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# **Highways to Health:** Does BR-364 Enhance Access to Healthcare in Acre?

Juiz de Fora
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Defesa de Mestrado em Economia Aplicada apresentada ao Programa de Pós-Graduação em Economia da Universidade Federal de Juiz de Fora como requisito parcial à obtenção do título de Mestre em Economia. Área de concentração: Economia Social e do Trabalho.

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**ABSTRACT**

This dissertation investigates the impact of road infrastructure improvements on access to healthcare services along the BR-364 highway, with a focus on the paving works in the state of Acre. The study is based on the hypothesis that transportation investments reduce geographical barriers and promote greater equity in healthcare access, especially in isolated and less urbanized areas. The Synthetic Differences-in-Differences (SDID) method is employed to estimate the causal effect of road improvements on the utilization of services provided by the Unified Health System (SUS). The results show that paving the BR-364 had heterogeneous effects on access to health care, with these effects concentrated in specific services. Road improvements reduced the use of clinical procedures and low-complexity diagnostic exams outside treated municipalities, while significantly increasing access to magnetic resonance imaging. Hospitalizations exhibit significant changes in their spatial distribution rather than in total volume. Overall, the findings indicate that road infrastructure improvements have reshaped patient flows and referral patterns, thereby strengthening the al integration of the health system.

**Keywords:** Access to Health; Highways; Legal Amazon.

**RESUMO**

Esta dissertação investiga o impacto das melhorias na infraestrutura rodoviária sobre o acesso aos serviços de saúde ao longo da rodovia BR-364, com foco nas obras de pavimentação da BR-364 no estado do Acre. O estudo parte da hipótese de que investimentos em transporte reduzem barreiras geográficas e promovem maior equidade no acesso à saúde, especialmente em áreas isoladas e menos urbanizadas. O método de Diferenças-em-Diferenças Sintético (SDID) é utilizado para estimar o efeito causal das melhorias rodoviárias sobre a utilização dos serviços prestados pelo Sistema Único de Saúde (SUS). Os resultados mostram que a pavimentação da BR-364 gerou efeitos heterogêneos sobre o acesso à saúde, concentrados em serviços específicos. As melhorias reduziram o uso de procedimentos clínicos e de exames diagnósticos de baixa complexidade fora dos municípios tratados, enquanto ampliou significativamente o acesso a exames de ressonância magnética. As internações hospitalares apresentaram mudanças significativas na sua distribuição espacial, e não no volume total. De forma geral, os achados indicam que as melhorias na infraestrutura rodoviária reconfiguraram os fluxos de pacientes e os padrões de encaminhamento, fortalecendo a integração regional do sistema de saúde.
**Palavras-chave:** Acesso à Saúde; Rodovias; Amazonia Legal.

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# 1 INTRODUCTION

Access to healthcare refers to the timely, affordable, and appropriate use of medical services, encompassing dimensions such as coverage, service availability, qualified health personnel, geographic proximity, and the reduction of cultural and informational barriers. Although access to healthcare is recognized as a fundamental human right and a central determinant of population well-being, substantial inequalities persist worldwide, particularly in low- and middle-income countries. Despite sustained efforts by the World Health Organization to advance universal health coverage, a significant share of the population continues to face structural and geographic barriers that limit access to essential services, ultimately worsening health outcomes and reinforcing pre-existing social and regional disparities (Negash et al., 2025).

In Brazil, a growing body of literature has documented inequalities in health outcomes and healthcare utilization. However, empirical evidence directly linking improvements in physical infrastructure—especially road development—to access to healthcare services remains scarce. Much of the existing literature emphasizes health outcomes without addressing the concrete mechanisms through which access could be improved, while the social and spatial dimensions of infrastructure remain comparatively underexplored. This gap is particularly evident in the Amazon region, where geographic isolation, low population density, and limited connectivity play a decisive role in shaping access to public services and reinforcing territorial inequalities (Rocha et al., 2021; Travassos; Martins, 2004; Travassos et al., 2005; Travassos et al., 2006; Stopa et al., 2017; Viana et al., 2007; Garnelo; Sampaio; Pontes, 2019; Garnelo et al., 2018; Garnelo; Sousa; Silva, 2017; Garnelo, 2019; Amaral et al., 2017; Amaral et al., 2021).

This study investigates whether improvements to the BR-364 highway, which traverses the Legal Amazon in Acre, have improved healthcare access for local populations. It specifically examines whether the paving of a key highway segment at the end of 2018 altered how people use healthcare services geographically and enhanced access to health facilities at various levels of care, both within and outside the region. The main hypothesis suggests that upgrades to the BR-364 reduced geographic barriers and increased healthcare availability in nearby municipalities. By directly linking transportation improvements to healthcare access across different levels, this research advances understanding of how road networks can promote health equity in remote and vulnerable areas.

The Brazilian institutional context further underscores the relevance of this analysis. The universal access to healthcare is constitutionally guaranteed through the Unified Health System (SUS), established in the early 1990s (Brasil, 1988). Nonetheless, substantial regional disparities remain. Evidence from the 2013 National Health Survey indicates that access to health services is markedly higher in the Southeast and South than in other regions of the country (Tiguman; Silva; Galvão, 2022). Structural barriers are especially pronounced in small and remote municipalities, where access to medium- and high-complexity services is constrained by insufficient funding, organizational weaknesses, shortages of specialized professionals, and reliance on the private sector Santos, Vitorino and Pimentel (2017). These challenges are compounded by coordination failures between federal and state governments, particularly regarding financing and regionalization strategies.

Understanding access to healthcare, therefore, requires a broader analytical perspective that incorporates social, economic, and geographic determinants of health (Unglert, 1990; Giovanella; Fleury, 1995; Sanchez; Ciconelli, 2012). As emphasized by Dahlgren and Whitehead (1991), health outcomes are shaped by multiple, interacting layers ranging from individual characteristics to broader structural conditions such as income distribution, education, and access to public services. From this standpoint, policies aimed at promoting equity must extend beyond the provision of medical care and address the territorial and infrastructural mechanisms that shape opportunities to access services.

Building on this framework, the concept of healthcare access reflects the interaction between individuals and health systems in the presence of organizational, geographic, financial, and cultural barriers. Classical approaches emphasize that access depends both on service characteristics and on the population's ability to overcome obstacles such as distance, travel time, affordability, and acceptability. Complementary models focusing on effective use stress that true access occurs when individuals can obtain timely and appropriate care that improves health outcomes, a process shaped by predisposing factors, enabling resources, and perceived or clinically identified needs. Empirical evidence consistently shows that distance reduces the use of primary and preventive care, while effects on specialized and hospital services are more heterogeneous. More recent approaches introduce the notion of effective coverage, shifting attention from service entry to outcomes, while still distinguishing access from use, continuity, and effectiveness as analytically distinct dimensions (Donabedian, 1973; Penchansky; Thomas, 1981; Frenk, 1985; Medicine, 1993; Andersen, 1995; Carr-Hill et al., 1997; Organization, 2001; Travassos; Martins, 2004; Sanchez; Ciconelli, 2012).

From an economic perspective, the health capital model proposed by Grossman (1972) conceptualizes health as a durable stock that depreciates over time but can be augmented through investment. Improvements in transportation infrastructure directly affect this investment process by reducing the monetary and time costs associated with accessing healthcare services. Better road quality facilitates both preventive and curative care, enhances continuity of treatment, and increases the expected returns on health investments over the life cycle.

Barriers to specialized care remain pervasive and multifactorial, affecting both urban and rural settings and contributing to delays in treatment, poorer health outcomes, and persistent inequities (Garnelo et al., 2018; Cyr et al., 2019). Shortages of specialized professionals are not unique to Brazil; similar challenges have been documented in countries such as India, where understaffed public clinics often rely on inadequately trained personnel (Das et al., 2016). Evidence from Brazil further suggests that reduced demand for preventive care is associated with higher rates of hospital admissions, underscoring the importance of timely access to lower levels of care (Tiguman; Silva; Galvão, 2022). In this perspective, overcoming barriers to access is essential for effectively reducing morbidity and mortality associated with unmet healthcare needs, that tend to be particularly pronounced in low- and middle-income countries (Kobusingye et al., 2005; Clancy, 2013).

In response to these challenges, the organization of Health Care Networks has advanced as a central strategy for strengthening health systems. Grounded in principles articulated in the Dawson Report, this model emphasizes the integration of preventive and curative services, the central role of primary care as the entry point into the system, and the hierarchical coordination of secondary and tertiary services within defined territories of responsibility (Dawson, 1964). In Brazil, this approach has been progressively institutionalized through regionalization strategies, population-based planning, and the consolidation of care networks, culminating in the national guidelines established by Ordinance 4.279/2010. These reforms reflect a shared understanding that integrated networks are essential for addressing fragmentation and improving equity in access across levels of care (Conselho Nacional de Secretários de Saúde, 2006b; Conselho Nacional de Secretários de Saúde, 2006a; Fleury; Ouverney, 2007; Ministério da Saúde, 2008; Silva et al., 2008; Kuschnir; Chorny, 2010; Organização Pan-Americana da Saúde, 2011; Ministério da Saúde, 2010).

The Legal Amazon is a territorial region composed of nine Brazilian states comprising nine Brazilian states (Acre, Amapá, Amazonas, Mato Grosso, Maranhão, Pará, Rondônia, Roraima, and Tocantins) across three regions. Covering approximately 5,015,068 km$^2$, it represents about 59% of Brazil's total territory (Viana; Freitas; Giatti, 2016). Due to its vast territory and dense vegetation, the region remained sparsely populated for a long time. However, this began to change in the mid-20th century, when a government-led process of settlement began through the construction of highways, land grants, and tax incentives (Souza, 2020).

Despite the opening of highways, their quality remains lower in the Legal Amazon than in the rest of the country. According to Departamento Nacional de Infraestrutura de Transportes (2010), only about 37% of federal highways in the region were paved in 2006, compared to 54% in the rest of the country, highlighting a persistent infrastructure bottleneck that contributed to geographic isolation. Nevertheless, the data also indicate a gradual expansion of the federal road network over time: by 2010, the share of paved federal highways in the Legal Amazon had risen to approximately 41%, reaching approximately 50% by 2018.

Geographic and infrastructural barriers play a decisive role in shaping access to healthcare in these areas. Evidence shows that residents of riverside and rural communities may require many hours of travel to reach emergency or specialized care, often relying exclusively on river transport. For poorer households, transportation costs themselves constitute an additional barrier to access (Viana; Freitas; Giatti, 2016; Garnelo et al., 2018; Garnelo, 2019; Sousa; Cortes, 2024; Viegas; Carmo; Luz, 2015). Although road construction since the late 1960s has altered mobility patterns, many highways remain partially paved or poorly maintained, restricting circulation during the rainy season and limiting their potential to reduce isolation (Neto, 2019).

The challenges of access are particularly acute in the Brazilian Amazon, where large segments of the population living outside urban centers face precarious living conditions and limited access to healthcare, reflecting long-standing patterns of territorial neglect. Far from being a homogeneous region, the Amazon comprises diverse social, cultural, and environmental contexts shaped by distinct historical trajectories (Garnelo et al., 2018; Garnelo, 2019; Sousa et al., 2022). These structural and spatial inequalities are compounded by the uneven distribution of healthcare infrastructure across the country: in Brazil, the North, Midwest, and Northeast regions tend to exhibit greater distances to high-complexity hospitals, which are often concentrated in state capitals (Rocha et al., 2017).

Consistent with this perspective, the relationship between territorial infrastructure and access to healthcare can also be understood in light of the “inverse care law” proposed by Hart (1971), which states that the availability of medical services tends to vary inversely with the needs of the population. In contexts marked by socioeconomic inequalities and geographic constraints, areas with poorer social indicators and greater health needs often face lower service availability and higher barriers to access. This pattern is particularly relevant in remote and sparsely populated regions, where the spatial concentration of services and transportation difficulties reinforce inequalities in healthcare utilization. In this sense, improvements in transportation infrastructure may play an important role in reducing geographic barriers and mitigating the unequal distribution of healthcare provision, helping align service availability with population needs.

In 2019, the state of Acre had a population of 881,935 inhabitants, according to IBGE (2024). Of this total, only 4.8% had private health insurance, highlighting the population’s strong dependence on the Brazilian Unified Health System (SUS) (Agência Nacional de Saúde Suplementar (ANS), n.d.). This context is particularly relevant in a state characterized by the concentration of higher-complexity health services in the capital, Rio Branco, the presence of significant geographic barriers, and the location of several municipalities in border areas—factors that have historically hindered access to healthcare services, as in other states in Brazil (Teston et al., 2019; Rocha et al., 2021). The focus on Acre is particularly relevant given the unique territorial and institutional challenges that shape healthcare access in the state. The region is characterized by low population density, large geographic distances between municipalities, and strong dependence on fluvial and road transport, which complicate referrals across different levels of care (IBGE, 2024; Sousa; Cortes, 2024; Neto, 2025). In addition, healthcare services—especially those of medium and high complexity—are highly concentrated in the capital, Rio Branco, requiring patients from remote municipalities to travel long distances to obtain specialized care. These constraints are further reinforced by the state's border location and limited regional integration of health services, which create additional logistical and administrative challenges for care provision (Teston et al., 2019; Rocha et al., 2021). In this context, evaluating how transportation infrastructure affects access to healthcare is particularly important, as improvements in connectivity may play a central role in reducing spatial inequalities and expanding effective access to the public health system.

In this context, we shed light on one of the most isolated regions of Brazil, characterized by social and health indicators that remain below the national average (Costa; Marguti, 2015; Rocha et al., 2021). Acre has one of the lowest health insurance coverage rates in the country—the second lowest in 2019—which reinforces the central role of the SUS as the main provider of care for the population. In this setting, understanding how territorial constraints and infrastructure limitations shape access to public healthcare services becomes particularly important, especially in regions where service provision is spatially concentrated and reliance on the public system is high.

Comparable experiences from other parts of the Amazon Basin reinforce the relevance of transportation infrastructure for access to healthcare. In the Peruvian Amazon, the Inter-oceanic Highway improved travel times and access to regional hospitals, with many residents reporting better living conditions. At the same time, negative externalities such as environmental degradation and increased health risks were also observed, highlighting the complex and context-dependent nature of infrastructure investments (Riley-Powell; al., 2018). In a similar vein, Iimi et al. (2015) evaluates the social and economic impacts of rural road improvements in the state of Tocantins and finds that these effects are not uniform across regions. While some areas experienced a significant reduction in the number of families facing difficulties in accessing the health system, other regions showed no statistically significant changes. Moreover, this study focuses on a limited set of indicators and does not examine multiple healthcare access outcomes across different levels of care. Looking at prenatal and postnatal care indicators, Guimarães et al. (2016) relied on two cross-sectional surveys conducted in different periods to compare descriptive changes in a single municipality in Acre following the construction of the Pacific–Oceanic highway. Although not a causal study, the authors concluded that, despite improvements in some indicators, they remained below the national average, suggesting that even though the highway facilitated access, territorial isolation continued to outweigh these improvements.

Taken together, this literature highlights two main gaps. First, most studies rely on descriptive evidence or before-and-after comparisons, limiting causal interpretation. Second, existing analyses typically focus on a narrow set of indicators or a single level of care, overlooking how infrastructure may affect different dimensions of healthcare access.

This dissertation contributes to the literature by explicitly addressing these limitations. By employing a Synthetic Difference-in-Differences strategy, the analysis provides causal evidence on the relationship between transportation infrastructure and access to healthcare in a highly constrained territorial context. In addition, the study examines multiple healthcare access outcomes across different levels of care, allowing for a more comprehensive assessment of how road improvements affect service utilization. In doing so, it provides novel evidence on the role of road infrastructure in reducing spatial inequalities in healthcare access in a remote region of the Legal Amazon.

This work is organized into six sections. The current section provides the introduction. Section 2 presents the institutional background. Section 3 outlines the identification strategy, empirical strategy, and data. Section 4 presents the results, and Section 5 brings the conclusions.

# 2 INSTITUTIONAL BACKGROUND

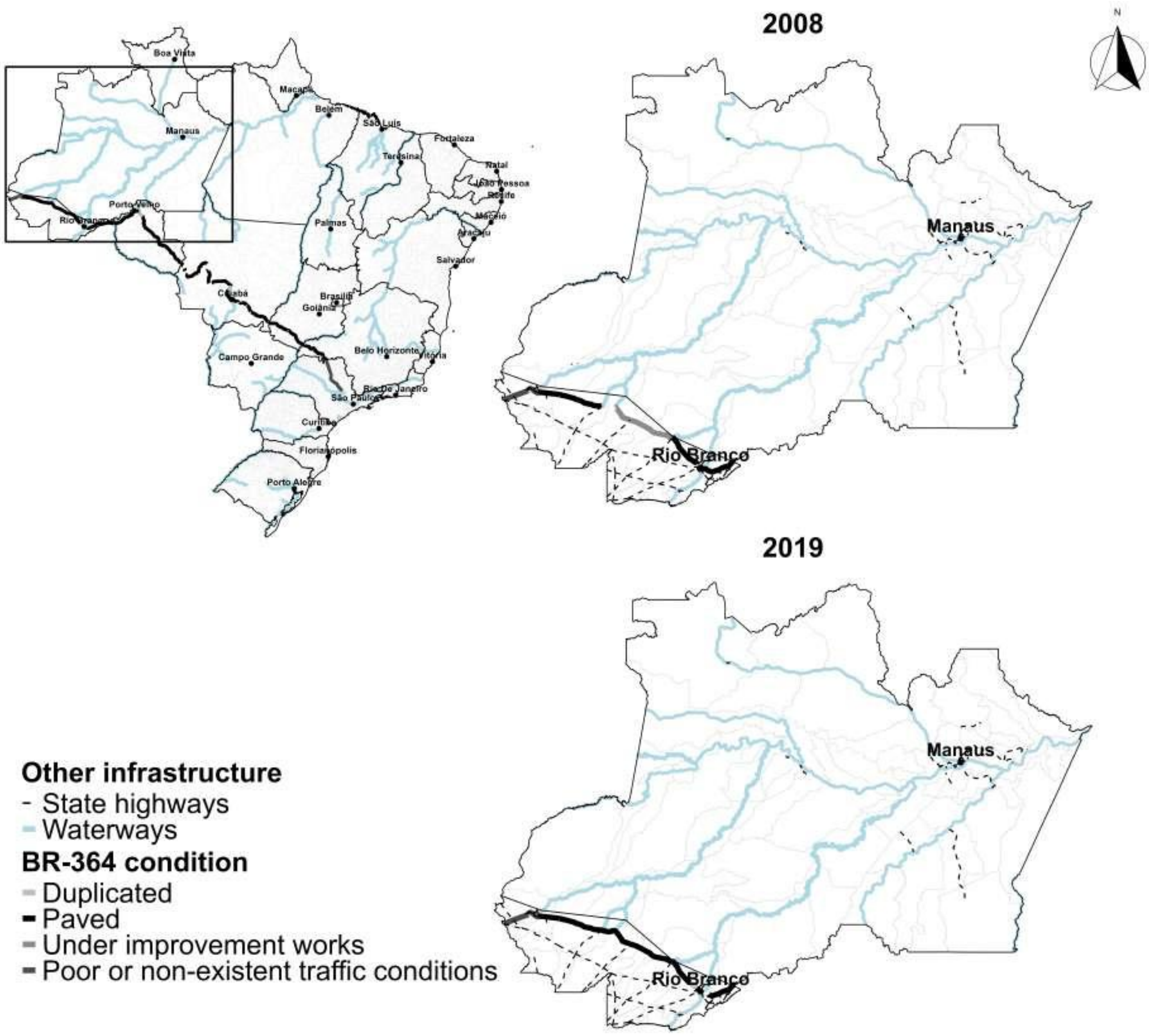
## 2.1 Highway BR-364

The construction of the Brasília–Acre highway (formerly BR-029, now BR-364) began in the 1950s during the administration of President Juscelino Kubitschek. Its main objectives were to integrate and populate the Amazon region and to stimulate the creation of a new agricultural frontier. The project aimed to connect Cuiabá, in Mato Grosso, to Porto Velho, in Rondônia, and subsequently link Acre to the rest of the country. When still designated as BR-029, traffic conditions were poor and nearly impassable during the rainy season due to the roads' unpaved condition. Nevertheless, even under these conditions, the route already catalyzed regional development, attracting workers seeking fertile land and facilitating the transport of agricultural products. When the highway was paved in the 1980s, it was officially designated BR-364 (Fiori, 2012). This was crucial for integrating the states of Acre and Rondônia with the rest of Brazil and for stimulating the economies of these previously isolated regions. Along the highway, settlements emerged that gave rise to the cities that exist today, driven by the migratory process encouraged by the road's construction (Fiori, 2012; Lima, 2022; Chein; Assunção; Lemos, 2009)

Although parts of the highway had been paved as early as the 1980s, several segments remained only partially improved for decades. In these sections, pavement was incomplete, and traffic depended on a rudimentary surface layer, substantially constraining mobility. In Acre, some of these stretches were still unpaved well into the 2000s. This situation changed markedly by 2012, as seen in Figure 1, following a major upgrade in the state's road infrastructure: the paving of the section connecting Tarauacá to Cruzeiro do Sul between 2007 and 2008 (Agência de Notícias do Acre, 2008; Agência de Notícias do Acre, 2009). These improvements strengthened connectivity between municipalities and directly affected the daily lives of local residents by easing mobility and access throughout the region (Chein; Pinto, 2015).

Within this broader process, the BR-364 played a central role. Stretching from the state of São Paulo to the westernmost part of Acre and crossing Goiás, Mato Grosso, and Rondônia, the highway underwent substantial upgrades during the period under analysis. In a general scenario in 2006, roughly 70% of the total length of the BR-364 was paved; by 2018, this share had increased to approximately 88%, underscoring the highway's importance as a backbone of regional integration and as a key conduit linking Acre to the rest of the country.

Figure 1 – BR-364




The Growth Acceleration Program (PAC), implemented during the 2007–2010 period, sought to promote economic growth, expand employment opportunities, and improve living standards nationwide. Within this framework, road infrastructure played a central role, with part of the program's investments directed toward the rehabilitation and paving of strategic segments of BR-364 in the state of Acre (Ministerio da Fazenda, 2007). The completion of the Cruzeiro do Sul–Tarauacá section represented a turning point in the state's social and economic dynamics. Approximately 25% of Acre's population directly benefited from the new infrastructure, which fostered regional integration and facilitated the circulation of goods and services. Beyond its effects on consumption, the paving also reshaped the region's geoeconomic structure, as freight traffic more than doubled relative to 2007, expanding the participation of truck drivers and other workers in the local economy (Agência de Notícias do Acre, 2008; Agência de Notícias do Acre, 2009).

Despite the financial resources allocated through the Growth Acceleration Program

(PAC), more than a decade elapsed before the project's primary objective was effectively achieved: connecting the westernmost region of Acre to Rio Branco and, consequently, to the rest of the country (Agência AC, 2021a; Agência AC, 2021b; AC24Horas, 2016; Departamento Nacional de Infraestrutura de Transportes, 2020). The road works, which had been underway since 2008, were only completed at the end of 2018, when approximately 99% of the BR-364 roadway had been paved, according to the National Transport Infrastructure Department (Departamento Nacional de Infraestrutura de Transportes, 2019). The final and most critical segment to be completed was the stretch between the municipalities of Feijó and Sena Madureira, whose paving ultimately closed the last gap in the highway. This intervention finalized the continuous road connection between Cruzeiro do Sul and Rio Branco, thereby enabling uninterrupted overland access between the state's western and eastern regions and substantially reducing the historical geographic isolation of the interior population.

## 2.2 Unified Health System (SUS)

Health is recognized by the 1988 Federal Constitution as a universal right and a duty of the State (Brasil, 1988). The creation of the Unified Health System (SUS) reflects the government's commitment to delivering healthcare at all levels of complexity, ranging from primary care to high-complexity treatments, free of charge and accessible to all individuals across Brazil.

Primary Health Care (PHC) in Brazil is primarily composed of basic health units, which are responsible for implementing actions and providing services focused on disease prevention and health promotion. Within these units, individuals have access to routine examinations and consultations, both with multidisciplinary teams and with family health specialists, aiming not only to deliver clinical care but also to promote the overall well-being of the community (Ministério da Saúde, 2022).

Moreover, the close and continuous contact between health professionals and the population enables the early identification of health risks, preventing complications that could otherwise be mitigated through timely intervention — such as in cases of diabetes, hypertension, and cardiovascular diseases (Ministério da Saúde, 2022).

The Secondary Level of Care, or medium complexity care, encompasses specialized services provided in hospitals and outpatient clinics. This level of care includes specialties such as pediatrics, orthopedics, cardiology, oncology, neurology, psychiatry, gynecology, and ophthalmology, among others. It ensures access to more complex diagnostic procedures and specialist consultations, complementing the care initiated within the Primary Health Care system (Ministério da Saúde, 2022).

In addition, the SUS provides high-complexity care services, which can be available in large general hospitals, university hospitals, and philanthropic institutions such as

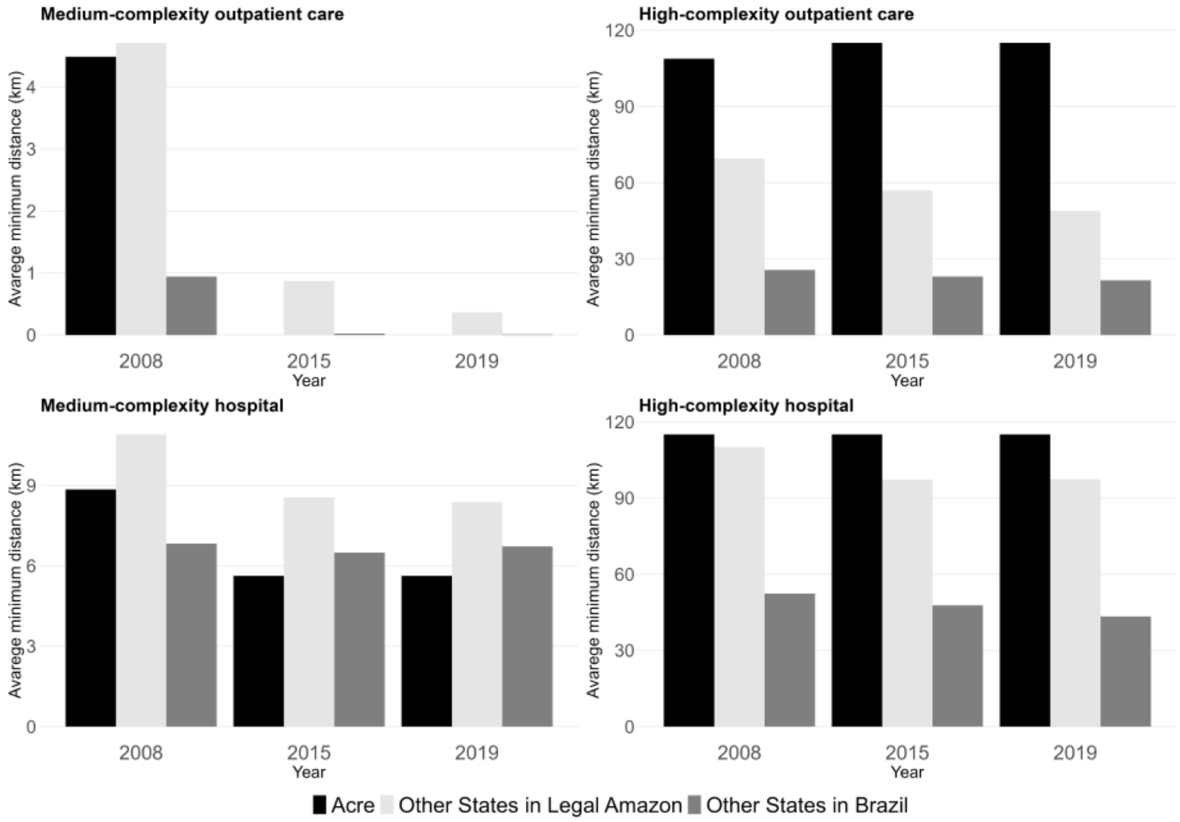
Santas Casas. These facilities are equipped with intensive care units, advanced surgical centers, and perform procedures that require cutting-edge technology and higher financial resources, such as oncological and cardiovascular treatments, organ transplants, and high-risk deliveries. At this level of care, health professionals are trained to manage conditions that fall beyond the scope of primary and secondary care, thereby ensuring the comprehensiveness and continuity of healthcare within the SUS framework (Ministério da Saúde, 2022).

The SUS is grounded in three fundamental principles: universality, equity, and comprehensiveness. Universality ensures that health is a right of all citizens and a duty of the State, meaning that access to healthcare services must be guaranteed to every individual, regardless of gender, race, occupation, or any other social or personal characteristic. Equity aims to reduce social and regional disparities in access to health services. While everyone has the right to healthcare, people have different needs; thus, equity involves allocating more resources to those in situations of greater vulnerability, recognizing that unequal conditions require unequal responses. Comprehensiveness refers to the provision of care that considers the person as a whole, addressing their physical, mental, and social needs. This principle encompasses actions ranging from health promotion and disease prevention to treatment and rehabilitation. It also emphasizes the need for intersectoral collaboration with other public policies that influence health and quality of life (Ministério da Saúde, ).

Building on these principles, the organization of the SUS increasingly relies on Health Care Networks (RAS), which the Ministry of Health formally defined as integrated arrangements of services with different technological densities designed to ensure continuity and comprehensiveness of care. These networks operate within clearly defined territories and populations, whose needs guide the planning and supply of services. Primary Health Care functions as the system's entry point and care coordinator, while specialized and hospital services complete the full cycle of prevention, diagnosis, treatment, rehabilitation, and palliative care. The effective operation of the RAS depends on unified governance across the territory, coordinated clinical and logistical support systems, robust information flows, qualified health professionals, and stable tripartite financing aligned with network goals. Organized around complete care pathways for specific health conditions, the RAS model seeks to strengthen regionalization by grouping municipalities into health regions that share social, cultural, and infrastructural characteristics, thereby promoting cooperative management and reinforcing the constitutional principles of universality, equity, and comprehensiveness within the SUS (Ministério da Saúde, 2010; Porter; Teisberg, 2007; Mendes, E., 2011).

It is important to understand the health scenario in Acre in comparison with other states in the Legal Amazon, as well as with Brazil as a whole, in order to understand how the dynamics of this region work. For this, Figure 2 presents the minimum average distance to health care facilities by class and level of complexity.

Figure 2 – Distance to Health Care Infrastructure - Acre, Legal Amazon, and Brazil




Source: authors' own elaboration, 2026.
Note: Distances are calculated from the municipal seat to the nearest municipal seat that hosts a SUS-affiliated facility in the corresponding category. This measure is computed annually using data from the National Registry of Health Facilities (CNES), made available by DATASUS. The average distance is obtained by summing the minimum distances within each reference group and dividing by the number of municipalities in that group.

For medium-complexity outpatient and hospital care, a similar pattern can be observed. There is a reduction in average distances over time, particularly in Acre, which moved from relatively higher values compared to other states in Brazil in 2008 to much shorter distances in 2010 and 2018. This pattern suggests a substantial expansion in the provision of medium-complexity services,thereby reducing access inequalities over the period analyzed.

In contrast, when considering high-complexity outpatient care—comprising technologically advanced and high-cost diagnostic procedures, as well as more specialized and complex treatments—the situation in Acre is considerably worse than in the other states analyzed (Ministério da Saúde, 2022). On average, the population in Acre needs to travel approximately 120 km to access this type of facility, and this pattern persists over time, indicating a sustained spatial concentration of high-complexity outpatient services.

A similar trajectory is observed for high-complexity hospitals in Acre and in the other states of the Legal Amazon. However, when compared to the rest of Brazil, the difference in average distance is striking. In 2008, individuals in the Legal Amazon had to travel, on average, more than 100 km to access high-complexity hospital care, whereas in the remainder of the country this distance was less than half of that value. This highlights a persistent and pronounced regional disparity in access to specialized hospital services.

Nevertheless, it is important to emphasize that the mere presence of a high-quality hospital, if not properly integrated into a health care network that includes primary care and secondary outpatient services, does not guarantee improvements in population health outcomes when services operate in isolation (Mendes, E., 2011). Overall, between 2008 and 2019, there was an expansion in the supply of most types of health services—particularly at the medium-complexity level—suggesting an increase in installed health care capacity over the period. Complementing Figure 2, Figure 3 reports the average minimum distance to different categories of hospital beds across Acre, the Legal Amazon, and Brazil. When focusing on clinical hospital beds[1], this category exhibits greater capillarity and relatively small disparities across groups. Average distances are lower and more homogeneous, indicating a broader and more evenly distributed supply of basic inpatient care.

In contrast, the access gap becomes substantially larger for surgical beds[2] and for urgency and emergency beds[3]. For these categories, Acre consistently displays average minimum distances that are more than twice those observed in other states within the Legal Amazon and in the rest of Brazil. This pattern suggests that limitations in transportation infrastructure may be particularly consequential in emergency situations, when timely access to hospital care is critical.

Finally, reflecting the spatial distribution of high-complexity outpatient care services and high-complexity hospitals, intensive care unit (ICU) beds [4] exhibit extremely large average distances in Acre. These findings underscore the state's severe spatial in accessing high-complexity care and reinforce the role of geographic isolation and infrastructure deficits in shaping inequalities in access to critical health services.

When analyzing some diagnostic equipment essential for providing health diagnoses, the situation in Legal Amazonia as a whole appears even more concerning, especially when we look to more complex equipment. In Figures 4 and 5, we present the minimum distance to four different types of diagnostic equipment: x-ray, ultrasound devices, computed tomography (CT), and magnetic resonance imaging (MRI). In all cases, the minimum distance to one of these devices in 2008 appears to be significantly higher than in 2019.

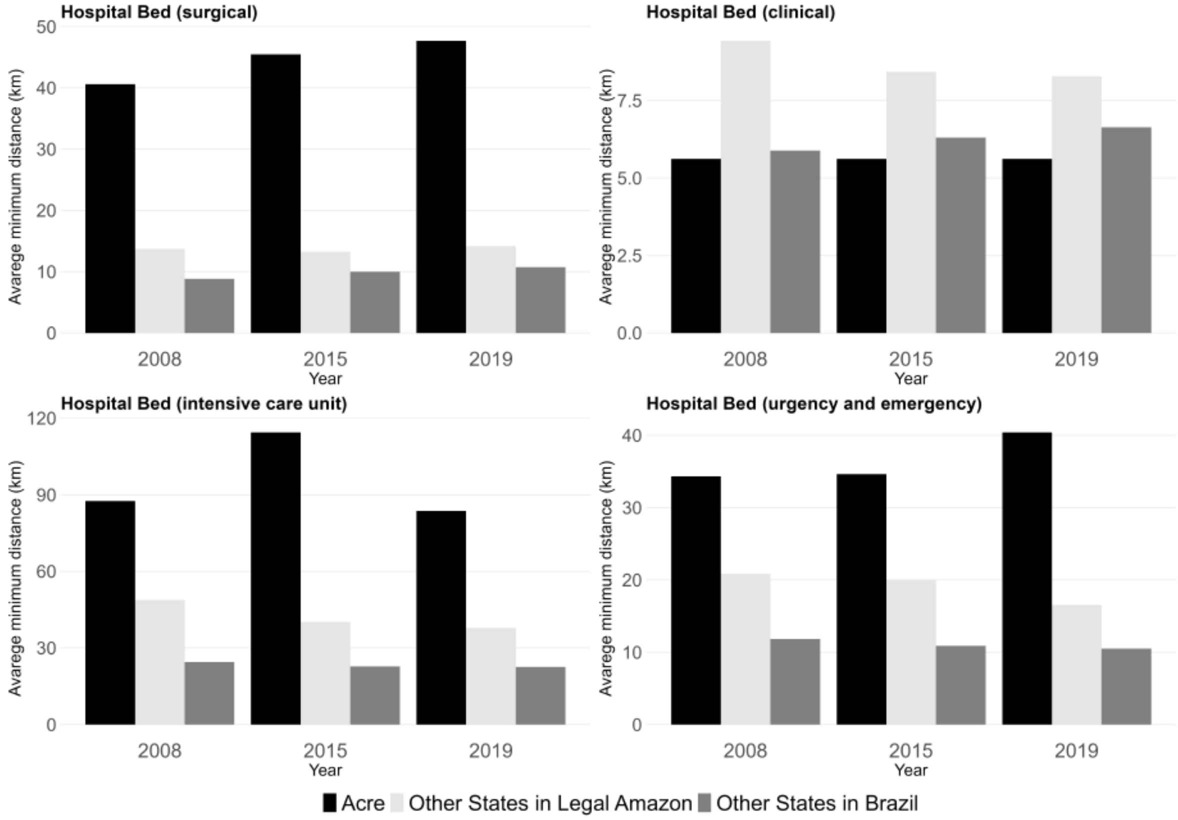
[1] Hospital inpatient beds intended to accommodate patients from any clinical specialty (Empresa Brasileira de Serviços Hospitalares, 2016).

[2] Hospital inpatient beds intended to accommodate patients from any surgical specialty (Empresa Brasileira de Serviços Hospitalares, 2016).

[3] Observation beds intended to provide immediate care to patients for periods shorter than 24 hours, classified according to risk and vulnerability (Empresa Brasileira de Serviços Hospitalares, 2016).

[4] Inpatient beds intended for patients requiring specialized care and specific infrastructure, such as isolation units and intensive or semi-intensive treatment units (Empresa Brasileira de Serviços Hospitalares, 2016).

Figure 3 – Distance to Hospital Beds - Acre, Legal Amazon, and Brazil



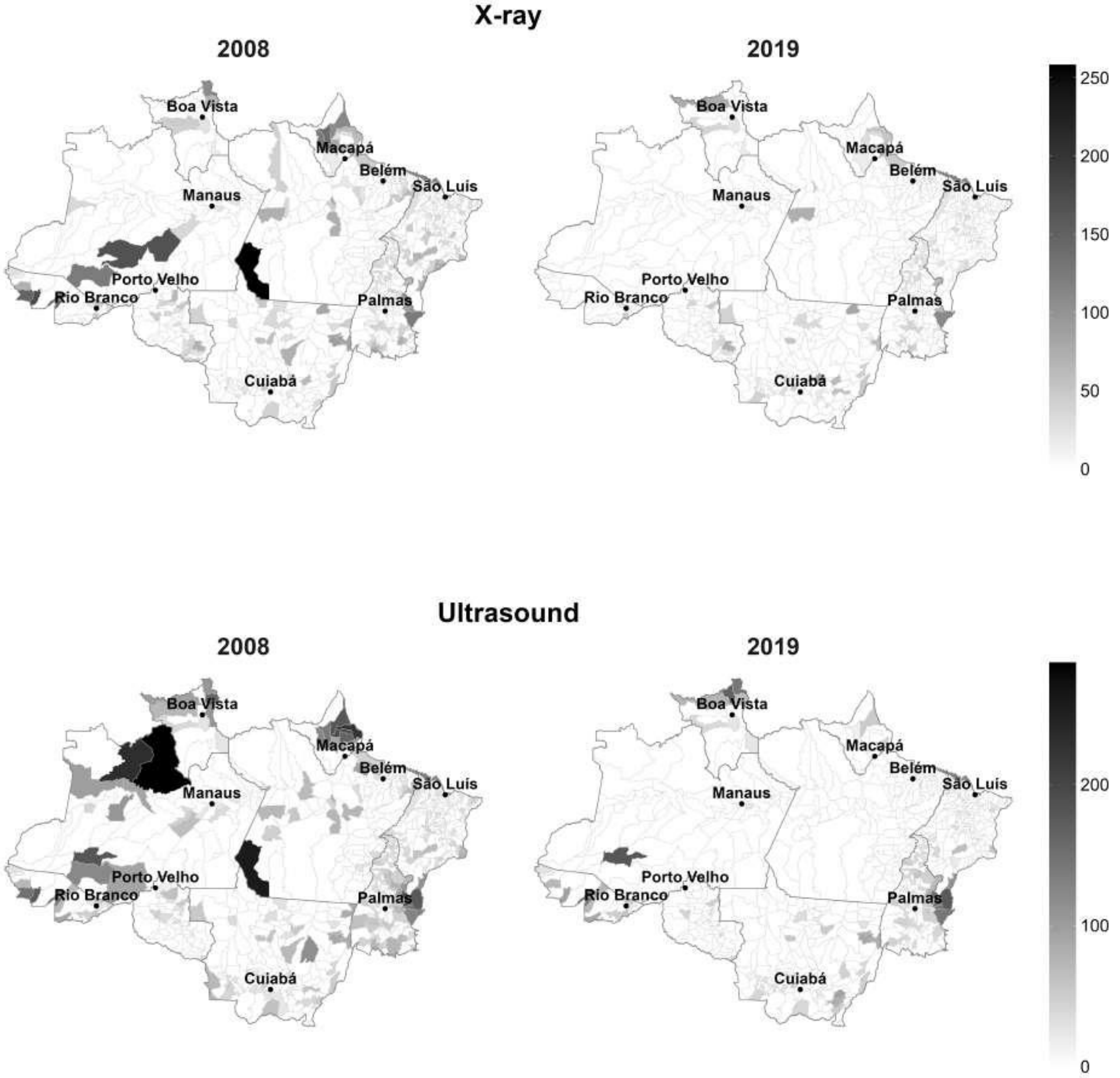

Source: authors' own elaboration, 2026.
Note: Distances are calculated from the municipal seat to the nearest municipal seat that hosts a SUS-affiliated facility in the corresponding category. This measure is computed annually using data from the National Registry of Health Facilities (CNES), made available by DATASUS. The average distance is obtained by summing the minimum distances within each reference group and dividing by the number of municipalities in that group.

The Figure 4 illustrates substantial changes in spatial access to medium-complexity medical imaging equipment between 2008 and 2019 across the Brazilian Legal Amazon as a whole. In 2008, access to both X-ray and ultrasound services was uneven, with large clusters of municipalities exhibiting very high minimum Euclidean distances to the nearest facility. These patterns are particularly pronounced in the western and northern portions of the region.

By 2019, the spatial distribution of distances changed markedly for both types of equipment. For X-ray services, Figure 4 shows a clear reduction in high-distance areas, indicating a broader spatial diffusion of facilities and improved regional coverage. Municipalities that, in 2008, faced long travel distances to the nearest provider appear substantially closer in 2019, suggesting an expansion of basic diagnostic infrastructure over the period.

A similar—yet more pronounced—pattern emerges for ultrasound equipment, which more closely reflects the distance parameters established by Brasil. Ministério da Saúde (2015), according to which adequate access should be ensured within a 30 km radius of

Figure 4 – Minimum Euclidean distance to X-ray and Ultrassond




Source: authors' own elaboration, 2026.
Note: Distances are calculated from the municipal seat to the nearest municipal seat that hosts a SUS-affiliated medical imaging equipment in the corresponding category. Distances are computed annually using information of the number of X-ray and Ultrasound available from the National Registry of Health Facilities (CNES), made available by DATASUS.

such equipment. In 2008, large areas—especially in the western Amazon—display very high distances, highlighting severe access constraints. By 2019, these dark, high-distance clusters largely disappear, and distances become considerably more homogeneous across municipalities. This shift points to a significant decentralization of ultrasound services and a reduction in geographic disparities in access.

Overall, the comparison between 2008 and 2019 suggests a meaningful improvement in spatial access to medium-complexity diagnostic services, with reductions in both the level and dispersion of minimum distances. These patterns are consistent with an expansion of health infrastructure over time and imply lower travel costs for accessing diagnostic care, particularly in previously underserved areas.

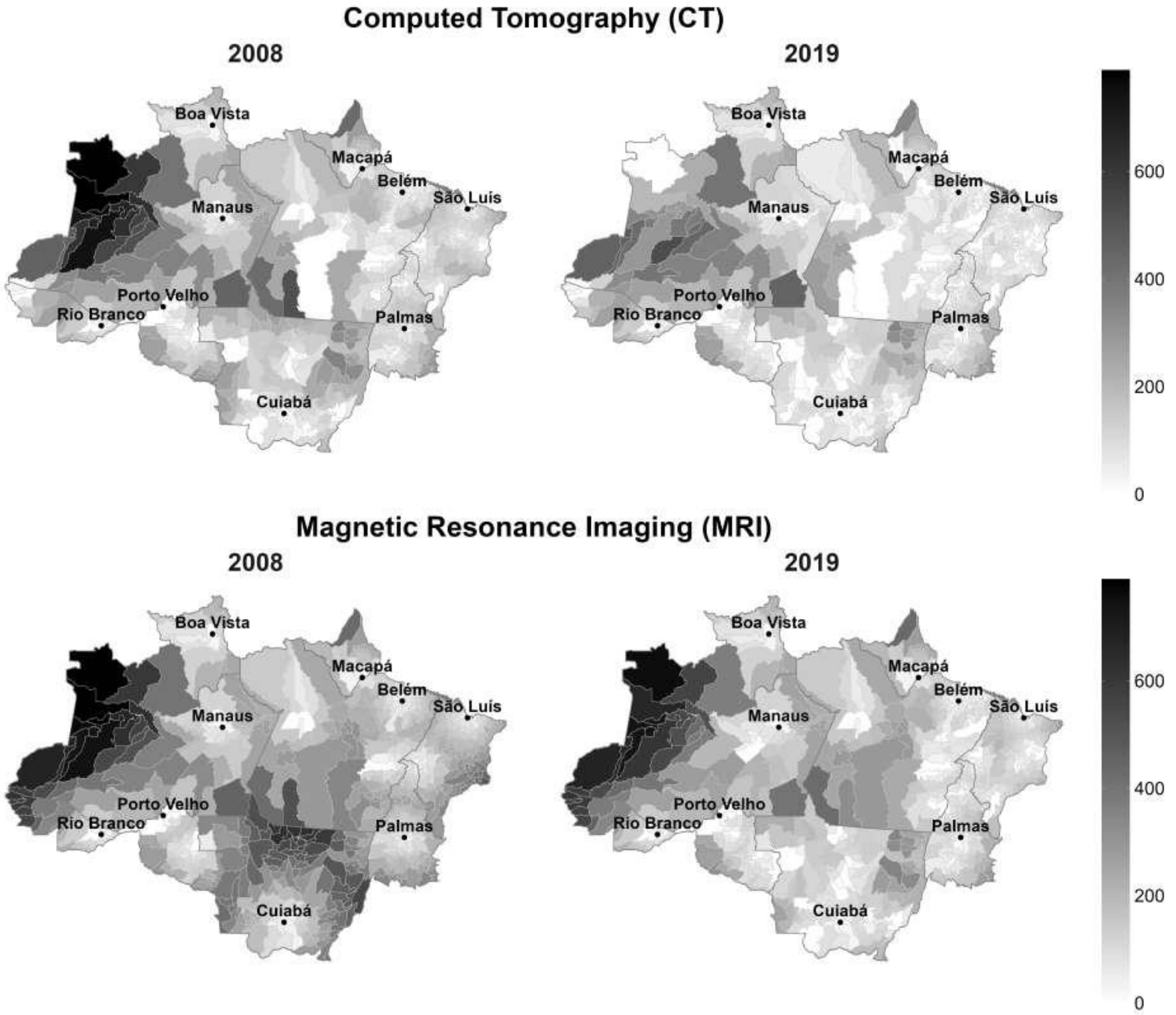
In contrast to the previous figure, which depicted the spatial distribution of distances to less complex health services, Figure 5 focuses exclusively on high-complexity medical imaging equipment. Consequently, the spatial pattern observed here differs markedly, revealing substantially greater geographic disparities across the Legal Amazon. Computed tomography (CT) and magnetic resonance imaging (MRI) are concentrated in a limited number of urban centers, resulting in much longer average distances for large portions of the territory, particularly in more remote municipalities.

These disparities are especially relevant when compared to the planning parameters established by Brasil. Ministério da Saúde (2015). For CT exams, the guidelines recommend the availability of at least one piece of equipment within a 75 km radius or one unit per 100,000 inhabitants. For MRI, the allocation of equipment should ensure user access within a maximum travel distance of 30 km or a travel time of up to 60 minutes.

This Figure highlights the persistence of spatial inequalities over time. While there is some reduction in distances in certain areas between 2008 and 2019—suggesting an expansion of high-complexity services—the overall pattern remains one of strong spatial concentration, especially for MRI. Large parts of the western and northern Legal Amazon continue to exhibit high distances, indicating persistent barriers to access to advanced diagnostic technologies despite improvements over the period.

In this context, where long distances pose a major barrier to access to diagnostic equipment and to medium- and high-complexity healthcare services, improvements in transport infrastructure are a crucial mechanism for reducing regional disparities and enhancing health outcomes. By lowering travel costs, shortening travel times, and strengthening connectivity between municipalities, investments in road infrastructure can play a central role in expanding effective access to healthcare, particularly in remote and under served areas.

Figure 5 – Minimum Euclidean distance to Computed Tomography and Magnetic Resonance




Source: authors' own elaboration, 2026.
Note: Distances are calculated from the municipal seat to the nearest municipal seat that hosts a SUS-affiliated medical imaging equipment in the corresponding category. Distances are computed annually using information of the number of Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) available from the National Registry of Health Facilities (CNES), made available by DATASUS.

# 3 EMPIRICAL STRATEGY

## 3.1 Identification Strategy

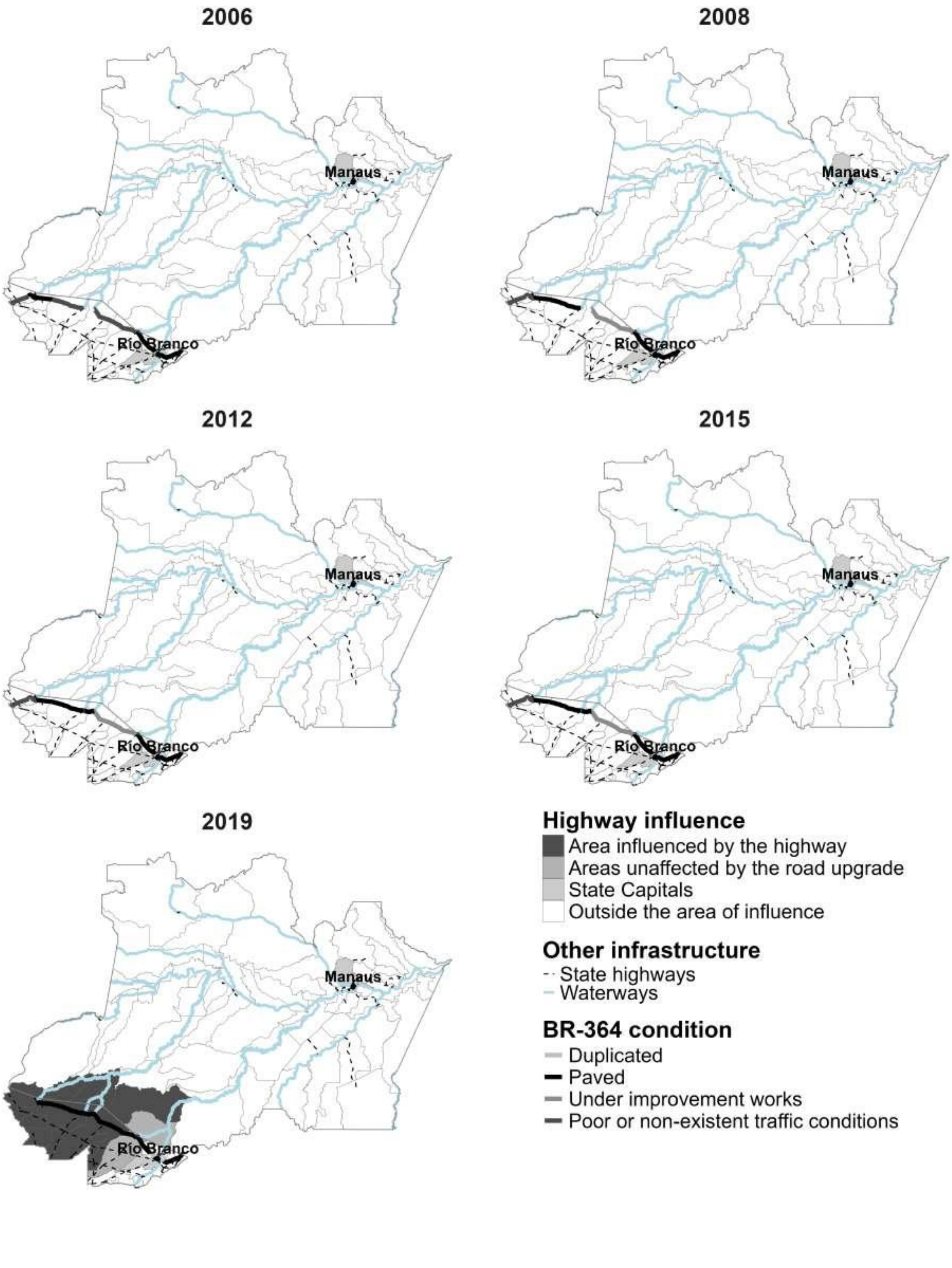
Figure 6 illustrates the spatial evolution of transportation infrastructure associated with BR-364 in the state of Acre and highlights the exogenous infrastructure shock exploited in this study: the paving and upgrading of previously unpaved road segments along the BR-364. By documenting changes in road conditions over time, the figure provides direct visual evidence of the timing and location of this intervention, which substantially altered terrestrial connectivity in a region historically characterized by high transportation costs and strong reliance on waterways (Sousa; Cortes, 2024). The panel structure by year further allows for a clear identification of when and where these improvements occurred, reinforcing their role as the primary source of exogenous variation used for causal inference.

Between 2006 and 2008, Figure 6 documents the paving of the BR-364 segment connecting the municipalities of Tarauacá and Cruzeiro do Sul, respectively the third- and second-most populous cities in the state of Acre (IBGE, 2024). While this initial intervention represents an improvement in local road conditions, it does not establish direct terrestrial access between the Juruá Valley and the state capital, Rio Branco, where higher-complexity health services are concentrated. Consequently, despite improvements in intra-regional connectivity, this first phase is unlikely to generate substantial changes in access to specialized services, thereby limiting its potential effects on health-related outcomes.

A second infrastructure shock occurs at the end of 2018, when the final paving segment is completed, connecting the municipalities of Feijó and Sena Madureira and thereby establishing continuous road access between Cruzeiro do Sul and Rio Branco. This event constitutes the source of exogenous variation exploited in this study, as it produces a discrete and permanent increase in terrestrial connectivity between the Juruá Valley and the state's main regional hub. The timing of this intervention sharply alters travel conditions, reducing geographic isolation and plausibly lowering the cost of accessing higher-complexity health services.

By explicitly depicting the interaction between the paved BR-364, state highways, and the hydrographic network, Figure 6 further supports the identification strategy by illustrating potential spillover channels. In particular, the figure suggests that the effects of the road intervention may extend beyond municipalities directly crossed by BR-364, affecting neighboring areas connected through complementary transportation infrastructures.

Figure 6 – Mapping Affected Areas in BR-364




Source: authors' own elaboration, 2026.

In this sense, the map plays a central role in the geographical contextualization of the empirical strategy adopted in this paper, as it makes explicit the criteria used to define the treatment and control groups and illustrates the potential spatial channels through which improvements in BR-364 may affect the outcomes analyzed over time.

Table 1 complements Figure 6 by providing a detailed breakdown of the municipalities included in the analysis. The table reports the number of municipalities assigned to the treatment group—defined as those affected by the upgrading of the BR-364 highway segment—as well as the number of municipalities that constitute the donor pool used for identification. The infrastructure improvement directly affected the municipalities of Cruzeiro do Sul, Tarauacá, Feijó, and Manuel Urbano, which are located along the upgraded segment. In addition, the intervention generated indirect exposure in neighboring municipalities that share borders with the directly affected areas, hereafter referred to as first-order neighbors. These include Rodrigues Alves, Mâncio Lima, Marechal Thaumaturgo, Jordão, Santa Rosa, and Porto Walter in the state of Acre, as well as Ipixuna, Envira, Eirunepé, Guarajá, and Pauini in the state of Amazonas.

The donor pool comprises all remaining municipalities within the Legal Amazon municipalities, aggregated at the minimum comparable area level to account for municipal splits over the study period. To enhance comparability, the donor pool excludes any municipality directly or indirectly affected by improvements in other major road infrastructures. State capitals are also excluded due to their distinct economic structure and superior access to infrastructure, and we also excluded municipalities in Maranhão outside Legal Amazon region. In addition, two other municipalities potentially not affected by the BR-364 upgrading are excluded. Under these criteria, the final donor pool consists of 357 municipalities.

Table 1 – Number of Municipalities Affected by Highway's Segment – BR-364

| **Municipalities** | **Treated** | **Donor Pool** | **Number** |
|---|---|---|---|
| Directly affected | X | | 4 |
| First-order spatial neighbors | X | | 11 |
| State Capitals | | | 9 |
| Areas potentially affected by other highway improvements | | | 406 |
| Donor Pool | | X | 357 |
| **Total sample** | | | 372 |

*Data from Legal Amazonia Municipalities.

## 3.2 Empirical Specification

The descriptive evidence presented in the previous sections indicates that a conventional Difference-in-Differences (DID) framework is unlikely to be appropriate in this context. Prior to the paving of the BR-364 segment, municipalities in Acre presented a worse health system situation to those observed in other municipalities in the Amazon region and also treated and control units were on distinct paths even in the pre-treatment period. As a result, the parallel trends assumption underlying standard DID estimators is violated, which precludes a credible causal interpretation of DID estimates in this setting, as emphasized by Roth (2022).

To address these challenges, this paper adopts the Synthetic Difference-in-Differences (SDID) estimator proposed by Arkhangelsky et al. (2021). The SDID approach is particularly well suited to empirical environments characterized by selective treatment assignment and systematic differences in pre-treatment dynamics between treated and untreated units. By combining elements of the traditional DID design with the data-driven weighting structure of the Synthetic Control method, SDID relaxes the stringent identifying assumptions of standard DID while retaining a transparent and interpretable regression-based framework.

The estimator is implemented using a balanced panel of municipalities observed over multiple years, in which a subset becomes exposed to the treatment following the paving of BR-364. In the first step, SDID constructs unit weights for control municipalities so that their weighted average closely replicates the pre-treatment outcome trajectory of the treated group, in the spirit of the Synthetic Control approach. In a second step, time weights are assigned to balance pre- and post-treatment periods, accounting for common shocks and differential time patterns. These unit and time weights are then incorporated into a two-way fixed effects structure, effectively localizing the DID comparison to the most comparable units and periods. By downweighting poorly matched comparisons and removing predictable components of the outcome, SDID improves both robustness and statistical efficiency.

Formally, the data can be represented as an $N \times T$ matrix, where $N$ denotes the number of municipalities observed over $T$ time periods. Let $N_0$ denote the number of control units and $N_1 = N - N_0$ the number of treated units. Similarly, let $T_0$ denote the number of pre-treatment periods and $T_1 = T - T_0$ the number of post-treatment periods. The estimand of interest, the average treatment effect on the treated (ATT), can be written as:

$$\widehat{ATT} = \frac{1}{N_1} \sum_{i=N_0+1}^{N} \left( \frac{1}{T_1} \sum_{t=T_0+1}^{T} Y_{it} - \frac{1}{T_0} \sum_{t=1}^{T_0} \lambda_t Y_{it} \right) - \sum_{i=1}^{N_0} \omega_i \left( \frac{1}{T_1} \sum_{t=T_0+1}^{T} Y_{it} - \sum_{t=1}^{T_0} \lambda_t Y_{it} \right) \quad (3.1)$$

In this expression, $Y_{it}$ denotes the outcome variable for municipality $i$ in period $t$, $\omega_i$ represents the weight assigned to control unit $i$, satisfying $\sum_{i=1}^{N_0} \omega_i = 1$, and $\lambda_t$ denotes the weight assigned to pre-treatment period $t$, satisfying $\sum_{t=1}^{T_0} \lambda_t = 1$. The first term on the right-hand side captures the difference between post- and pre-treatment average outcomes for the treated municipalities, while the second term represents the analogous weighted difference for the control group. The ATT is thus obtained by comparing the treated group to a synthetic counterfactual constructed from optimally weighted control units and time periods.

The use of SDID is particularly appropriate in the context of transportation infrastructure investments such as highway paving, where spillovers, spatial heterogeneity, and gradual adjustment dynamics are likely to play a central role. Improvements in connectivity may affect municipalities differently depending on their geographic location, baseline conditions, and exposure intensity, generating heterogeneous treatment effects that standard DID estimators are ill-equipped to capture. By allowing for flexible weighting across municipalities and over time, SDID accommodates these complexities in a principled manner.

An additional challenge in this setting concerns the choice of covariates. Several potential predictors of health outcomes—such as income, access to health services, or demographic composition—are plausibly affected by the improvement of BR-364 itself. Including such variables would introduce post-treatment bias and compromise causal interpretation. At the same time, observable municipal characteristics that are unlikely to be influenced by the intervention often exhibit limited explanatory power, particularly in contexts characterized by strong structural inequalities.

Given these concerns, the empirical specification relies exclusively on lagged outcome variables to construct the synthetic counterfactual. Specifically, the full pre-treatment trajectory of each outcome is used to balance treated and control municipalities. This strategy avoids endogeneity while ensuring comparability based on observed historical dynamics. Although this approach restricts the set of predictors, it represents a coherent and transparent solution in contexts where high-quality, exogenous covariates are scarce.

In sum, the SDID framework allows this paper to estimate the causal effects of the BR-364 paving project despite the presence of selection bias, non-parallel pre-treatment trends, and limited availability of valid covariates. By grounding identification in observed pre-treatment dynamics and leveraging flexible weighting across units and time, the approach provides a transparent and robust basis for evaluating the impacts of transportation infrastructure in the Amazon region.

### 3.3 Data

This study integrates multiple data sources in Brazil to analyze the relationships between transportation infrastructure and healthcare accessibility. For the estimation, we use a balanced panel covering the period from 2012 to 2019, comprising the municipalities defined in the identification strategy described in Table 1. The final dataset includes a total of 2,976 observations.

### 3.3.1 Highways

For the main part of our analysis, we use data from the National Department of Transport Infrastructure (DNIT) to construct both the treatment group and the donor pool. Specifically, we rely on information from the National Road System (Sistema Nacional de Viação – SNV)[1] and the National Transport Plan (Plano Nacional de Viação – PNV)[2]. When combined, these datasets allow us to track changes in the quality of the Brazilian road network over time, enabling the identification of municipalities in the Brazilian Legal Amazon that were affected by upgrades to other highways between 2000 and 2020.

In addition, the DNIT datasets provide detailed information on the road network, including geometric attributes, reference years, and categorical indicators describing the surface conditions of each road segment. This information allows us to precisely monitor the evolution of paving conditions along BR-364 in the state of Acre and to accurately characterize the timing and spatial extent of the infrastructure improvements analyzed in this study.

### 3.3.2 Outpatient Information System (SIA)

Our second data source is the Outpatient Information System (SIA), provided by DATASUS, using the Individualized Outpatient Production Bulletin (BPA-I) as the underlying record. This dataset enables the identification of both the municipality of residence and the municipality where care was provided, allowing us to analyze not only the total number of outpatient procedures but also to distinguish between procedures performed within and outside the patient's municipality of residence. In addition, the BPA-I contains detailed information on the type of procedure delivered, allowing for a fine-grained classification of outpatient care.

To construct a balanced panel, observations were aggregated by year and by the minimum comparable area (AMC) of individuals' municipality of residence. The final dataset was further enriched by merging AMC-level population data, thereby ensuring comparability over time.

From this dataset, we construct the following outcomes [3] aggregated by procedure group according to the classification of Ministério da Saúde (2025a): procedures with diagnostic purposes and clinical procedures (appointments). We further disaggregated these outcomes by procedure subgroups, namely specimen collection, clinical laboratory diagnostics, radiology, ultrasonography, computed tomography, magnetic resonance imaging, endoscopy, specialist diagnostic procedures, and rapid diagnostic testing.

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[1] 2011–present
[2] 1983–2010
[3] All outcomes are weighted by 100,000 inhabitants

### 3.3.3 Hospital Information System (SIH)

Our third data source is the Hospital Information System (SIH), provided by DATASUS. This database enables us to identify both the municipality of residence and the municipality where the hospitalization occurred, allowing us to analyze not only the total number of hospitalizations but also to distinguish between hospitalizations occurring within and outside the patient's municipality of residence. In addition, the SIH contains detailed information based on the ICD-10 classification, which enables the aggregation of hospitalizations by disease chapters and facilitates the analysis of cause-specific outcomes (Ministério da Saúde, 2025b).

To construct a balanced panel, the data were aggregated by year and by minimum comparable area (AMC) of the individuals' municipality of residence. The resulting dataset was further enriched by merging AMC-level population data, which ensures comparability across areas and over time.

Using this dataset, we construct the following outcomes[4], aggregated by ICD-10 chapter according to the classification of Ministério da Saúde (2025b): infectious and parasitic diseases; neoplasms; diseases of the circulatory system; diseases of the nervous system; pregnancy, childbirth and the puerperium; and injury, poisoning, and certain other consequences of external causes. We also consider the total number of hospitalizations as an aggregate outcome.

[4] All outcomes are weighted by 100,000 inhabitants

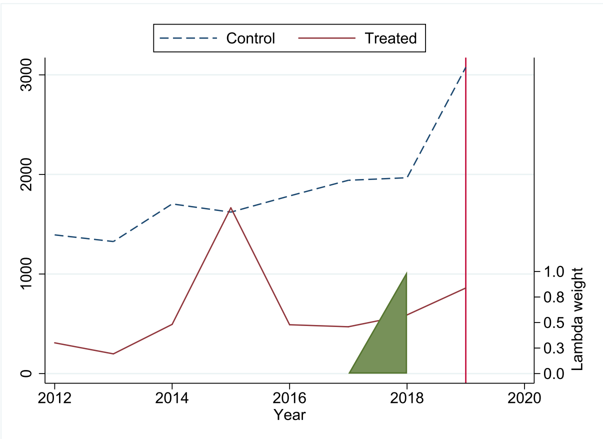
# 4 RESULTS

Based on the econometric model presented in the empirical strategy section, results were estimated to identify the impact of the improvements to BR-364 on healthcare visits, diagnostic examinations, and hospitalizations.

## 4.1 Outpatient Information System (SIA)

In Table 2 and Figure 8[1], there is a statistically significant reduction in the number of clinical procedures performed outside the municipality, while the estimated effect within the municipality is positive but not statistically significant. One possible explanation is that improvements in road infrastructure may have reduced transportation costs for health professionals, potentially facilitating their presence in more isolated municipalities. With improved connectivity, professionals who previously worked or provided care primarily in regional hubs may have become more likely to travel to these municipalities. As a result, activity outside the municipality may decline, even in the absence of a statistically significant increase within the municipality, possibly reflecting changes in the spatial allocation of service provision rather than migration to other municipalities.

Figure 7 – Synthetic Difference-in-Differences estimates for clinical procedures outside the municipalities




This pattern is consistent with the literature that highlights persistent difficulties in attracting and retaining specialized health professionals in remote and underserved areas (Almeida et al., 2019; Silva et al., 2017; Das et al., 2016). In this context, improvements in road infrastructure likely promote primarily a spatial reallocation of service provision, reducing the need for patients to travel to regional hubs rather than inducing an increase in consultations outside the municipality.

[1] Figures related to results without statistical significance are presented in the Appendix.

Table 2 – ATT on Clinical Procedures weighted by 100,000 inhabitants

| Outcome | Total | Inside [2] | Outside [3] |
|---|---|---|---|
| Clinical Procedures | 271.040 | 910.532 | -858.310 *** |
| (appointments) | (1,970.988) | (2,018.543) | (285.153) |
| Number of observations | 2.976 | 2.976 | 2.976 |

Notes: Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.
1.Inside the municipality
2.Outside the municipality

Table 3 and Figure 8[4] report the results for the provision of diagnostic tests, weighted by 100,000 inhabitants. The findings indicate that road improvements had heterogeneous effects on the use of diagnostic services, generating important changes not only in overall volumes but, more notably, in the spatial distribution of tests between those performed within and outside the treated municipality. At the aggregate level, although there is a positive but not statistically significant effect on the total number of diagnostic tests or within municipalities, suggesting that the intervention did lead to a expansion in diagnostic inside demand, this hypotheses is reinforced by the statistically significant reduction in total diagnostic tests outside the municipalities.

This interpretation is reinforced by the strongly significant and negative results observed for clinical laboratory diagnostics and for rapid diagnostic testing performed outside the municipality. For these categories, there is a substantial and statistically significant reduction in tests performed outside the municipality, accompanied by an increase—albeit not statistically significant—in tests conducted within the municipality. This pattern indicates that improvements in road infrastructure may have strengthened local diagnostic capacity and reduced the need for patients to travel to other municipalities to access these services, following improvements in access, logistics, and the availability of trained professionals.

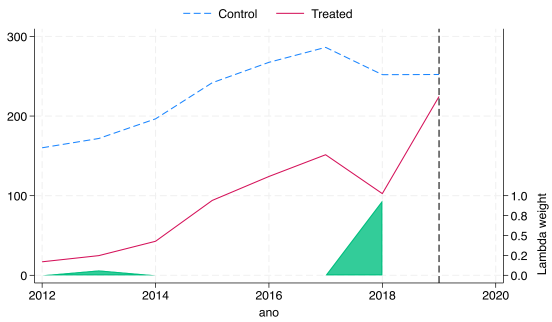
In contrast, technologically intensive exams, such as magnetic resonance imaging, exhibit a significant increase in both total volume and tests performed outside the municipality. This result is consistent with the notion that improved road connectivity facilitated access to highly specialized services concentrated in regional hubs—as illustrated in Figure 5—thereby expanding the use of these exams without necessarily implying an expansion of local supply.

However, the significant reduction in total endoscopy exams indicates that network reorganization and gains in referral efficiency may have reduced the use of invasive diagnostic procedures or shifted part of this demand to other levels of care not captured within this category. Taken together, these results suggest that road improvements

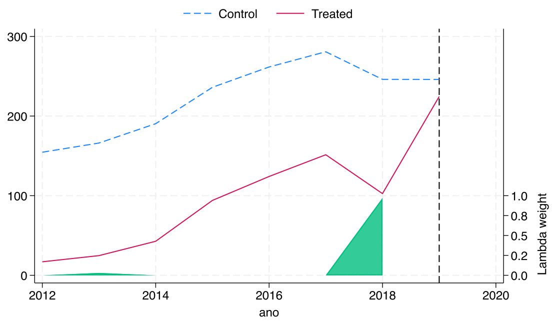
[4] Figures related to results without statistical significance are presented in the Appendix.

operate less as a pure demand shock for diagnostic services and more as a mechanism of integration and reorganization of the health system, reshaping the mix of diagnostic tests, reducing geographic barriers to specialized care outside the municipality, and simultaneously strengthening the availability and effectiveness of local diagnostic services.

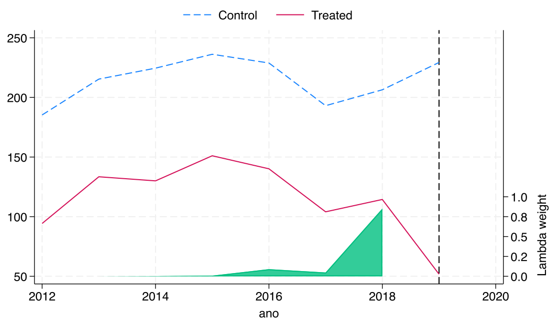
Figure 8 – Synthetic Difference-in-Differences estimates for diagnostic tests



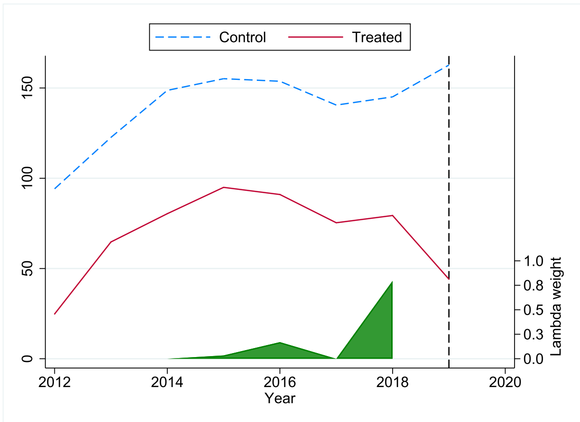

(a) Total – Magnetic Resonance Imaging



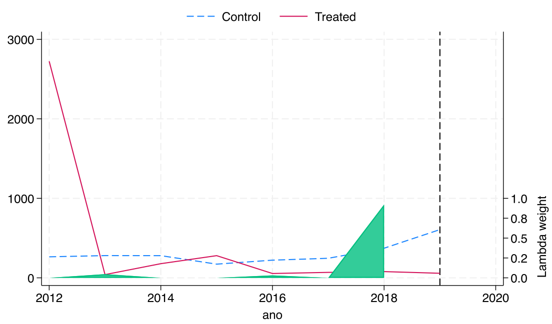

(b) Outside – Magnetic Resonance Imaging



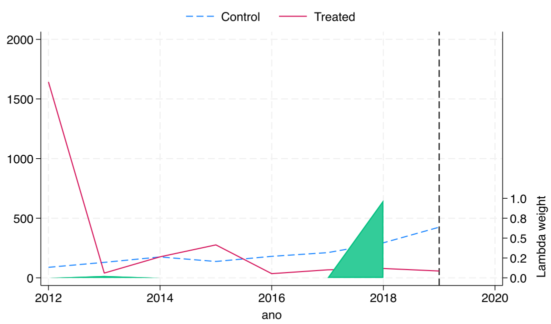

(c) Total – Endoscopy



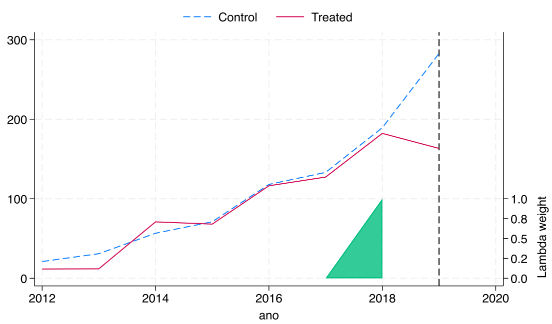

(d) Outside – Endoscopy



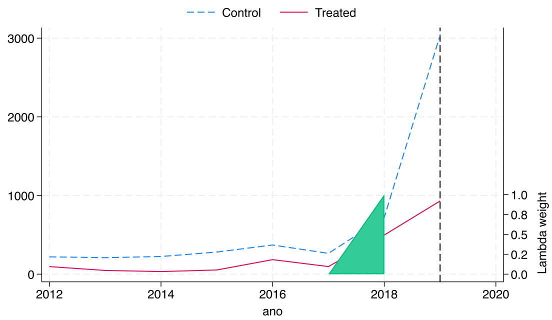

(e) Total – Specialist Diagnostic Procedures



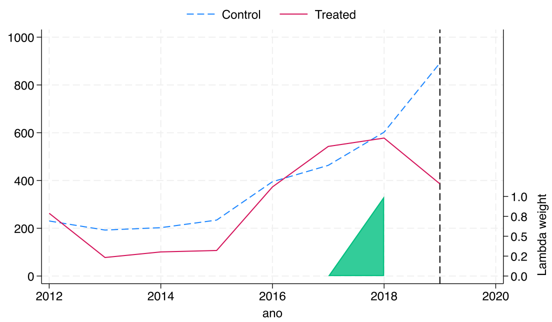

(f) Outside – Specialist Diagnostic Procedu-ress



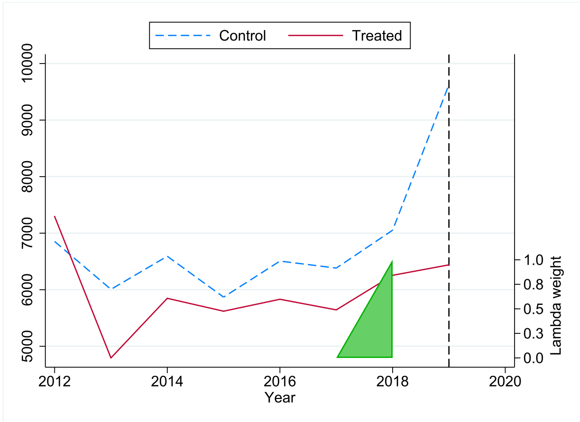

(g) Outside – Rapid Diagnostic Testing




(h) Outside – Clinical Laboratory Diagnostics




(i) Outside – Radiology




(j) Outside – Total diagnostic tests

Figure 8 – (continued)

In addition, for several diagnostic categories, no statistically significant effects are detected in any of the three dimensions considered—total volume, tests performed within the municipality, or tests performed outside the municipality. These null results should be interpreted with caution, as they do not necessarily imply the absence of effects, but rather indicate that any potential changes associated with road improvements are not precisely estimated within the available data. For these services, the findings suggest that improvements in road infrastructure may have had limited or diffuse impacts, possibly because their provision depends primarily on pre-existing local capacity, fixed investments, and institutional arrangements that are less responsive to marginal reductions in transportation costs. Overall, these results reinforce the view that the effects of road improvements on diagnostic services are heterogeneous and concentrated in specific types of exams, rather than representing a uniform shift in diagnostic utilization patterns.

Table 3 – ATT on Diagnostic Tests weighted by 100,000 inhabitants

| Outcome | Total | Inside [5] | Outside [6] |
|---|---|---|---|
| Total diagnostic tests | 4,943.851 | 7,273.827 | -2,399.428 *** |
| | (6,707.166) | (6,889.128) | (424.082) |
| Specimen Collection | 2,346.363 | 2,350.383 | 3.025 |
| | (2,294.476) | (2,291.668) | (7.003) |
| Clinical Laboratory Diagnostics | 1,609.644 | 3,503.188 | -1,879.941*** |
| | (3,637.597) | (3,548.048) | (169.701) |
| Radiology | -39.759 | 407.057 | -481.183*** |
| | (511.938) | (476.946) | (164.763) |
| Ultrasonography | 179.050 | 48.711 | -29.343 |
| | (437.229) | (283.087) | (89.632) |
| Computed | -52.070 | 29.519 | -73.581 |
| Tomography | (128.306) | (70.039) | (102.202) |
| Magnetic Resonance | 121.537** | -0.540 | 121.926** |
| Imaging | (53.829) | (0.904) | (54.325) |
| Endoscopy | -86.003*** | -38.554 | -52.731 ** |
| | (32.499) | (28.652) | (23.713 ) |
| Specialist Diagnostic | -261.491*** | -80.920 | -155.347*** |
| Procedures | (80.421) | (79.257) | (42.384) |
| Rapid Diagnostic Testing | 712.088 | 778.329 | -112.278*** |
| | (1,873.834) | (1,867.109) | (43.360) |
| Number of observations | 2.976 | 2.976 | 2.976 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
3.Inside the municipality
4.Outside the municipality

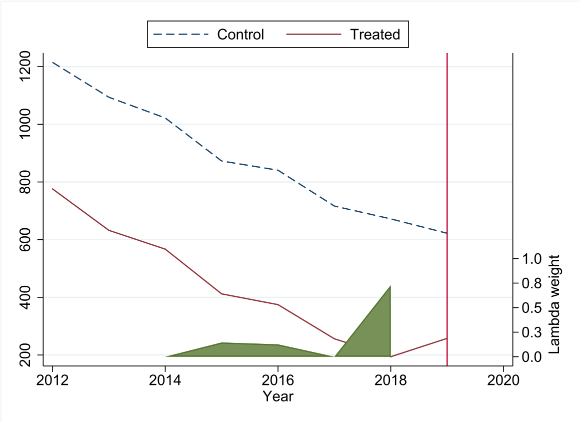
## 4.2 Hospital Information System (SIH)

The results reported in Table 4 and Figure 9[7] indicate that improvements in road infrastructure in the treated area were associated with meaningful changes in the pattern of medium-complexity hospitalizations, particularly when focusing on statistically significant effects and their decomposition between hospitalizations occurring within and outside the municipality of residence.

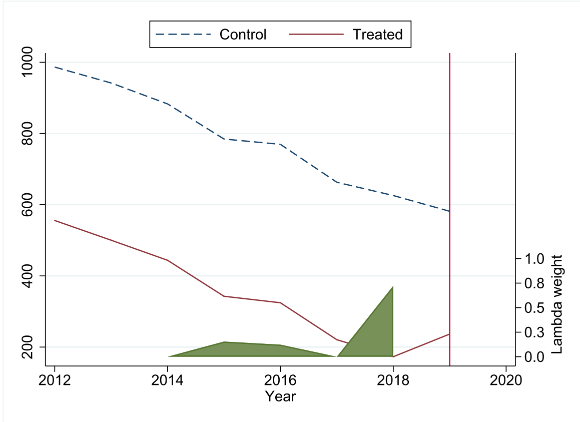
There is evidence of an increase in hospitalizations due to infectious and parasitic diseases and conditions related to pregnancy, childbirth, and the puerperium, both statistically significant at the 10% level. Although the direction is the same, the reason may be different.

[7] Figures related to results without statistical significance are presented in the Appendix.

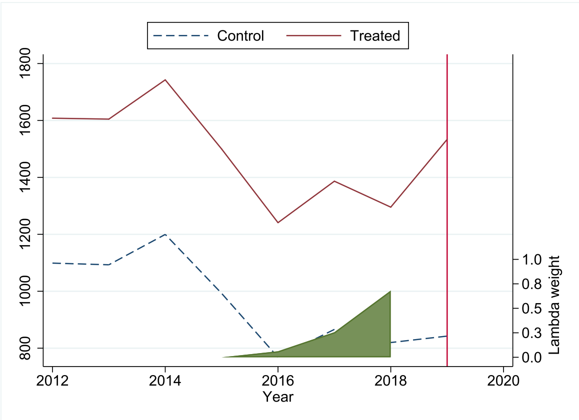
Figure 9 – Synthetic Difference-in-Differences estimates for medium-complexity hospitalization outcomes



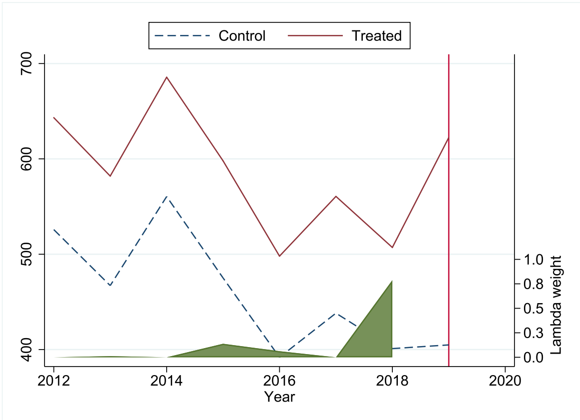

(a) Total – Infectious and parasitic diseases




(b) Inside – Infectious and parasitic diseases




(c) Total – Pregnancy, childbirth and the puerperium

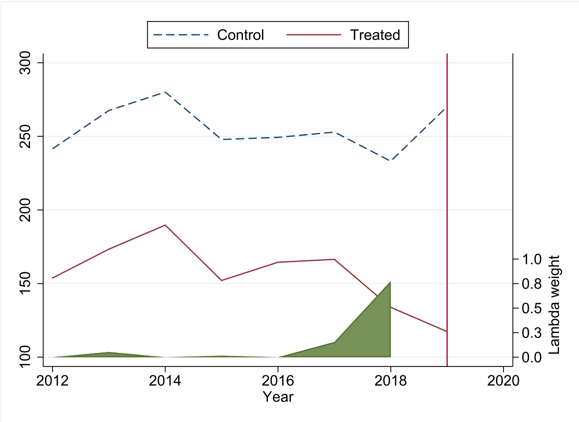



(d) Outside – Pregnancy, childbirth and the puerperium

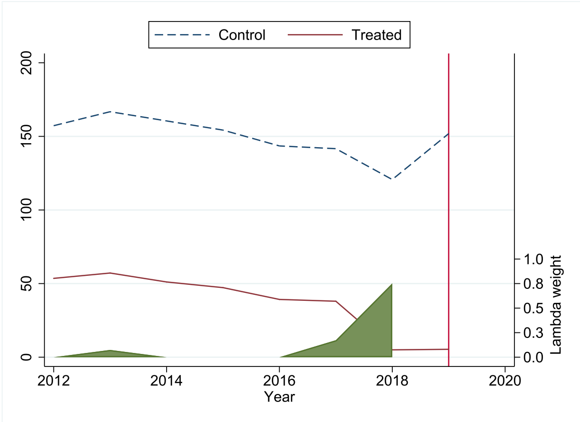
For conditions related to pregnancy, this effect appears to be partly driven by a pronounced increase in hospitalizations outside the municipality for pregnancy, childbirth, and the puerperium, with a positive and highly significant coefficient. This pattern indicates that better road conditions facilitated the movement of pregnant women to health facilities, where greater clinical capacity and specialized care are available.

A substantial body of literature links infectious and parasitic diseases—such as malaria, yellow fever, leishmaniasis, leprosy, and tuberculosis—to migration flows and to the construction and improvement of highways (Najar, 1990; Peixoto, 2020; Pereira et al., 2021; Magalhães et al., 2011). In this context, the observed increase in infectious and parasitic diseases can be directly associated with road improvements. Although this result may appear counterintuitive at first glance, existing studies indicate that the intensification of population mobility, facilitated by road expansion, is often accompanied by a rise in the incidence of these diseases.

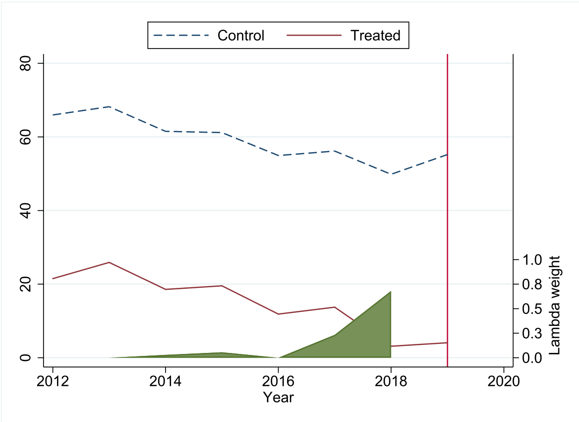
Figure 9 – (continued)




(e) Total – Injury, poisoning and certain other consequences of external causes




(f) Outside – Injury, poisoning and certain other consequences of external causes




(g) Outside – Diseases of the circulatory system

By contrast, there is a significant reduction in hospitalizations occurring outside the municipality for diseases of the circulatory system and for injuries, poisoning, and other consequences of external causes. These results may reflect two complementary mechanisms. On the one hand, improved local access to medium-complexity hospital services may have reduced the need for referrals to other municipalities. On the other hand, in the case of external causes, the findings may capture indirect gains associated with shorter response times and improved access to initial care, although this interpretation should be treated with caution, and further robustness checks are warranted.

At the aggregate level, the results were not statistically significant, although they indicate an increase in total hospitalizations, reinforcing the idea that road infrastructure functions as a mechanism of regional integration of the health system.

Table 4 – Effects on Medium-Complexity Hospitalizations weighted by 100,000 inhabitants

| Outcome | Total | Inside [8] | Outside [9] |
|---|---|---|---|
| Infectious and parasitic diseases | 109.573* | 105.378* | -5.398 |
| | (62.440) | (60.333) | (11.380) |
| Neoplasms | 15.051 | 14.673 | 1.124 |
| | (13.833) | (12.802) | (6.034) |
| Diseases of the circulatory system | 20.913 | 25.069 | -5.817* |
| | (19.928) | (21.139) | (3.208) |
| Diseases of the nervous system | -2.099 | -0.315 | -1.344 |
| | (5.335) | (5.423) | (1.008) |
| Pregnancy, childbirth and | 204.088* | 123.098 | 109.075*** |
| the puerperium | (123.250) | (120.082) | (30.557) |
| Injury, poisoning and certain other | -55.789** | -19.643 | -33.374*** |
| consequences of external causes | (22.641) | (22.842) | (7.552) |
| Total hospitalizations | 369.250 | 297.709 | 75.141 |
| | (368.047) | (377.134) | (49.929) |
| Number of observations | 2.976 | 2.976 | 2.976 |

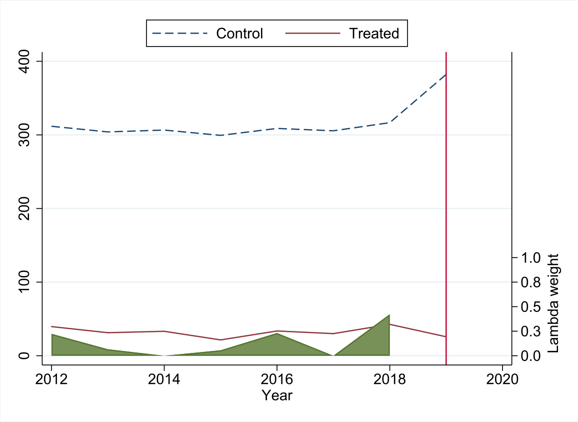
Notes: Robust standard errors in parentheses.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$.
5.Inside the municipality
6.Outside the municipality

The results presented in Table 5 and Figure 10[10] indicate that road improvements had more concentrated and selective effects on high-complexity hospitalizations, primarily affecting the composition and location of admissions rather than their aggregate volume. Overall, there is no statistically significant effect on the total number of high-complexity hospitalizations, suggesting that the intervention did not lead to a generalized increase in the use of this level of care; rather, it altered specific referral and access patterns.

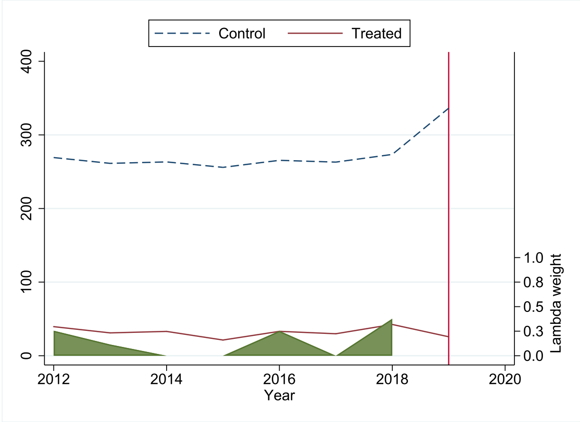
The most robust finding concerns hospitalizations related to pregnancy, childbirth, and the puerperium, for which there is a large and highly significant reduction both in total hospitalizations and, in particular, in those occurring outside the municipality of residence. This result is consistent with the Table 4 and the hypothesis that improved road infrastructure contributed to a reorganization of the obstetric care network, potentially shifting part of high-complexity care toward lower levels of attention or enabling earlier and more effective interventions that reduced the need for complex hospitalizations. Alternatively, it may reflect greater efficiency in referral processes, avoiding unnecessary admissions to high-complexity facilities, especially in other municipalities.

[10] Figures related to results without statistical significance are presented in the Appendix.

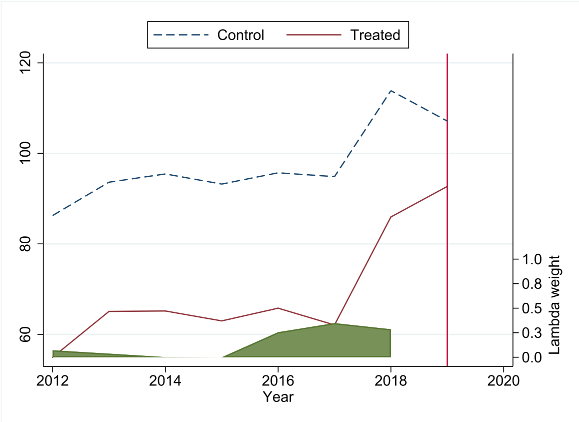
Figure 10 – Synthetic Difference-in-Differences estimates for high-complexity hospitalization outcomes




(a) Total hospitalizations – Pregnancy, childbirth and the puerperium




(b) Outside hospitalizations – Pregnancy, childbirth and the puerperium




(c) Outside hospitalizations – Diseases of the circulatory system

For diseases of the circulatory system, there is a statistically significant increase in hospitalizations occurring outside the municipality, with no corresponding effect on total hospitalizations or those within the municipality. This pattern suggests that improved road conditions facilitated access to regional referral centers for cardiovascular conditions that require advanced technology and specialized care, reinforcing the role of road infrastructure as a mechanism for health system integration and for reducing geographic barriers to specialized treatment.

The remaining cause groups—infectious and parasitic diseases, neoplasms, diseases of the nervous system, and external causes—do not exhibit statistically significant effects, indicating that road improvements did not substantially alter the pattern of high-complexity hospitalizations for these conditions. Taken together, the results suggest that the effects of road infrastructure on high-complexity care operate mainly through changes in patient flows and in the allocation of patients to the appropriate level of care, rather than through an indiscriminate expansion of hospital admissions, reinforcing the interpretation of road improvements as a factor enhancing efficiency and regional coordination within the health care system.

Table 5 – Effects on High-Complexity Hospitalizations weighted by 100,000 inhabitants

| Outcome | Total | Inside [11] | Outside [12] |
|---|---|---|---|
| Certain infectious and parasitic diseases | 4.842 | 5.719 | -9.160 |
| | (13.134) | (6.528) | (10.663) |
| Neoplasms | 4.953 | -3.037 | 6.186 |
| | (9.591) | (3.057) | (9.568) |
| Diseases of the circulatory system | 15.405 | -2.028 | 15.955* |
| | (9.368) | (2.983) | (9.143) |
| Diseases of the nervous system | 3.976 | 0.389 | 4.122 |
| | (4.090) | (0.903) | (4.094) |
| Pregnancy, childbirth and | -82.407*** | -1.810 | -79.615*** |
| the puerperium | (11.219) | (2.312) | (11.451) |
| Injury, poisoning and certain other | -4.534 | 1.847 | -1.988 |
| consequences of external causes | (14.841) | (3.856) | (13.711) |
| Total hospitalizations | 3.477 | 0.852 | -26.748 |
| | (63.185) | (29.952) | (53.228) |
| Number of observations | 2.976 | 2.976 | 2.976 |

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
7.Inside the municipality
8.Outside the municipality

# 5 CONCLUSION

This dissertation examined whether improvements in road infrastructure—specifically the paving of the final stretch of the BR-364 highway in the state of Acre—contributed to expanding access to health services in one of the most isolated regions of the Brazilian Legal Amazon. Grounded in the hypothesis that transportation investments reduce geographic barriers and thereby facilitate access to public services, the study exploited the completion of the paving works in 2019 as an exogenous connectivity shock, allowing for an evaluation of its effects on the use of outpatient and hospital services within the Brazilian Unified Health System (SUS) across different levels of complexity.

The empirical results indicate that the effects of paving the BR-364 on access to health care were heterogeneous and concentrated in specific dimensions of the health system. In outpatient care, there is a statistically significant reduction in the use of clinical procedures and some lower-complexity diagnostic exams outside the municipalities directly affected by the road improvement. These findings, together with other non-significant but consistent results, suggest that improved land connectivity may have altered local health care dynamics. Two avenues for future research emerge to better understand the mechanisms underlying this reduction: first, whether there was an increase in the number of health facilities in the affected regions, and second, whether improvements in accessibility induced a migration of health professionals toward these previously highly isolated areas. In contrast, for high-complexity diagnostic services—specifically magnetic resonance imaging, which until 2019 was only available in Rio Branco for this population—there is a clear increase in the number of exams per 100,000 inhabitants, reinforcing the interpretation that road improvements also acted as a driver of demand and a facilitator of access to specialized care.

For medium-complexity hospitalizations, the results indicate that road infrastructure improvements led to significant changes in both the pattern and spatial distribution of admissions in treated municipalities. There is evidence of increased hospitalizations for infectious and parasitic diseases and for conditions related to pregnancy, childbirth, and the puerperium, suggesting that improved road conditions expanded timely access to care for conditions requiring continuous, time-sensitive treatment both within and outside the municipalities. This effect is particularly strong for obstetric-related hospitalizations occurring outside the municipality of residence, pointing to enhanced access to regional referral facilities with greater clinical capacity. By contrast, hospitalizations outside the municipality declined for circulatory diseases and for injuries and external causes, which may reflect improved local availability of medium-complexity services and, in the case of external causes, potentially faster access to initial care. At the aggregate level, no statistically significant change in hospitalization rates is observed; however, the estimates suggest that a potential increase may have occurred. These findings underscore the function of road infrastructure as a mechanism for regional integration of health systems, mitigating geographic access barriers and transforming not only the overall volume, but also the spatial distribution, of hospital service utilization.

In turn, the results for high-complexity hospitalizations indicate that road improvements had selective and concentrated effects, primarily influencing the composition and spatial allocation of admissions rather than their overall volume. While there is no statistically significant impact on the total number of high-complexity hospitalizations, a substantial and highly significant reduction is observed for admissions related to pregnancy, childbirth, and the puerperium—especially those occurring outside the municipality—suggesting a reorganization of obstetric care and more efficient referral patterns. Conversely, hospitalizations for circulatory system diseases increase significantly outside the municipality, indicating that improved road conditions facilitate access to specialized regional cardiovascular care centers. For other cause groups, no significant effects are detected. Overall, these findings indicate that road infrastructure improvements primarily influence patient flows and the allocation of high-complexity care across locations, enhancing system efficiency and regional integration rather than indiscriminately expanding hospital utilization.

Taken together, these results reinforce the interpretation of transportation infrastructure as an intermediate social determinant of health: one that can alleviate access constraints but is insufficient to eliminate structural inequalities in the absence of complementary policies. In contexts such as the Legal Amazon—and particularly in Acre—where the supply of medium- and high-complexity services is scarce and highly concentrated, reductions in physical distance do not automatically translate into effective access unless accompanied by coordinated expansion of health service networks, investments in human resources, and stronger mechanisms of regionalization within the SUS.

From a public policy perspective, the findings suggest that investments in road infrastructure can produce meaningful gains in access, particularly to outpatient and diagnostic care, thus helping to reduce territorial inequalities in remote regions. However, for these gains to translate into broader and more sustainable improvements in health access, transportation policies must be articulated with strategies to expand and integrate health care networks, particularly at higher levels of complexity. The experience of the BR-364 in Acre highlights that connectivity is a necessary—but not sufficient—condition for promoting equity in access to health services in the Amazon.

Finally, this study contributes to the literature by providing causal evidence on the relationship between transportation infrastructure and access to health care in a setting characterized by severe geographic and institutional constraints. By exploiting an exogenous infrastructure shock and examining multiple outcomes across the healthcare continuum, the dissertation deepens the understanding of the mechanisms through which logistical investments can affect population well-being. As a future research agenda, further studies could explore longer-term effects, impacts on health outcomes, and heterogeneous effects across dry and rainy seasons, and by gender, in addition to examining the interaction among road infrastructure, health workforce mobility, and the regional organization of health services.

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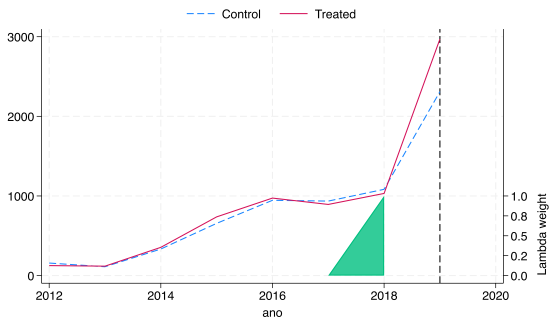
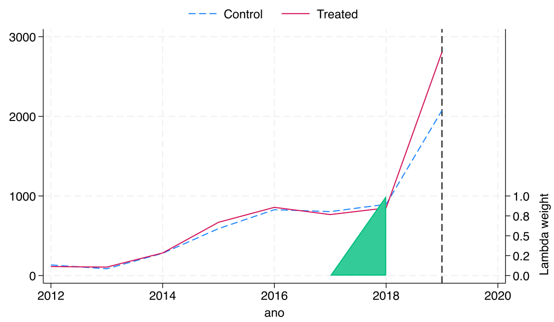
# 6 APPENDICES

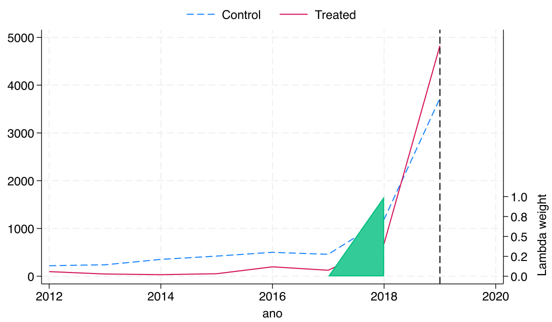
Figure 11 – Synthetic Difference-in-Differences estimates for diagnostic services



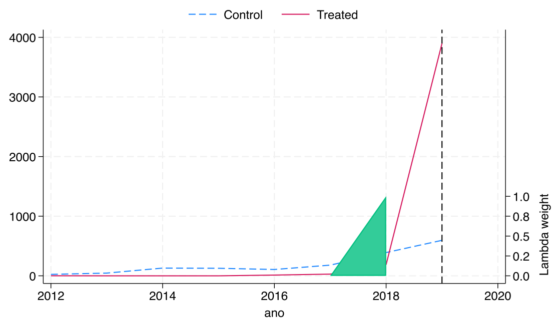

(a) Total – Rapid Diagnostic Tests



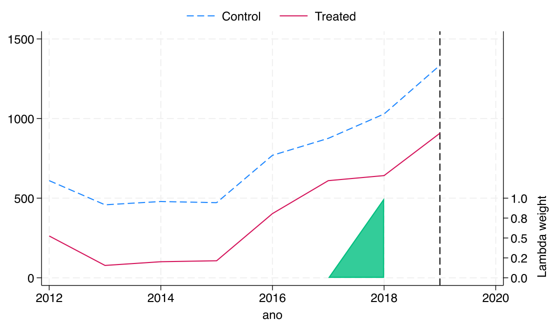

(b) Within municipality – Rapid Diagnostic Tests



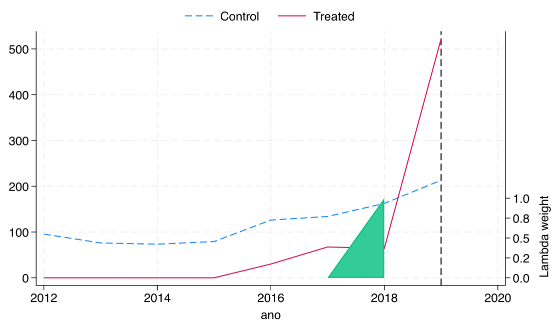

(c) Total – Clinical Laboratory Tests



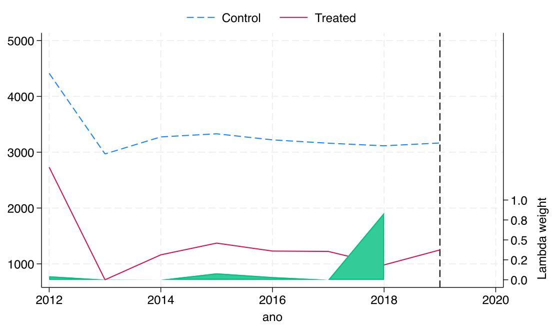

(d) Inside – Clinical Laboratory Tests



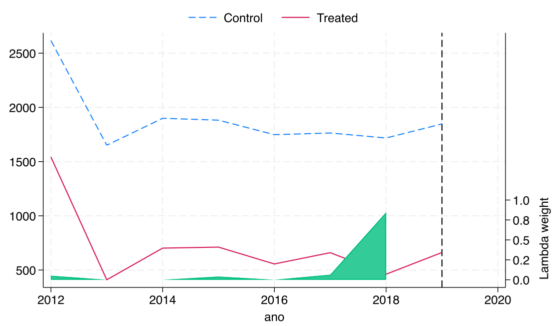

(e) Total – Radiology




(f) Inside – Radiology

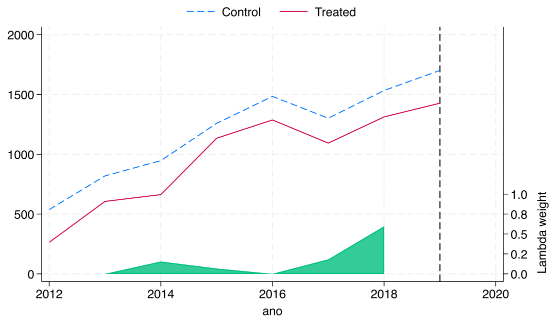



(g) Total – Ultrasound

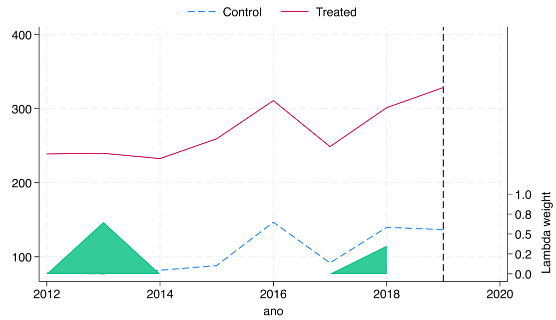



(h) Inside – Ultrasound

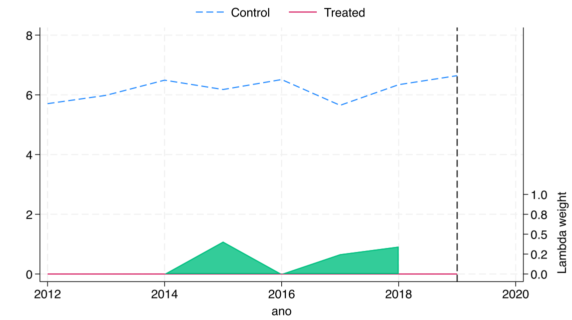
Figure 11 – (continued)



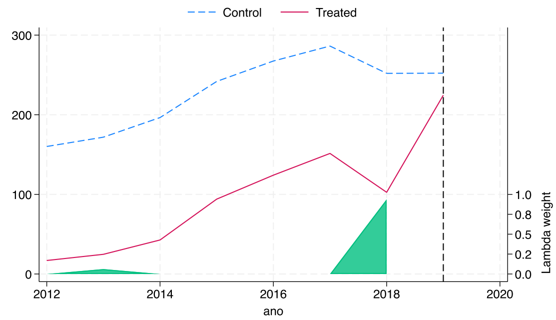

(i) Total – Computed Tomography



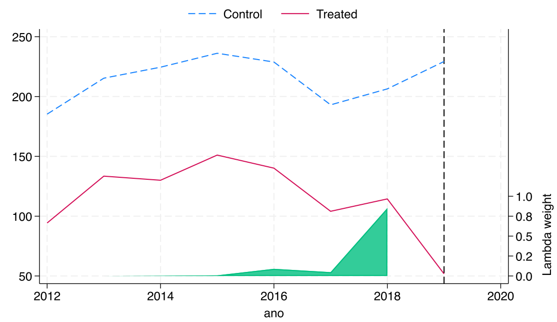

(j) Inside – Computed Tomography



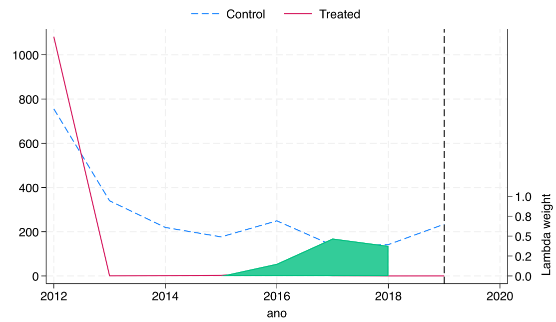

(k) Inside – Magnetic Resonance Imaging



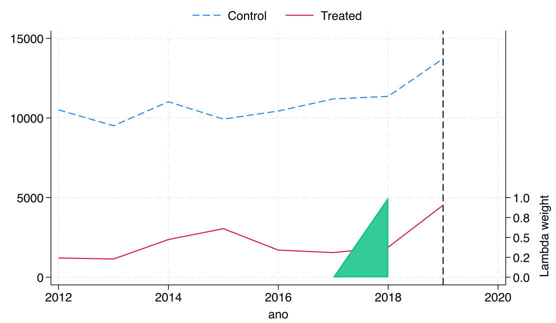

(l) Total – Magnetic Resonance Imaging




(m) Total – Diagnostic Endoscopy

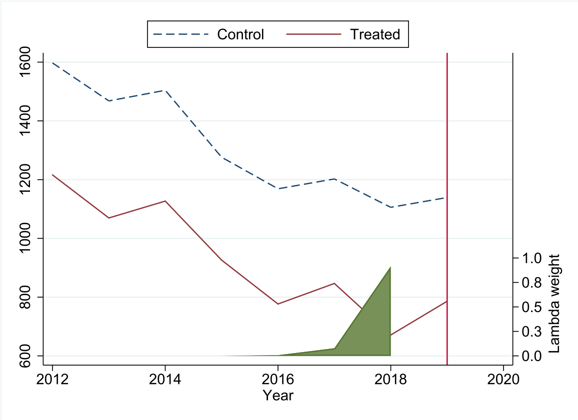



(n) Inside – Specialist Diagnostic Procedures

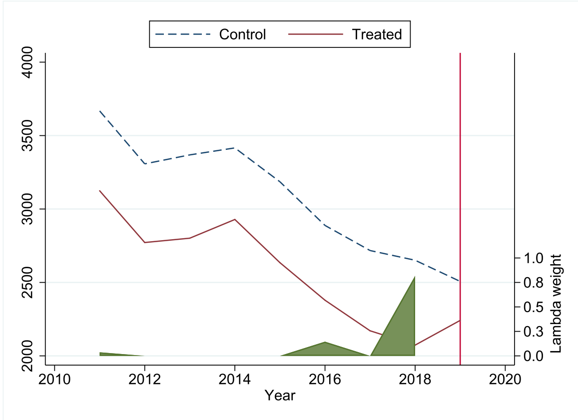



(o) Total – Clinical Procedures

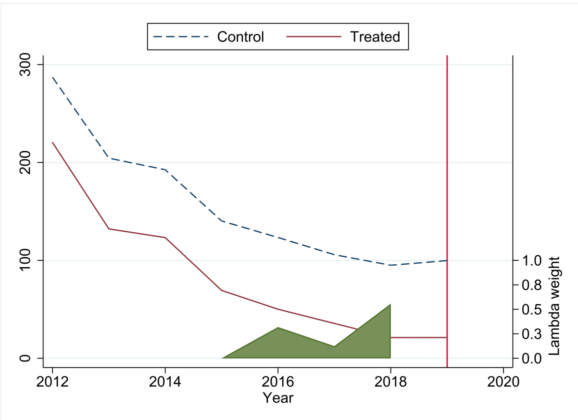
Figure 12 – Synthetic Difference-in-Differences estimates for medium-complexity hospitalization outcomes



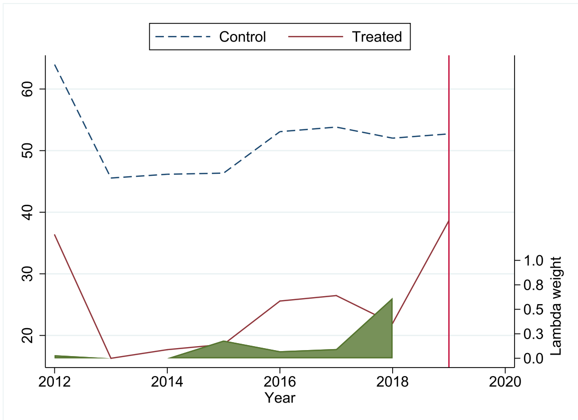

(a) Outside – Total hospitalizations



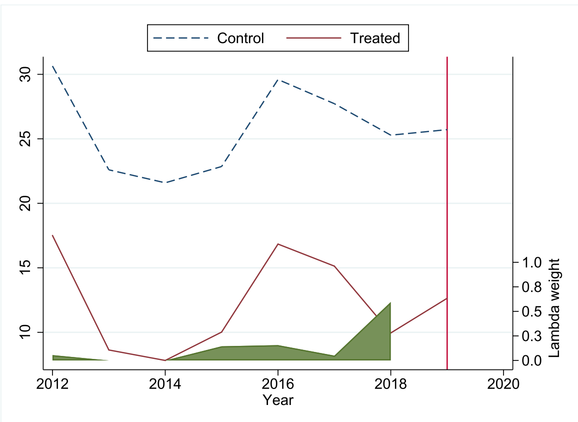

(b) Inside – Total hospitalizations



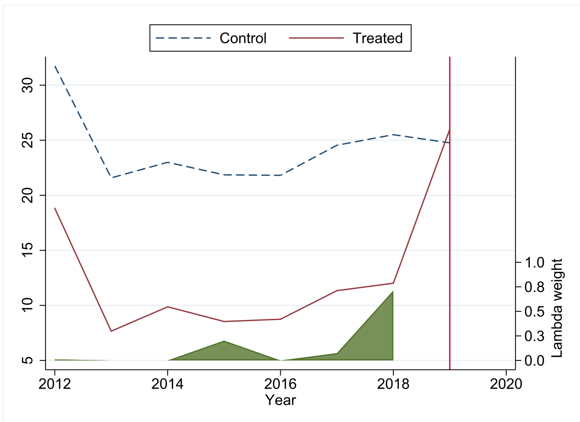

(c) Outside – Infectious and parasitic diseases



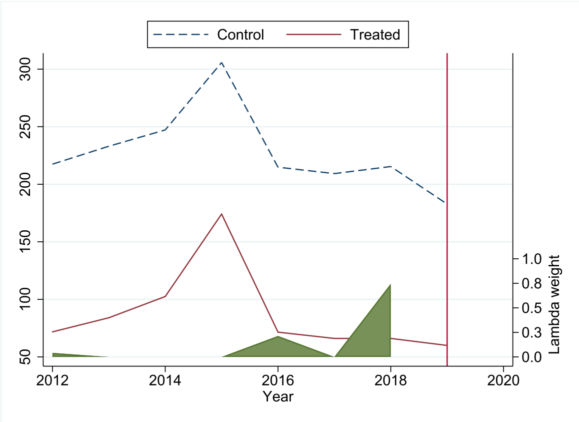

(d) Total – Neoplasms



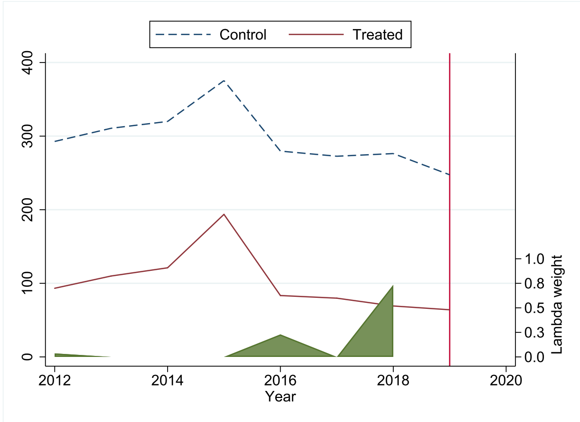

(e) Outside – Neoplasms



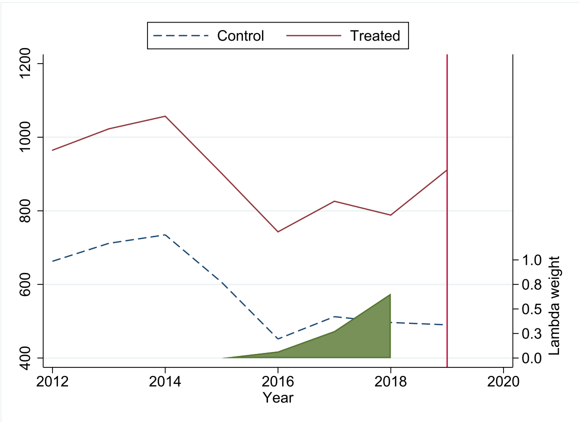

(f) Inside – Neoplasms



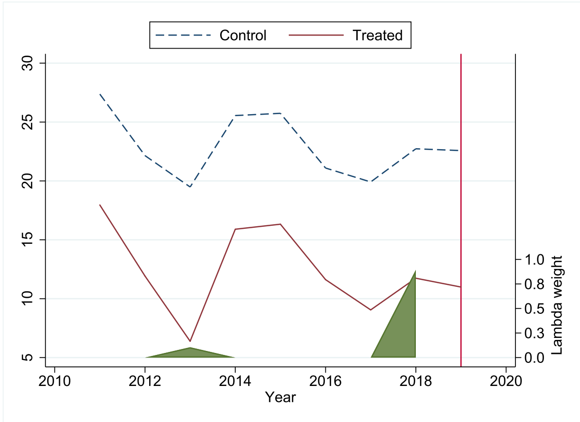

(g) Inside – Diseases of the circulatory system



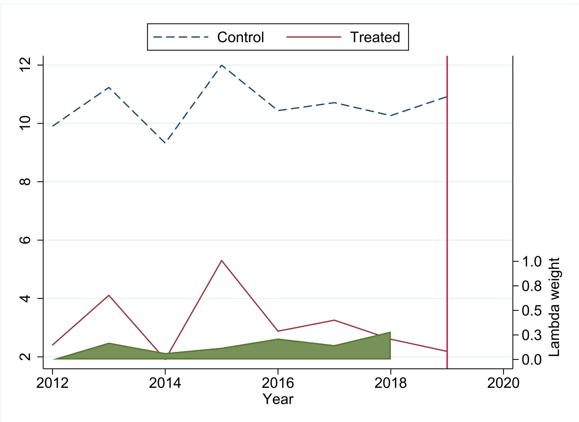

(h) Total – Diseases of the circulatory system



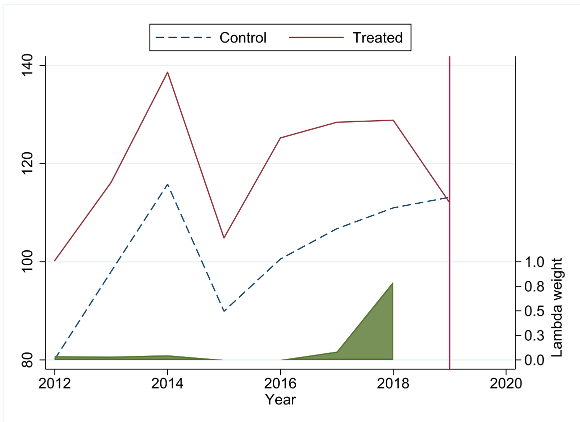

(i) Inside – Pregnancy, childbirth and the puerperium




(j) Inside – Diseases of the nervous system



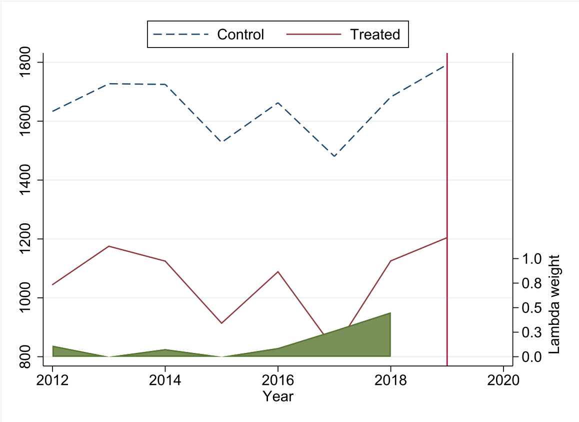

(k) Outside – Diseases of the nervous system



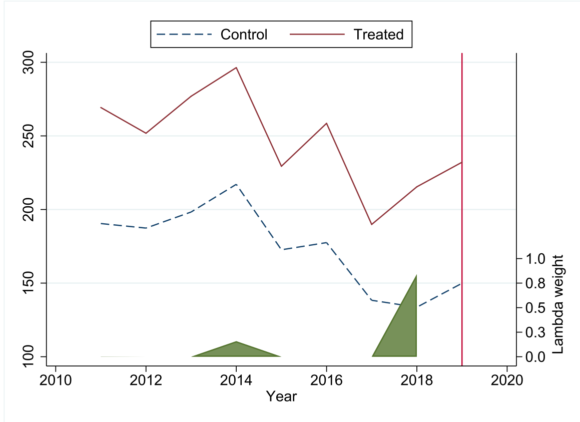

(l) Inside – Injury, poisoning and certain other consequences of external causes

Figure 12 – (continued)

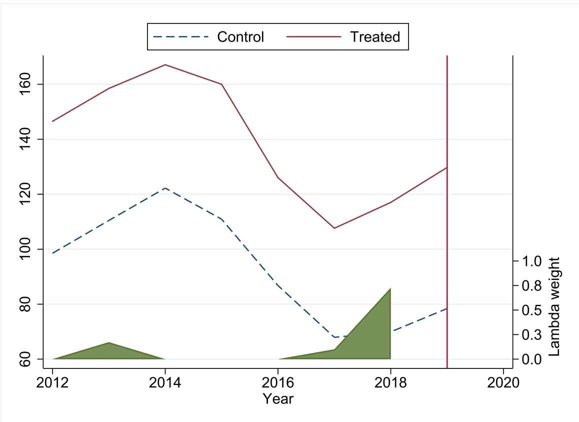
Figure 13 – Synthetic Difference-in-Differences estimates for high-complexity hospitalization outcomes



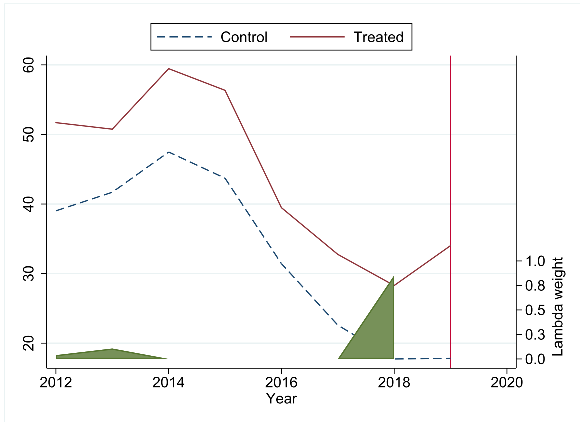

(a) Total – Total hospitalizations



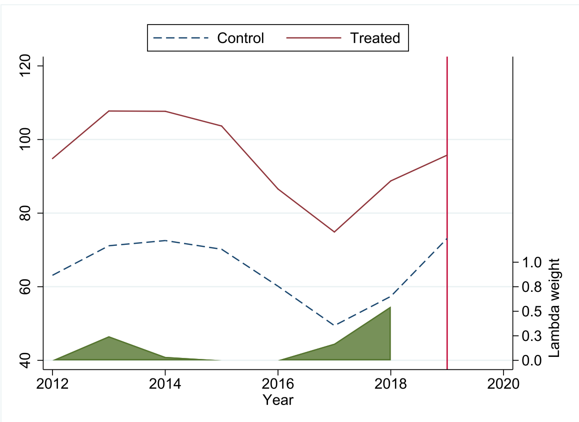

(b) Inside – Total hospitalizations



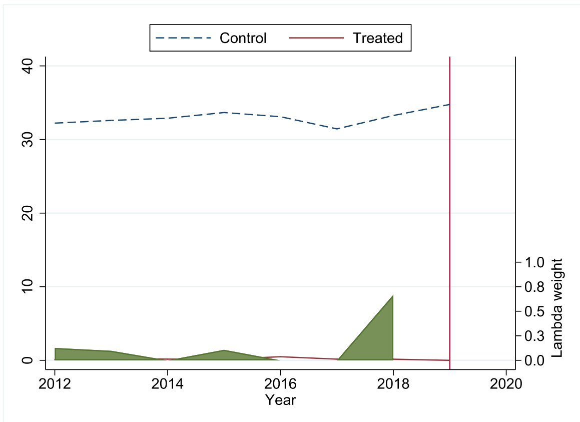

(c) Total – Infectious and parasitic diseases



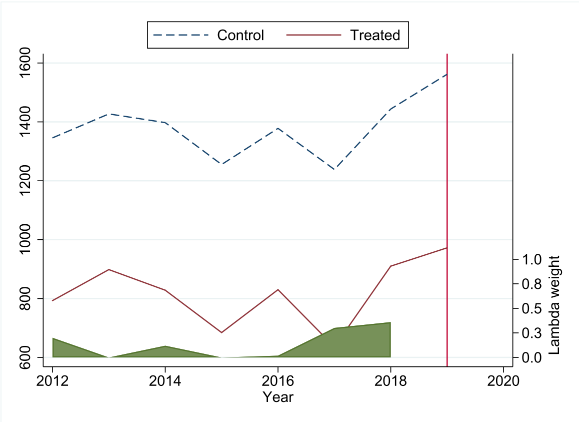

(d) Inside – Infectious and parasitic diseases



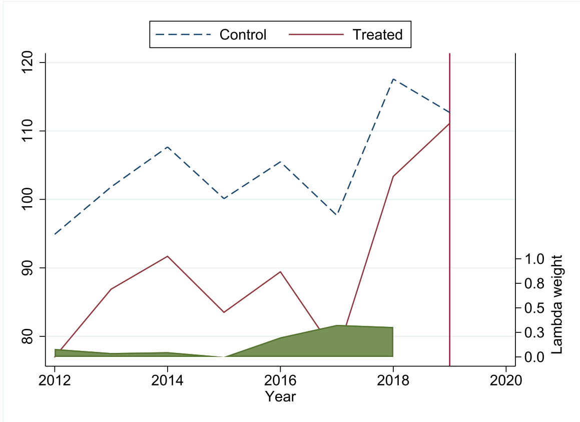

(e) Outside – Infectious and parasitic diseases



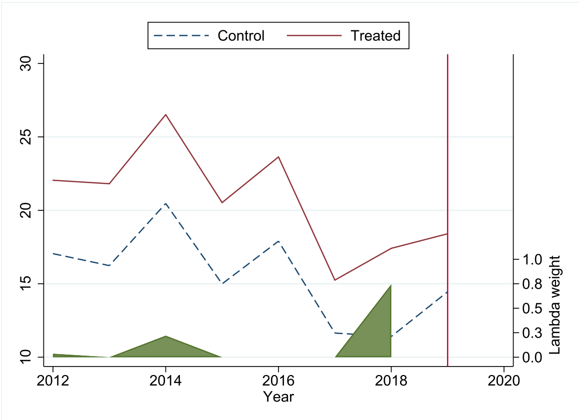

(f) Inside – Pregnancy, childbirth and puerperium



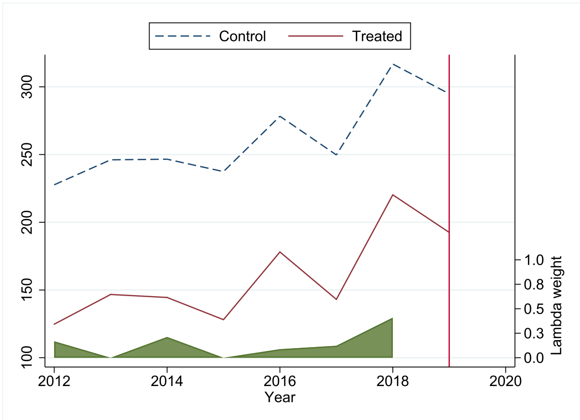

(g) Outside – Total hospitalizations



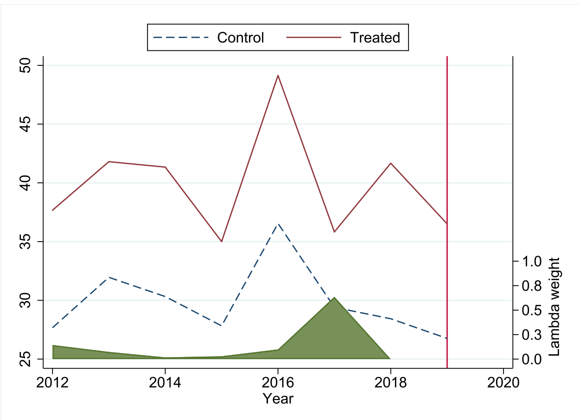

(h) Total – Diseases of the circulatory system



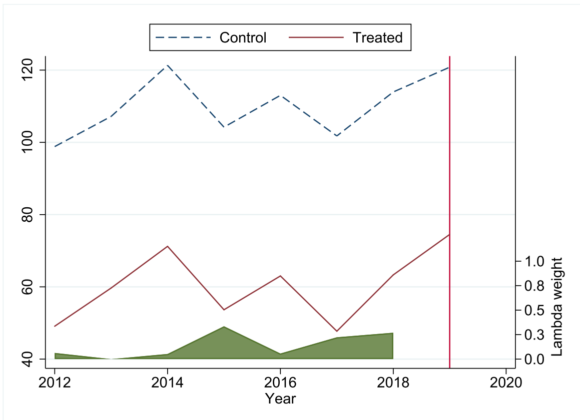

(i) Inside – Diseases of the circulatory system




(j) Outside – Injuries and external causes

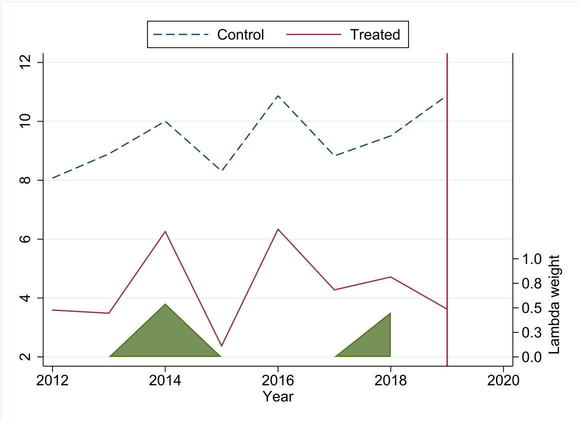



(k) Inside – Injuries and external causes

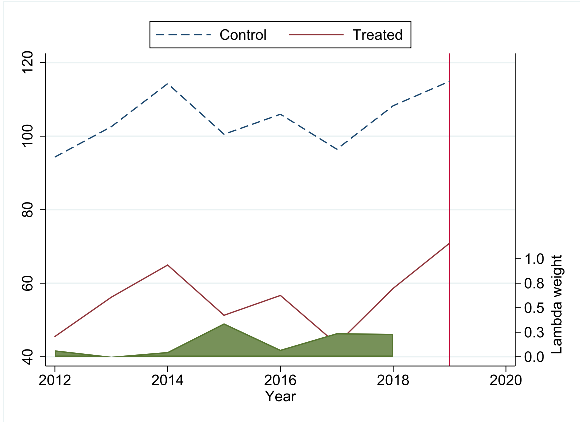



(l) Total – Neoplasms

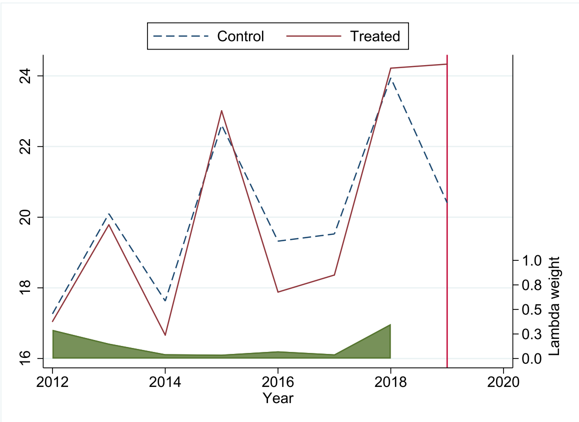
Figure 13 – (continued)



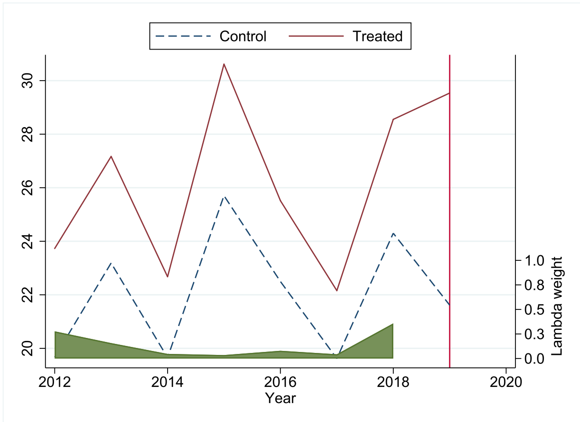

(m) Inside – Neoplasms



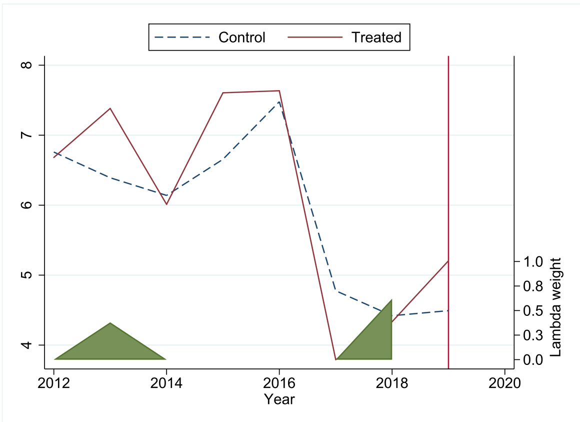

(n) Outside – Neoplasms




(o) Outside – Diseases of the nervous system




(p) Total – Diseases of the nervous system




(q) Inside – Diseases of the nervous system

Figure 13 – (continued)

**Angélica Raminelly Escovedo**

**Highways to Health:** Does BR-364 Enhance Access to Helthcare in Acre?

Dissertação apresentada ao Programa de Pós-graduação em Economia da Universidade Federal de Juiz de Fora como requisito parcial à obtenção do título de Mestre em Economia Aplicada. Área de concentração: Economia

Aprovada em 12 de fevereiro de 2026.

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Universidade Federal de Minas Gerais

Juiz de Fora, 29/01/2026.

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**Angélica Raminelly Escovedo**

**Highways to Health:** Does BR-364 Enhance Access to Helthcare in Acre?

Dissertação apresentada ao Programa de Pós-graduação em Economia da Universidade Federal de Juiz de Fora como requisito parcial à obtenção do título de Mestre em Economia Aplicada. Área de concentração: Economia

Aprovada em 12 de fevereiro de 2026.

BANCA EXAMINADORA

**Dr.ª Flávia Lúcia Chein Feres** - Orientadora

Universidade Federal de Juiz de Fora

**Dr. Igor Vieira Procópio -** Coorientador

Universidade Federal de Juiz de Fora

**Dr. Fernando Salgueiro Perobelli**

Universidade Federal de Juiz de Fora

**Dr. Pedro Vasconcelos Maia do Amaral**

Universidade Federal de Minas Gerais

Juiz de Fora, 29/01/2026.

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**UNIVERSIDADE FEDERAL DE JUIZ DE FORA**

**PRÓ-REITORIA DE PÓS-GRADUAÇÃO E PESQUISA**

**ATA DE DEFESA DE TRABALHO DE CONCLUSÃO DE PÓS-GRADUAÇÃO**

**STRICTO SENSU**

PROGRAMA DE PÓS-GRADUAÇÃO EM ECONOMIA

N° PPG: EM-187

Formato da Defesa: ( ) presencial (X) virtual ( ) híbrido

Ata da sessão (X) pública ( ) privada referente à defesa da (X) dissertação ( ) tese intitulada "Highways to Health: Does BR-364 Enhance Access to Helthcare in Acre?", para fins de obtenção do título de (X) mestra ( ) doutora em Economia Aplicada, área de concentração Economia, pela discente Angélica Raminelly Escovedo (matrícula 120180022 - início do curso em 28/02/2024), sob orientação da Prof.ª Dr.ª Flávia Lúcia Chein Feres e coorientação do Dr. Igor Vieira Procópio.

Ao 12 dia do mês de fevereiro do ano de 2026, às 10 horas, de forma não presencial conforme Resolução nº 10/2022-CSPP e nº 16/2023-CSPP da Universidade Federal de Juiz de Fora (UFJF), reuniu-se a Banca examinadora da (X) dissertação ( ) tese em epígrafe, aprovada pelo Colegiado do Programa de Pós- Graduação, conforme a seguinte composição:

| Titulação | Nome | Na qualidade de: | Vínculo Institucional |
|---|---|---|---|
| Prof.ª Dr.ª | Flávia Lúcia Chein Feres | Orientadora e Presidente da Banca | UFJF |
| Dr. | Igor Vieira Procópio | Coorientador | UFJF |
| Prof. Dr. | Fernando Salgueiro Perobelli | Membro titular interno | UFJF |
| Prof. Dr. | Pedro Vasconcelos Maia do Amaral | Membro titular externo | UFMG |

**AVALIAÇÃO DA BANCA EXAMINADORA**

Tendo a senhora Presidente declarado aberta a sessão, mediante o prévio exame do referido trabalho por parte de cada membro da Banca, a discente procedeu à apresentação de seu Trabalho de Conclusão de Curso de Pós-graduação Stricto sensu e foi submetida à arguição pela Banca Examinadora que, em seguida, deliberou sobre o seguinte resultado:

( X ) APROVADO

( ) APROVADO CONDICIONALMENTE, mediante o atendimento das alterações sugeridas pela Banca Examinadora, constantes do campo Observações desta Ata

( ) REPROVADO, conforme parecer circunstanciado, registrado no campo Observações desta Ata e/ou em documento anexo, elaborado pela Banca Examinadora

Novo título da Dissertação/Tese (só preencher no caso de mudança de título):

| |
|---|
| |

Observações da Banca Examinadora caso haja necessidade de anotações gerais sobre a dissertação/tese e sobre a defesa, as quais a banca julgue pertinentes

| |
|---|
| Banca de defesa realizada de forma não presencial de acordo com a Resolução nº 10/2022 CSPP/UFJF. Todos os membros e a discente participaram da sessão de Defesa e a acompanharam na sua integralidade. |

Nada mais havendo a tratar, a senhora Presidente declarou encerrada a sessão de Defesa, sendo a presente Ata lavrada e assinada pelos(as) senhores(as) membros da Banca Examinadora e pela discente, atestando ciência do que nela consta.

**INFORMAÇÕES**

**Para fazer jus ao título de mestre(a)/doutor(a), a versão final da dissertação/tese, considerada Aprovada, devidamente conferida pela Secretaria do Programa de Pós-graduação, deverá ser tramitada para a PROPP, em Processo de Homologação de Dissertação/Tese, dentro do prazo de 60 dias, ou 90 dias para discentes aprovados**

**condicionalmente, a partir da data da defesa. Se as condições descritas na ata não forem atestadamente atendidas dentro do prazo de 90 dias, a aprovação condicional será convertida em reprovação. Após o envio dos exemplares definitivos, o processo deverá receber homologação e, então, ser encaminhado à CDARA.**

**Esta Ata de Defesa é um documento padronizado pela Pró-Reitoria de Pós-Graduação e Pesquisa. Observações excepcionais feitas pela Branca Examinadora poderão ser registradas no campo disponível acima ou em documento anexo, desde que assinadas pelo(a) Presidente(a).**

**Esta Ata de Defesa somente poderá ser utilizada como comprovante de titulação se apresentada junto á Certidão da Coordenadoria de Assuntos e Registros Acadêmicos da UFJF (CDARA) atestando que o processo de confecção e registro do diploma está em andamento.**

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