and disseminating trustworthy information. The review found that debunking messages/videos were effective in several experimental studies.

These findings suggest that the impact of the pandemic may be experienced differently across various ideological groups, highlighting the importance of understanding the social factors that shape individuals' responses to major crises, as was the case with the COVID-19 global pandemics.

In developing countries, Brazil being one of them, other challenges are observed. (FONSECA; SHADLEN; BASTOS, 2021) illustrate the circumstances focusing on procurement and production, regulation of marketing registration, and distribution and uptake. They propose that pandemic preparedness and response must include sharing knowledge of how to produce vaccines and recognition of the crucial linkages between procurement, regulation, delivery, and uptake that are necessary for ensuring access to these products.

Regarding hesitancy, as already mentioned, surveys show that Brazilian population displays high levels of vaccine acceptance, including pertaining to immunization against COVID-19 (GRAMACHO; TURGEON, 2021; MOORE et al., 2021). Nonetheless, the country is a relevant study case for different factors. Firstly, Brazil had a highly regarded public vaccination program before the pandemics (BERNARDEAU-SERRA et al., 2021), which implies that there existed a reasonable knowledge about vaccines in the general population. Secondly, the government response was incoherent. Then-President Jair Bolsonaro undermined the importance of vaccines against COVID-19 (LOTTA et al., 2022) and non-pharmaceutical interventions (AJZENMAN; CAVALCANTI; MATA, 2020), while the federal government provided vaccines for the entire population and governors and mayors enforced strict measures of social distancing and mask-wearing (LANCET, 2020). Finally, the country makes available the full data on vaccines applied, which contains individual information and allows for the combination with other public data sets in order to investigate the determinants of vaccine acceptance in Brazil.

Also, it must be highlighted that most studies connecting vaccine hesitancy to political preferences, as presented in this section, is comprised of surveys. Therefore, the empirical investigation introduced in the next chapters intend to provide new and relevant evidences from a particularly important case study in the subject.

4.2 EMPIRICAL STRATEGY

This section displays the data collection and empirical analyses.

4.2.1 Data Description

This study used publicly available data from various sources to examine the relationship between vaccination rates and political affiliation in Brazil. The data was collected at the municipal level, as Brazil is comprised of 5,570 municipalities. Several city-level control variables were included aiming to isolate the correlation between both phenomena

Vaccination data was provided by the Health Ministry and included information on every shot administered in Brazil. The data was utilized to construct two dependent variables: vaccines received, which were identified based on the city of residence for each patient, and vaccines applied, which were determined based on the location where the doses were administered, such as health facilities, vaccination centers, or other medical institutions. In addition, municipal-level data on the coverage of general vaccination and polio shots was collected to further test the hypothesis that the COVID-19 vaccination became specifically politicized.

Considering the high level of political polarization in the country, it is safe to assume that a portion of Bolsonaro's voters are not ideologically aligned with the Brazilian former President, but instead chose to reject the left-wing challenger Lula da Silva. One possible strategy to measure the actual ideological base is to use the votes for congresspeople, which tend to better reflect ideology. However, since we are evaluating municipality voting shares, we have to accommodate the fact that there are several cities where no candidate running for the parties of the two main candidates received votes. Consequently, using such variables would introduce undesired noise in the estimations. To address this issue, we used the voting share for the presidential election as a proxy for ideology in the current study.

Election results were collected from the Superior Electoral Court (TSE) and used to create proxies for political affiliation. First, the correlation between the COVID-19 vaccination coverage and the support for then-President Bolsonaro was evaluated using his share of votes in 2022 general election as proxy. Next, the share of votes that ultraconservative candidate Padre Kelmon and the libertarian party (Partido Novo) received in the 2022 election was used as a proxy for far-right support. As the left-wing elected President Lula da Silva won the majority of the support from the far-left in the last election, while also capturing the votes from Bolsonaro's opposition, municipal level election results for socialist and communist parties in the 2018 general election served as measure for the far-left. These variables were then used to test the hypothesis that voters with different political affiliations would exhibit varying COVID-19 vaccination rates.

Sociodemographic data was collected from the Brazilian statistics bureau (IBGE) and included information on population demographics such as age and skin color, as well as data on income, education level, and religion. The data was used as control variables in the analysis, as socioeconomic factors are known to influence general behavior.

Data cleaning and preparation were conducted to address any missing data, inconsistencies, and outliers in the dataset, resulting in a final sample of 5,507 from the universe of 5,570 cities. Table 4.1 presents the full descriptive statistics, while separate data showing the information regarding separate geographic regions are displayed in the Appendix 4.5.1.

This dataset was used to test the hypotheses of the study using statistical methods commonly used in economics to estimate relationships between variables. The results were interpreted in the context of social identity theory and previous literature on the politicization of vaccines in other developing as well as Western countries. The limitations of the research, such as the generalizability of the findings and potential confounding variables, will be discussed in the remainder of the study.

Table 4.1 – Descriptive statistics

	Count	Mean	St.Dev.	Min	Max
Bolsonaro Share 22	5507	0.439	0.187	0.061	0.890
Far-left 18	5507	0.004	0.002	0.000	0.025
Far-right 22	5507	0.004	0.004	0.000	0.032
Dose1 Applied	5507	0.754	0.176	0.009	3.999
Dose2 Applied	5507	0.620	0.182	0.000	3.256
Dose3 Applied	5507	0.139	0.083	0.000	0.827
Dose1 Received	5507	0.793	0.159	0.179	3.120
Dose2 Received	5507	0.648	0.172	0.085	2.811
Dose3 Received	5507	0.140	0.080	0.004	0.744
Vaccination coverage	5507	76.939	24.189	2.280	245.580
BCG coverage	5507	73.169	36.321	0.000	772.860
Polio coverage	5507	88.714	29.959	0.000	436.360
Elderly(>70yo)	5507	5.543	1.729	0.340	14.380
Rural pop.	5507	35.893	21.889	0.000	95.820
Pop. density	5507	108.420	572.574	0.130	13024.560
White	5507	46.561	24.046	0.670	99.580
Black	5507	6.390	4.948	0.000	55.110
Brown	5507	45.363	21.481	0.270	90.820
Indigenous	5507	0.715	4.341	0.000	88.560
Catholic	5507	0.716	0.174	0.153	3.053
Evangelic	5507	0.033	0.051	0.000	0.681
Pentecostal Evangelic	5507	0.102	0.062	0.000	1.152
Umbanda/Candomble	5507	0.001	0.003	0.000	0.049
No religion	5507	0.048	0.047	0.000	0.503
Education 8y less	5507	77.307	9.571	35.690	99.590
Education 8-10y	5507	11.185	4.511	0.180	28.890
Education 11-14y	5507	8.881	4.715	0.070	28.300
Education 15y plus	5507	1.442	1.555	0.000	19.020
Income (BRL)	5507	1372.155	564.920	370.480	5179.030

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

4.2.2 Predictions

According to the studies displayed in section 4.1.2, the following predictions will be evaluated:

1. city-level voting patterns should be significantly correlated to vaccination rates, specially concerning to immunization against COVID-19, given the high level of politicization regarding the subject;

2. support for then-President Jair Bolsonaro will be negatively correlated to the vaccination rates against COVID-19, given his public stance casting doubts on COVID-19

shots and refusing himself to get a shot. Nonetheless, it is not expected to hold in relation to other vaccines, once conservative ideology in Brazil was not linked to vaccine refusal before the pandemics;

3. voting share for far-right and far-left parties should be negatively correlated to vaccination rates in general, considering that trust in government and public institutions tend to be lower among outer wing supporters;
4. however, far-left city-level voting share is expected to be positively correlated to vaccination rates against COVID-19 shots, once right-wing parties became more associated with vaccine hesitancy during the pandemics.

Next, the statistical method used to test such predictions will be introduced.

4.2.3 Data Analysis

The estimation of the impact of political preferences on vaccination rates across Brazilian cities was performed through ordinary leas squares (OLS) approach given the cross-section nature of the obtained data. Several specifications were designed with the intent of evaluating the hypotheses. The final set of control variables[2] was built intending to avoid omitted variable bias.

The general model possesses the following specification:

$$Y_i = \alpha + \sum_{j=0}^{J} \beta_j x_{i,j} + \epsilon_i, \tag{4.1}$$

where Y_i is the value of the dependent variable in municipality i, $x_{i,j}$ is the observation for city i from each of the J explanatory variables, and ϵ_i is the normally distributed error term with mean equals to zero. The values of interest are represented by β_j, as they indicate the direction and magnitude of the correlation between each explanatory feature and the endogenous variables representing city-level vaccination rates.

The first specification presented the share of voters who supported then-President Jair Bolsonaro in the run-off in 2022 general elections. It intended to capture whether his public response to the crisis correlated with vaccination rates at city-level. The dependent variables were: (1) COVID-19 vaccines applied per capita; (2) COVID-19 vaccines received per capita; (3) COVID-19 booster shots applied per capita; (1) COVID-19 booster shots received per capita; (5) general vaccine coverage; and (6) vaccination rate against poliomyelitis. Full results are displayed in table 4.2.

[2] The covariate matrix is displayed in the Appendix 4.5. When a pair of variables presented high correlation (>0.5), one of them was excluded aiming to avoid multi-collinearity. The decision on which one to keep was subjective and intended to maintain the variables that relate more directly to the hypotheses. However, as voting patterns are usually correlated with income and education levels, some degree of collinearity was expected from the specification of the models.

The second set of models were intended to estimate the relation between outer wing ideologies and vaccination. The far-right municipal level voting share included the 2022 presidential electoral results of ultraconservative and libertarian candidates. The far-left was constituted by the 2018 presidential voting share of communist and socialist parties. The estimations are presented in table 4.3. Models (7) until (12) possess the same endogenous variable as (1) until (6), respectively.

The third and fourth specifications aimed to evaluate geographical heterogeneity. Table 4.4 displays the results based on the same specification as model (1), but with five separate samples representing each of the main geographical regions in Brazil. Table 4.5 follows the same logic regarding model (5).

The main results will be presented and discussed in the following sections. Estimations were performed using Python Statsmodels library robust linear models (SEABOLD; PERKTOLD, 2010), thus controling for possible heteroskedasticity. Durbin-Watson tests showed no autocorrelation in the residuals for every specification. Jarque-Bera tests indicated that the data presented skewness and kurtosis not matching a normal distribution, which does not invalidate the applied method. Full regression summaries are available in the online supplement.[3]

4.2.4 Main Results

Although the statistical specification does not allow for causal inference, it is important to note that most models presented high coefficients of determination (R^2), and the majority of the explanatory variables were statistically significant. This is particularly true when observing the models evaluating COVID-19 shots, with R^2 no lower than 0.378 in model (16). Therefore, it can be inferred that the heterogeneity among city-level vaccination rates, especially regarding immunization against COVID-19, is correlated to the set of variables utilized in the empirical investigation.

Concerning the first prediction, the majority of the results support the hypothesis that vaccination rates are related to voting patterns. However, tables 4.4 and 4.5 suggest that this relation is not homogeneous throughout the entire country, as North, South, and Southeast regions did not present significant coefficients linking city-level voting share for then-President Jair Bolsonaro and vaccination rates.

Table 4.2 indicates that the second prediction is mostly supported by the empirical investigation. A statistically significant negative relationship was observed between electoral support for Bolsonaro and vaccination against COVID-19 (models 1 through 4). It is also noteworthy that the coefficient related to the rate of received vaccines (-0.124) was higher in comparison to the rate of shots applied (-0.098). Conversely, models (5) and (6) show

[3] <https://github.com/hssitja/PhD-Dissertation/blob/Chapter-3/Chapter4_Empirical.ipynb>

that general vaccine coverage (16.215) and vaccination against Polio (12.467) were highly and positively correlated to municipal vote share for the former Brazilian President.

Predictions three and four were not fully supported by the results, as shown in table 4.3. Far-left support was highly and negatively correlated to general (-744.284) and Polio (-800.441) vaccine coverage, as hypothesized. Regarding COVID-19 shots, only model (7) displayed a positive (3.782) but weakly significant coefficient. Hence, the fourth prediction must be rejected.

As for the far-right proxy, it was correctly predicted to be negatively related to vaccination rates against COVID-19 according to models (8, -2.810), (9, -2.240), and (10, -2.167). Nonetheless, the general (659.326) and Polio vaccination (786.031) rates displayed highly positive coefficients. These results, as well as others, will be discussed in more depth in the following section.

4.3 DISCUSSION

First and foremost, it is essential to reiterate that the applied method does not allow for causal inference concerning the estimated results. However, the plausibility of the explanatory power of the observed results is reinforced by the control variables. Although the coefficients of determination relating to the specifications evaluating COVID-19 vaccination rates were consistently high, most of the covariates exhibited low magnitudes. This is expected, as the Brazilian health system provides comprehensive vaccine coverage for the entire population, as indicated in the literature. Consequently, sociodemographic variables do not exert a significant impact on vaccination rates, unlike what is observed in the majority of countries.

A closer examination of models (6), (7), (11), and (12), which pertain to general vaccination and immunization against Polio, reveals the limited influence of household income and population density, typically important predictors for vaccine uptake. The rate of Catholic individuals consistently presents a high and significant relationship with vaccination rates, while the proportion of the population without religion emerges as the most important negative predictor for non-COVID-19 vaccination rates. This observation may be attributed to the average ideologies associated with both groups; the former tends to prioritize fulfilling social duties and helping others, which aligns with the act of getting vaccinated and/or vaccinating their children.

The main findings offer valuable insights that complement existing evidence from other studies. They suggest that then-President Jair Bolsonaro's stance against COVID-19 vaccines played a role in altering the relationship between conservative support and vaccination rates. City-level voting share for the former Brazilian President exhibited a strong positive correlation with general vaccination and immunization against poliomyelitis.

Table 4.2 – Results - vaccination Bolsonaro votes

Dependent variable:	Doses app.	Doses rec.	3rd app.	3rd rec.	Vaxx cvrg.	Polio cvrg.
	(1)	(2)	(3)	(4)	(5)	(6)
Bolsonaro Share 22	-0.098**	-0.124***	-0.028***	-0.020**	16.215***	12.467***
	(0.049)	(0.041)	(0.010)	(0.008)	(3.469)	(4.706)
elderly(>70yo)	0.047***	0.065***	0.018***	0.018***	2.417***	2.860***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.264)	(0.361)
Rural pop.	0.000	-0.001***	0.000***	0.000**	-0.016	-0.015
	(0.000)	(0.000)	(0.000)	(0.000)	(0.021)	(0.026)
Pop. density	-0.000	-0.000	-0.000	-0.000	-0.001**	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
White	-0.023***	-0.020***	-0.001	-0.001	-1.194***	-1.282***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.337)	(0.436)
Black	-0.024***	-0.026***	-0.002**	-0.002**	-1.341***	-1.498***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.357)	(0.460)
Brown	-0.028***	-0.025***	-0.002*	-0.002**	-1.326***	-1.442***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.340)	(0.439)
Indigenous	-0.026***	-0.024***	-0.001	-0.001	-1.471***	-1.705***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.343)	(0.440)
Catholic	1.015***	1.189***	0.086***	0.100***	11.293***	11.695***
	(0.071)	(0.119)	(0.014)	(0.015)	(3.141)	(3.946)
Evangelic	0.599***	0.657***	0.007	0.015	-4.523	-13.108
	(0.109)	(0.148)	(0.028)	(0.027)	(8.022)	(13.051)
Pentecostal Evangelic	1.016***	1.096***	0.122***	0.123***	7.030	5.178
	(0.104)	(0.185)	(0.029)	(0.030)	(6.436)	(8.460)
No religion	1.171***	1.123***	0.112***	0.113***	-55.505***	-44.039***
	(0.142)	(0.169)	(0.027)	(0.025)	(9.692)	(12.508)
Education 11-14y	0.052***	0.007*	0.006***	0.005***	-0.366	-0.552
	(0.006)	(0.004)	(0.001)	(0.001)	(0.312)	(0.395)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.010***	0.008***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.002)
Observations	5,507	5,507	5,507	5,507	5,507	5,507
Adjusted R^2	0.466	0.570	0.449	0.502	0.189	0.122
Residual Std. Error	0.303	0.257	0.062	0.057	21.786	28.066
F Statistic	345.757***	335.626***	262.437***	304.512***	63.345***	36.637***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

However, it demonstrated a consistent negative relationship with COVID-19 vaccination rates, particularly when measured as vaccines received in each municipality, as observed in model (2).

Another important aspect is the fact that his support appear to have shifted from 2018 to 2022. The results obtained through sensitivity tests with the former president's voting share in the 2018 election show a positive correlation 4.12 with total doses of COVID-19 vaccines applied and received (models 23 and 24). This could constitute a study in its own terms, aiming to further investigate this result.

Regarding the results in table 4.3, it is plausible that combining votes for ultra-conservative candidate Padre Kelmon and the libertarian party Novo may not accurately capture far-right support. A significant portion of far-right voters might have cast their

Table 4.3 – Results - vaccination outer-wings

Dependent variable:	Doses app.	Doses rec.	3rd app.	3rd rec.	Vaxx cvrg.	Polio cvrg.
	(7)	(8)	(9)	(10)	(11)	(12)
Far-left 18	3.782*	1.698	-0.166	-0.135	-744.284***	-800.441***
	(2.003)	(1.741)	(0.447)	(0.398)	(135.364)	(172.286)
Far-right 22	-1.270	-2.810**	-2.240***	-2.167***	659.326***	786.031***
	(1.228)	(1.256)	(0.333)	(0.309)	(111.274)	(151.826)
elderly(>70yo)	0.049***	0.066***	0.018***	0.018***	2.123***	2.571***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.261)	(0.356)
Rural pop.	-0.000	-0.001***	0.000***	0.000*	-0.002	0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.021)	(0.026)
Pop. density	-0.000	-0.000	-0.000	0.000	-0.001**	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
White	-0.022***	-0.020***	-0.000	-0.000	-1.322***	-1.420***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.339)	(0.438)
Black	-0.024***	-0.024***	-0.001	-0.002	-1.572***	-1.730***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.360)	(0.463)
Brown	-0.028***	-0.024***	-0.001	-0.001	-1.476***	-1.588***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.341)	(0.440)
Indigenous	-0.026***	-0.023***	-0.000	-0.000	-1.582***	-1.811***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.343)	(0.441)
Catholic	1.028***	1.205***	0.090***	0.103***	9.028***	9.817**
	(0.070)	(0.118)	(0.013)	(0.014)	(3.098)	(3.896)
Evangelic	0.582***	0.634***	0.001	0.010	-1.859	-11.218
	(0.108)	(0.146)	(0.027)	(0.026)	(7.904)	(12.838)
Pentecostal Evangelic	0.967***	1.020***	0.096***	0.102***	16.855***	13.405
	(0.100)	(0.175)	(0.027)	(0.028)	(6.258)	(8.342)
No religion	1.136***	1.081***	0.088***	0.090***	-44.536***	-31.601**
	(0.143)	(0.168)	(0.027)	(0.025)	(9.594)	(12.358)
Education 11-14y	0.051***	0.006	0.006***	0.005***	-0.246	-0.500
	(0.006)	(0.004)	(0.001)	(0.001)	(0.310)	(0.391)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.012***	0.009***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)
Observations	5,507	5,507	5,507	5,507	5,507	5,507
Adjusted R^2	0.466	0.569	0.453	0.507	0.194	0.128
Residual Std. Error	0.303	0.257	0.061	0.056	21.719	27.971
F Statistic	325.764***	313.782***	251.494***	292.564***	62.929***	36.768***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

ballots for then-President Jair Bolsonaro, given that his overall discourse aligns with far-right ideas to some extent. However, using his vote share as a proxy for right-wing support would overlook the fact that a considerable part of his base opposes the left-wing policies of former President Lula da Silva's Workers' Party.

Moreover, ultraconservative candidate Padre Kelmon was relatively unknown, and it is reasonable to assume that part of his electoral support stemmed from the eccentricity of his political character rather than his ideology. Libertarian ideology, in turn, is not inherently linked to vaccine refusal. Instead, it is primarily associated with opposition to government mandates, which may encompass those related to immunization. Consequently,

Table 4.4 – Results by region - COVID-19 vaccination Bolsonaro votes

Dependent variable:	Doses received per capita				
Region:	Center-West	Northeast	North	Southeast	South
	(13)	(14)	(15)	(16)	(17)
Bolsonaro Share 22	-0.638***	-0.398***	-0.140	-0.053	-0.080
	(0.159)	(0.092)	(0.096)	(0.087)	(0.081)
elderly(>70yo)	0.015	0.059***	0.091***	0.056***	0.040***
	(0.012)	(0.007)	(0.014)	(0.006)	(0.006)
Rural pop.	-0.000	-0.001***	0.001*	-0.000	-0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
Pop. density	-0.000***	-0.000***	-0.000**	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
White	-0.027*	-0.013**	0.004	-0.015*	-0.002
	(0.014)	(0.006)	(0.011)	(0.009)	(0.009)
Black	-0.053***	-0.016***	-0.012	-0.025***	0.002
	(0.016)	(0.006)	(0.012)	(0.009)	(0.009)
Brown	-0.034**	-0.020***	-0.007	-0.020**	-0.005
	(0.014)	(0.006)	(0.011)	(0.009)	(0.009)
Indigenous	-0.033**	-0.015***	-0.005	-0.018**	-0.004
	(0.014)	(0.006)	(0.011)	(0.009)	(0.009)
Catholic	1.409***	1.525***	0.907***	1.114***	1.409***
	(0.102)	(0.218)	(0.104)	(0.115)	(0.102)
Evangelic	-0.481	0.100	0.132	0.819***	1.260***
	(0.501)	(0.426)	(0.484)	(0.195)	(0.130)
Pentecostal Evangelic	1.825***	1.028***	0.279	1.030***	1.537***
	(0.172)	(0.260)	(0.205)	(0.182)	(0.199)
No religion	1.010***	1.649***	0.645	0.962***	0.994**
	(0.347)	(0.240)	(0.409)	(0.289)	(0.474)
Education 11-14y	-0.010	-0.013**	-0.003	-0.003	0.013
	(0.029)	(0.006)	(0.012)	(0.010)	(0.011)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	446	1,787	449	1,666	1,159
Adjusted R^2	0.598	0.485	0.558	0.378	0.544
Residual Std. Error	0.255	0.248	0.233	0.255	0.213
F Statistic	48.105***	64.706***	37.512***	57.674***	50.457***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

the coefficients in models (11) and (12) may not accurately reflect the actual stance of far-right Brazilians regarding vaccination in general. However, the results pertaining to far-left support and general vaccination lend credence to the notion that anti-establishment ideologies correlate with lower vaccination rates, as proposed by the literature review.

Finally, it should be noted that the models were built intending to relate political preferences with COVID-19 vaccination. The coefficients of determination show a steep decrease when comparing vaccination rates for other diseases. It should be expected and provide further strength for the findings, indicating that vaccine refusal was not a political issue in Brazil before the pandemics.

Table 4.5 – Results, by region - general vaccination Bolsonaro votes

Dependent variable:	General vaccine coverage				
Region:	Center-West	Northeast	North	Southeast	South
	(18)	(19)	(20)	(21)	(22)
Bolsonaro Share 22	22.848	-14.567*	2.954	5.798	-8.120
	(15.463)	(7.975)	(8.986)	(9.019)	(9.207)
elderly(>70yo)	1.209	2.149***	4.574***	1.877***	1.949***
	(1.062)	(0.442)	(1.257)	(0.539)	(0.569)
Rural pop.	0.118	0.004	-0.163**	-0.051	0.128***
	(0.083)	(0.036)	(0.068)	(0.047)	(0.046)
Pop. density	-0.004	-0.002	-0.015***	-0.000	-0.004**
	(0.003)	(0.002)	(0.003)	(0.001)	(0.002)
White	0.140	-1.755***	-1.490	-1.076*	0.842
	(1.194)	(0.494)	(1.146)	(0.606)	(0.836)
Black	-0.690	-2.132***	-1.776	-1.364**	0.377
	(1.358)	(0.533)	(1.183)	(0.626)	(0.940)
Brown	-0.047	-2.032***	-2.065*	-1.262**	0.743
	(1.162)	(0.497)	(1.127)	(0.615)	(0.863)
Indigenous	-0.420	-2.247***	-2.114*	-1.061*	0.456
	(1.156)	(0.507)	(1.132)	(0.610)	(0.877)
Catholic	11.880	8.624	8.739	3.567	1.407
	(8.691)	(5.369)	(7.368)	(8.589)	(7.892)
Evangelic	-22.192	19.249	-5.364	19.076	-13.027
	(51.583)	(31.490)	(32.068)	(15.424)	(13.616)
Pentecostal Evangelic	-5.470	-15.464	-5.156	2.973	4.627
	(16.816)	(15.765)	(15.604)	(15.306)	(15.519)
No religion	18.183	-9.534	-19.988	-109.255***	-104.747***
	(30.968)	(16.175)	(24.950)	(28.447)	(37.442)
Education 11-14y	3.697	-1.443***	2.845**	-2.876***	-1.918**
	(2.399)	(0.472)	(1.140)	(0.948)	(0.924)
Income (BRL)	-0.002	0.011**	0.008	0.005*	0.012***
	(0.005)	(0.005)	(0.006)	(0.003)	(0.003)
Observations	446	1,787	449	1,666	1,159
Adjusted R^2	0.044	0.114	0.226	0.137	0.164
Residual Std. Error	22.256	20.675	19.745	22.163	21.439
F Statistic	5.007***	16.669***	12.893***	16.281***	10.829***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

4.4 CONCLUDING REMARKS

This study offers valuable insights into the relationship between city-level voting patterns and vaccination rates in Brazil. The findings reveal that most models have high coefficients of determination (R^2), and several explanatory variables are statistically significant, particularly concerning COVID-19 vaccinations. The study supports the hypothesis that vaccination rates are related to voting patterns, but this relationship is not uniform across the country.

A key finding is the relationship between vote share for then-President Jair Bolsonaro and vaccination rates. The results demonstrate a strong positive correlation between city-level voting share for the former Brazilian President in the 2022 election and general vaccination and immunization against polio. In contrast, the relationship is consistently negative concerning COVID-19 vaccination, especially when measured as vaccines received in each municipality. These results suggest that the former President's stance undermining the public confidence in COVID-19 vaccines may have influenced the correlation between his support and vaccination rates against the novel coronavirus in Brazil.

The study also reveals that far-left support is negatively correlated with general and polio vaccine coverage, while the correlation with COVID-19 shots is weakly positive. Far-right support exhibits a negative relationship with COVID-19 vaccination rates but is positively related to general and polio vaccine coverage.

These findings emphasize the importance of considering political views and voting patterns when analyzing vaccination rates and highlight the need for further research to understand the complexities and heterogeneity of this relationship. Additionally, the study indicates that sociodemographic variables, such as household income and population density, do not significantly impact vaccination rates, unlike in most countries. The rate of Catholic individuals is positively related to vaccination rates, while the rate of the population without religion is negatively related, suggesting that general ideology and values may play a role in vaccination decisions.

It is crucial to interpret the results with caution since the study did not allow for causal inference, and the results related to far-right support should be viewed with skepticism due to data limitations. Future studies could benefit from a more nuanced approach to capturing the far-right stance on vaccination and exploring the impact of other factors, such as health care infrastructure, media coverage, health literacy, on vaccination rates.

In summary, this study contributes to the literature by emphasizing the importance of considering voting patterns and political views when analyzing vaccination rates and sheds light on the complexities of this relationship. The results underscore the necessity for further research to better comprehend the relationship between voting patterns and vaccination rates and to investigate the influence of other factors on vaccination decisions.

4.5 APPENDIX

Current section presents the appendix to chapter 3.

4.5.1 Descriptive Statistics - Regions

Table 4.6 – Descriptive statistics - North

	count	mean	std	min	max
Bolsonaro Share 22	449.0	0.454	0.166	0.086	0.829
Far-left 18	449.0	0.005	0.003	0.000	0.020
Far-right 22	449.0	0.001	0.001	0.000	0.006
Dose1 Applied	449.0	0.617	0.164	0.175	2.252
Dose2 Applied	449.0	0.446	0.145	0.051	1.197
Dose3 Applied	449.0	0.068	0.047	0.001	0.406
Dose1 Received	449.0	0.617	0.173	0.179	1.636
Dose2 Received	449.0	0.445	0.151	0.085	0.961
Dose3 Received	449.0	0.066	0.043	0.004	0.309
Vaccination coverage	449.0	68.026	22.440	19.030	136.230
BCG coverage	449.0	75.867	31.241	5.130	235.470
Polio coverage	449.0	76.046	28.301	18.870	231.250
elderly(>70yo)	449.0	3.293	1.178	0.340	6.870
Rural pop.	449.0	43.231	19.658	0.250	95.820
Pop. density	449.0	22.257	142.072	0.130	2477.560
White	449.0	21.270	8.261	0.670	47.830
Black	449.0	7.292	4.194	0.360	49.240
Brown	449.0	66.885	11.085	8.840	90.820
Indigenous	449.0	3.354	10.399	0.000	88.560
Catholic	449.0	0.591	0.167	0.238	2.467
Evangelic	449.0	0.037	0.034	0.000	0.289
Pentecostal Evangelic	449.0	0.161	0.074	0.018	1.152
Umbanda/Candomble	449.0	0.000	0.000	0.000	0.004
No religion	449.0	0.063	0.051	0.000	0.503
Education 8y less	449.0	82.735	7.469	51.480	96.930
Education 8-10y	449.0	9.407	3.729	1.510	22.830
Education 11-14y	449.0	6.265	3.599	0.270	22.070
Education 15y plus	449.0	0.556	0.688	0.000	5.840
Income (BRL)	449.0	1123.827	330.681	558.330	2896.730

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

Table 4.7 – Descriptive statistics - Northeast

	count	mean	std	min	max
Bolsonaro Share 22	1787.0	0.235	0.089	0.061	0.623
Far-left 18	1787.0	0.003	0.002	0.000	0.022
Far-right 22	1787.0	0.002	0.001	0.000	0.008
Dose1 Applied	1787.0	0.676	0.227	0.009	3.999
Dose2 Applied	1787.0	0.530	0.205	0.000	3.256
Dose3 Applied	1787.0	0.101	0.066	0.000	0.827
Dose1 Received	1787.0	0.750	0.148	0.269	3.120
Dose2 Received	1787.0	0.581	0.157	0.113	2.811
Dose3 Received	1787.0	0.102	0.060	0.007	0.690
Vaccination coverage	1787.0	68.263	21.967	5.100	214.260
BCG coverage	1787.0	64.670	39.712	0.000	772.860
Polio coverage	1787.0	82.101	27.105	0.000	259.070
elderly(>70yo)	1787.0	5.465	1.425	1.150	10.730
Rural pop.	1787.0	44.679	19.619	0.000	91.680
Pop. density	1787.0	90.155	418.108	0.940	9068.360
White	1787.0	28.195	10.992	5.050	70.870
Black	1787.0	7.920	6.134	0.580	55.110
Brown	1787.0	62.235	9.305	11.140	90.420
Indigenous	1787.0	0.446	3.228	0.000	76.360
Catholic	1787.0	0.772	0.151	0.286	3.053
Evangelic	1787.0	0.021	0.021	0.000	0.152
Pentecostal Evangelic	1787.0	0.075	0.045	0.008	0.477
Umbanda/Candomble	1787.0	0.000	0.002	0.000	0.025
No religion	1787.0	0.057	0.054	0.000	0.394
Education 8y less	1787.0	84.564	6.279	48.630	99.590
Education 8-10y	1787.0	7.126	2.911	0.180	20.330
Education 11-14y	1787.0	5.602	3.318	0.070	26.910
Education 15y plus	1787.0	0.577	0.809	0.000	9.360
Income (BRL)	1787.0	864.790	241.265	370.480	3340.190

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

Table 4.8 – Descriptive statistics - Center-West

	count	mean	std	min	max
Bolsonaro Share 22	446.0	0.564	0.101	0.174	0.811
Far-left 18	446.0	0.004	0.002	0.000	0.014
Far-right 22	446.0	0.003	0.001	0.000	0.008
Dose1 Applied	446.0	0.785	0.134	0.370	2.081
Dose2 Applied	446.0	0.635	0.142	0.304	1.730
Dose3 Applied	446.0	0.135	0.076	0.000	0.447
Dose1 Received	446.0	0.809	0.184	0.378	2.484
Dose2 Received	446.0	0.655	0.171	0.297	1.990
Dose3 Received	446.0	0.136	0.072	0.015	0.461
Vaccination coverage	446.0	81.013	22.759	21.360	196.690
BCG coverage	446.0	75.959	31.371	4.000	220.000
Polio coverage	446.0	91.849	29.115	8.000	280.000
elderly(>70yo)	446.0	4.558	1.554	0.400	8.880
Rural pop.	446.0	27.310	16.958	0.000	81.890
Pop. density	446.0	30.409	162.730	0.330	2197.140
White	446.0	40.048	10.290	12.770	66.960
Black	446.0	5.899	3.027	1.180	28.420
Brown	446.0	51.225	9.504	20.440	82.880
Indigenous	446.0	1.563	5.636	0.000	56.520
Catholic	446.0	0.617	0.158	0.275	2.149
Evangelic	446.0	0.027	0.023	0.000	0.164
Pentecostal Evangelic	446.0	0.154	0.068	0.017	0.652
Umbanda/Candomble	446.0	0.000	0.001	0.000	0.007
No religion	446.0	0.070	0.040	0.002	0.336
Education 8y less	446.0	76.366	6.439	46.910	90.700
Education 8-10y	446.0	12.067	2.782	4.530	21.250
Education 11-14y	446.0	9.651	3.369	3.180	23.840
Education 15y plus	446.0	1.422	1.164	0.000	9.580
Income (BRL)	446.0	1568.067	388.342	768.810	4517.690

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

Table 4.9 – Descriptive statistics - Southeast

	count	mean	std	min	max
Bolsonaro Share 22	1666.0	0.511	0.129	0.155	0.812
Far-left 18	1666.0	0.004	0.003	0.000	0.025
Far-right 22	1666.0	0.007	0.004	0.000	0.023
Dose1 Applied	1666.0	0.806	0.093	0.420	1.609
Dose2 Applied	1666.0	0.681	0.123	0.172	1.395
Dose3 Applied	1666.0	0.165	0.077	0.001	0.741
Dose1 Received	1666.0	0.832	0.125	0.437	1.658
Dose2 Received	1666.0	0.700	0.140	0.229	1.498
Dose3 Received	1666.0	0.166	0.075	0.010	0.744
Vaccination coverage	1666.0	80.422	23.858	2.280	210.880
BCG coverage	1666.0	73.449	32.653	0.000	230.770
Polio coverage	1666.0	92.630	30.844	0.000	436.360
elderly(>70yo)	1666.0	6.043	1.549	1.660	12.470
Rural pop.	1666.0	25.044	19.109	0.000	81.440
Pop. density	1666.0	192.564	906.904	1.360	13024.560
White	1666.0	53.256	18.825	7.110	92.240
Black	1666.0	6.927	4.393	0.420	31.890
Brown	1666.0	38.807	16.569	5.710	85.220
Indigenous	1666.0	0.157	1.726	0.000	65.740
Catholic	1666.0	0.677	0.159	0.172	1.291
Evangelic	1666.0	0.032	0.043	0.000	0.681
Pentecostal Evangelic	1666.0	0.112	0.053	0.010	0.397
Umbanda/Candomble	1666.0	0.001	0.002	0.000	0.019
No religion	1666.0	0.047	0.040	0.000	0.336
Education 8y less	1666.0	72.244	9.007	35.690	95.160
Education 8-10y	1666.0	13.302	3.604	2.980	25.800
Education 11-14y	1666.0	11.616	4.559	1.420	28.300
Education 15y plus	1666.0	2.253	1.852	0.000	19.020
Income (BRL)	1666.0	1607.293	510.128	642.430	5179.030

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

Table 4.10 – Descriptive statistics - South

	count	mean	std	min	max
Bolsonaro Share 22	1159.0	0.598	0.115	0.282	0.890
Far-left 18	1159.0	0.004	0.002	0.000	0.024
Far-right 22	1159.0	0.005	0.003	0.000	0.032
Dose1 Applied	1159.0	0.842	0.099	0.396	2.252
Dose2 Applied	1159.0	0.734	0.108	0.272	1.950
Dose3 Applied	1159.0	0.188	0.083	0.006	0.503
Dose1 Received	1159.0	0.864	0.129	0.377	2.575
Dose2 Received	1159.0	0.751	0.131	0.296	2.177
Dose3 Received	1159.0	0.189	0.082	0.022	0.509
Vaccination coverage	1159.0	87.193	23.442	5.760	245.580
BCG coverage	1159.0	83.753	36.360	0.000	300.000
Polio coverage	1159.0	96.981	30.117	6.780	383.330
elderly(>70yo)	1159.0	6.197	1.744	2.110	14.380
Rural pop.	1159.0	38.404	23.565	0.000	94.480
Pop. density	1159.0	79.031	268.026	2.060	4024.840
White	1159.0	77.558	13.242	36.450	99.580
Black	1159.0	3.098	2.242	0.000	14.200
Brown	1159.0	18.180	12.248	0.270	57.800
Indigenous	1159.0	0.583	3.413	0.000	49.090
Catholic	1159.0	0.771	0.178	0.153	2.476
Evangelic	1159.0	0.055	0.087	0.000	0.642
Pentecostal Evangelic	1159.0	0.087	0.056	0.000	0.475
Umbanda/Candomble	1159.0	0.001	0.005	0.000	0.049
No religion	1159.0	0.023	0.032	0.000	0.470
Education 8y less	1159.0	71.657	7.665	39.020	91.880
Education 8-10y	1159.0	14.747	3.251	4.770	28.890
Education 11-14y	1159.0	10.724	3.981	2.120	27.660
Education 15y plus	1159.0	1.960	1.473	0.000	15.280
Income (BRL)	1159.0	1837.251	470.341	806.620	4380.320

Notes: *i*) Number of doses received and applied refers to 28-02-2023 and present the same total, but the municipal average shots per individual varies once some inhabitants from smaller cities get vaccinated in bigger cities due to work. *ii*) Demographic info, education level, skin color, religion and household income refers to the 2010 census results aggregated at city-level.
Source: author's preparation.

Table 4.11 – Correlation matrix - Selected variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1																							
2	0.78																						
3	0.78	0.75																					
4	0.72	0.82	0.96																				
5	0.33	0.38	0.34	0.35																			
6	0.27	0.31	0.28	0.28	0.90																		
7	0.39	0.33	0.36	0.38	0.23	0.14																	
8	0.35	0.28	0.31	0.33	0.22	0.13	0.98																
9	0.05	-0.01	-0.01	-0.01	-0.11	-0.11	0.24	0.20															
10	0.28	0.25	0.21	0.22	0.21	0.16	0.51	0.44	0.24														
11	0.04	0.04	0.07	0.07	0.02	0.04	0.07	0.07	-0.06	-0.07													
12	-0.00	-0.03	-0.02	-0.02	-0.07	-0.07	0.07	0.05	0.25	0.10	-0.01												
13	0.44	0.55	0.52	0.56	0.26	0.24	0.08	0.02	-0.17	0.18	0.03	-0.08											
14	-0.12	-0.10	-0.07	-0.09	0.04	0.06	-0.46	-0.38	-0.28	-0.25	-0.10	-0.16	0.06										
15	0.01	-0.01	-0.01	-0.01	-0.09	-0.08	0.09	0.06	0.33	0.12	0.00	0.44	-0.10	-0.22									
16	0.52	0.52	0.54	0.57	0.33	0.24	0.72	0.69	0.11	0.48	0.08	0.01	0.39	-0.19	0.03								
17	-0.18	-0.23	-0.25	-0.27	-0.19	-0.15	-0.31	-0.33	0.08	-0.09	-0.09	0.04	-0.15	-0.02	0.05	-0.50							
18	-0.52	-0.50	-0.52	-0.55	-0.30	-0.22	-0.71	-0.68	-0.15	-0.49	-0.07	-0.02	-0.36	0.19	-0.04	-0.96	0.33						
19	0.27	0.40	0.24	0.26	0.19	0.19	-0.33	-0.33	-0.26	-0.01	-0.07	-0.14	0.45	0.40	-0.17	0.05	-0.11	-0.02					
20	0.10	0.07	0.09	0.09	0.05	0.02	0.22	0.26	0.03	0.09	-0.00	0.01	0.10	0.03	0.01	0.20	-0.05	-0.21	-0.28				
21	-0.15	-0.22	-0.21	-0.22	-0.26	-0.21	-0.03	-0.02	0.16	-0.22	0.04	0.09	-0.29	-0.20	0.13	-0.31	0.33	0.24	-0.50	0.10			
22	-0.34	-0.33	-0.33	-0.35	-0.09	-0.03	-0.71	-0.64	-0.38	-0.43	-0.06	-0.23	-0.12	0.68	-0.28	-0.57	0.14	0.58	0.31	-0.11	0.01		
23	0.28	0.25	0.27	0.29	0.04	-0.00	0.56	0.49	0.34	0.41	0.09	0.30	0.16	-0.57	0.27	0.49	-0.13	-0.50	-0.24	0.05	-0.01	-0.81	
24	0.40	0.35	0.37	0.39	0.20	0.11	0.81	0.78	0.32	0.52	0.06	0.22	0.09	-0.51	0.22	0.70	-0.24	-0.70	-0.26	0.17	-0.10	-0.83	0.76

Variables: 1 = Doses Applied, 2 = Doses Received, 3 = Dose3 Applied, 4 = Dose3 Received, 5 = Vaccination coverage, 6 = Polio coverage, 7 = Bolsonaro Share 18, 8 = Bolsonaro Share 22, 9 = Far-left 18, 10 = Far-right 22, 11 = PL coligation 22, 12 = Population, 13 = elderly (>70yo), 14 = Rural pop., 15 = Pop. density, 16 = White, 17 = Black, 18 = Brown, 19 = Catholic, 20 = Evangelic, 21 = No religion, 22 = Education 8y less, 23 = Education 15y plus, 24 = Income (BRL).
Source: author's preparation.

4.5.2 Sensitivity Tests

Table 4.12 – Results - vaccination   Bolsonaro share in 2018

Dependent variable:	Doses app.	Doses rec.	3rd app.	3rd rec.	Vaxx cvrg.	Polio cvrg.
	(23)	(24)	(25)	(26)	(27)	(28)
Bolsonaro Share 18	0.254***	0.129***	0.011	0.014*	20.530***	19.632***
	(0.046)	(0.038)	(0.009)	(0.008)	(3.114)	(4.134)
elderly(>70yo)	0.044***	0.061***	0.017***	0.017***	2.013***	2.511***
	(0.003)	(0.004)	(0.001)	(0.001)	(0.258)	(0.346)
Rural pop.	0.000	-0.001***	0.000***	0.000**	0.006	0.009
	(0.000)	(0.000)	(0.000)	(0.000)	(0.021)	(0.026)
Pop. density	-0.000	-0.000	-0.000	-0.000	-0.002***	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
White	-0.017***	-0.019***	-0.000	-0.000	-1.059***	-1.157***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.336)	(0.435)
Black	-0.016***	-0.023***	-0.001	-0.002*	-1.173***	-1.328***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.354)	(0.457)
Brown	-0.022***	-0.023***	-0.001	-0.001	-1.176***	-1.289***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.339)	(0.438)
Indigenous	-0.020***	-0.022***	-0.000	-0.000	-1.337***	-1.572***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.341)	(0.438)
Catholic	1.067***	1.233***	0.091***	0.105***	14.083***	14.813***
	(0.072)	(0.119)	(0.014)	(0.015)	(3.259)	(4.095)
Evangelic	0.665***	0.710***	0.018	0.027	4.069	-5.903
	(0.104)	(0.142)	(0.027)	(0.026)	(7.908)	(12.951)
Pentecostal Evangelic	1.048***	1.040***	0.133***	0.131***	9.459	4.626
	(0.103)	(0.181)	(0.029)	(0.030)	(6.386)	(8.412)
No religion	1.108***	1.046***	0.097***	0.098***	-56.870***	-44.865***
	(0.137)	(0.166)	(0.026)	(0.025)	(9.728)	(12.515)
Education 11-14y	0.010***	0.009***	0.002***	0.002***	-0.984***	-1.066***
	(0.002)	(0.002)	(0.000)	(0.000)	(0.135)	(0.173)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.006***	0.003*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)
Observations	5,507	5,507	5,507	5,507	5,507	5,507
Adjusted R^2	0.452	0.563	0.441	0.496	0.179	0.118
Residual Std. Error	0.307	0.259	0.062	0.057	21.917	28.139
F Statistic	413.609***	393.285***	302.360***	347.956***	74.378***	44.313***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

Table 4.13 – Results - vaccination Ciro Gomes share (3rd place in 2018)

Dependent variable:	Doses app.	Doses rec.	3rd app.	3rd rec.	Vaxx cvrg.	Polio cvrg.
	(29)	(30)	(31)	(32)	(33)	(34)
Ciro Share 18	-1.143***	0.035	-0.029**	0.009	-5.168	-0.384
	(0.088)	(0.063)	(0.013)	(0.014)	(4.363)	(5.248)
elderly(>70yo)	0.057***	0.065***	0.018***	0.018***	2.361***	2.787***
	(0.003)	(0.005)	(0.001)	(0.001)	(0.265)	(0.362)
Rural pop.	-0.001***	-0.001***	0.000***	0.000**	-0.018	-0.013
	(0.000)	(0.000)	(0.000)	(0.000)	(0.021)	(0.026)
Pop. density	0.000	-0.000	-0.000	-0.000	-0.002***	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
White	-0.020***	-0.020***	-0.001	-0.001	-1.243***	-1.326***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.335)	(0.434)
Black	-0.024***	-0.025***	-0.002**	-0.002**	-1.480***	-1.605***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.354)	(0.458)
Brown	-0.025***	-0.024***	-0.002*	-0.002**	-1.418***	-1.520***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.337)	(0.436)
Indigenous	-0.024***	-0.023***	-0.001	-0.001	-1.559***	-1.777***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.340)	(0.437)
Catholic	1.002***	1.204***	0.089***	0.102***	9.279***	10.224***
	(0.065)	(0.119)	(0.013)	(0.015)	(3.106)	(3.941)
Evangelic	0.447***	0.637***	-0.002	0.012	-1.902	-10.676
	(0.107)	(0.149)	(0.027)	(0.027)	(7.966)	(12.904)
Pentecostal Evangelic	0.769***	1.035***	0.102***	0.114***	14.926**	11.858
	(0.084)	(0.181)	(0.027)	(0.029)	(6.283)	(8.333)
No religion	1.044***	1.122***	0.108***	0.113***	-55.466***	-43.623***
	(0.137)	(0.169)	(0.026)	(0.025)	(9.617)	(12.449)
Education 11-14y	0.026***	0.006	0.005***	0.005***	-0.278	-0.404
	(0.005)	(0.004)	(0.001)	(0.001)	(0.322)	(0.412)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.012***	0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)
Observations	5,507	5,507	5,507	5,507	5,507	5,507
Adjusted R^2	0.510	0.569	0.448	0.501	0.186	0.121
Residual Std. Error	0.290	0.257	0.062	0.057	21.830	28.088
F Statistic	356.371***	331.465***	259.738***	302.181***	62.725***	36.208***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

Table 4.14 – Results - vaccination   Simone Tebet share (3rd place in 2022)

Dependent variable:	Doses app.	Doses rec.	3rd app.	3rd rec.	Vaxx cvrg.	Polio cvrg.
	(35)	(36)	(37)	(38)	(39)	(40)
Tebet Share 22	2.731***	1.634***	0.457***	0.437***	-27.288	-24.085
	(0.320)	(0.294)	(0.075)	(0.069)	(23.787)	(30.837)
elderly(>70yo)	0.048***	0.066***	0.018***	0.018***	2.310***	2.777***
	(0.004)	(0.004)	(0.001)	(0.001)	(0.263)	(0.357)
Rural pop.	-0.000	-0.001***	0.000***	0.000	-0.012	-0.011
	(0.000)	(0.000)	(0.000)	(0.000)	(0.021)	(0.026)
Pop. density	-0.000	-0.000	-0.000	-0.000	-0.002***	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
White	-0.023***	-0.020***	-0.001	-0.001	-1.248***	-1.322***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.335)	(0.434)
Black	-0.024***	-0.025***	-0.002**	-0.002**	-1.478***	-1.603***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.354)	(0.458)
Brown	-0.027***	-0.024***	-0.002*	-0.002*	-1.430***	-1.522***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.337)	(0.436)
Indigenous	-0.025***	-0.023***	-0.001	-0.001	-1.569***	-1.780***
	(0.005)	(0.004)	(0.001)	(0.001)	(0.340)	(0.437)
Catholic	1.033***	1.207***	0.090***	0.103***	9.330***	10.179***
	(0.071)	(0.120)	(0.014)	(0.015)	(3.118)	(3.926)
Evangelic	0.592***	0.641***	0.003	0.013	-1.435	-10.748
	(0.110)	(0.148)	(0.028)	(0.027)	(7.957)	(12.901)
Pentecostal Evangelic	0.909***	0.996***	0.098***	0.103***	16.343***	12.400
	(0.103)	(0.177)	(0.028)	(0.029)	(6.260)	(8.303)
No religion	1.167***	1.119***	0.111***	0.112***	-54.914***	-43.585***
	(0.142)	(0.168)	(0.027)	(0.025)	(9.616)	(12.427)
Education 11-14y	0.045***	0.002	0.005***	0.004***	-0.106	-0.345
	(0.006)	(0.004)	(0.001)	(0.001)	(0.316)	(0.399)
Income (BRL)	0.000***	0.000***	0.000***	0.000***	0.013***	0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)
Observations	5,507	5,507	5,507	5,507	5,507	5,507
Adjusted R^2	0.472	0.572	0.452	0.506	0.185	0.121
Residual Std. Error	0.301	0.256	0.062	0.056	21.831	28.086
F Statistic	345.473***	333.672***	260.823***	303.545***	63.386***	36.236***

Significance markers: *p<0.1; **p<0.05; ***p<0.01
Source: author's preparation.

5 GENERAL CONCLUSIONS

This thesis consisted of three essays analysing different aspects of the political economy and individual behavior during the COVID-19 pandemics. In summary, the combination of the studies allows for a nuanced evaluation of some of the connections between individual characteristics, social context, and political preferences with pandemics related phenomena in Brazil.

As a joint effort, the three studies presented in this thesis provide a comprehensive understanding of the individual and social aspects of the COVID-19 pandemic in Brazil. The first study investigates how electoral incentives shaped the policies adopted by mayors during the pandemic. The findings suggest that right-wing incumbents running for reelection adopted less stringent measures against COVID-19, likely in response to the negative impact of non-pharmaceutical interventions on the local economy.

The second study explores the factors influencing vaccine hesitancy, measured as the number of COVID-19 vaccine doses and the interval between them in Brazil. The findings show that factors such as age, skin color, income, gender, and political ideology are correlated with the number of vaccine shots received, highlighting the importance of addressing vaccine hesitancy and promoting vaccine uptake.

The third study sheds light on the relationship between city-level voting patterns and vaccination rates in Brazil. The results suggest that voting patterns and political views play a significant role in vaccination decisions, with a negative correlation between vote share for then-President Jair Bolsonaro and COVID-19 vaccination rates, while far-left and far-right support were negatively and positively related to general and polio vaccine coverage, respectively.

The findings of chapter 2, while informative, are limited by the scope of the data and the potential for self-selection bias. The discrepancy between the results in chapters 2 and 3 highlights the complexity of factors influencing vaccine hesitancy and the importance of considering multiple levels of analysis. Chapter 3's examination of city-level data provides valuable insights and complements the individual-level analysis of chapter 2, allowing for a more comprehensive understanding of vaccine hesitancy in Brazil. By combining the findings of both chapters, we can better identify trends and patterns related to COVID-19 immunization coverage and political ideology, and inform future public health strategies to address vaccine hesitancy in different communities.

The political economy of vaccination and public health represents a new and nascent research field with significant potential for both academic and practical contributions. As this area of study is still in its infancy, there is a pressing need for rigorous research on both theoretical and empirical fronts. By exploring the complex relationships between political, economic, and social factors that influence vaccination and public health outcomes, researchers can generate valuable insights that not only advance our understanding of the subject but also provide practical implications for public policy.

In the practical sense, the findings of this thesis can inform policymakers about the factors that shape vaccine uptake, political response, and public health outcomes. By offering insights into the underlying causes of vaccine hesitancy, the role of political incentives, and the impact of various demographic, socioeconomic, and ideological factors, this thesis can help guide the design of more effective policies and interventions that promote vaccination and protect public health. In a broader sense, the study contributes to the development of a theoretical framework for understanding the political economy of vaccination and public health, paving the way for further research that can refine and expand upon these initial insights.

While the thesis and the papers it comprises represent a small but important and original step in the development of this research field, there is still much work to be done. The study opens up new avenues of inquiry and highlights the need for additional research to further explore the intricate relationships between politics, economics, and public health. It is our hope that this epilogue will serve as a prologue for future studies in this area, inspiring other researchers to build upon the foundations laid by this thesis and contribute to the ongoing development and expansion of the political economy of vaccination and public health as a field of study. By fostering continued research and collaboration, we can collectively enhance our understanding of these complex issues and work towards more effective and evidence-based solutions to the pressing public health challenges of our time.

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